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The Complexities in Fostering Critical Thinking through School-based Curriculum Innovation: Research Evidence from Singapore

Abstract

Singapore's strong performance in international benchmarking studies - Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) - poses a conundrum to researchers who view Singapore's pedagogy as characterized by the teaching of facts and procedures, and lacking in constructivist learning principles. In this paper, we examine the impact of different curriculum innovations on critical thinking as measured by the Watson-Glaser Critical Thinking Assessment - UK (WGCTA-UK). This includes two innovations that are subject-specific and short-term, one that strongly infuses the arts into the curriculum throughout the whole course of study, and the innovation of the Integrated Programme (IP) which allows academically stronger students to skip the GCE 'O' Levels and enter directly into the next level of education, with the time previously allocated to exam preparation now spent on greater breadth in the academic and non-academic curriculum. This paper takes the sociocultural approach to investigate the contexts, process and outcomes, reports the state of critical thinking, and sheds light on how critical thinking is being promoted. Through our analysis, we find support for the claim that only curriculum that is rigorously designed to foster critical thinking competencies will reap the intended student outcome.

Key words: Critical thinking; Curriculum innovation; Secondary; Integrated Programme; 21st Century competencies

Issues in Fostering Critical Thinking in Schools

In the 21st century, the capacity to think critically is essential for effective communication, problem solving and mastery of content. Studies have shown a positive relation between critical thinking, content knowledge (Manshaee, Mahmoudian Dastnaee, Seidi, & Davoodi, 2014), as well as higher order knowledge (Tishman, Perkins, & Jay, 1995a). However, teachers generally face challenges in fostering critical thinking during curriculum time (Lim, 2014). For instance, utilizing an experimental research design with control groups, Kılıç and Şen (2014) found that curriculum based on critical thinking supported with out-of-school learning activities was more effective in increasing students' critical thinking dispositions compared to a standard teaching approach. As such, unless out-of-school learning activities that promote critical thinking are available to all students, critical thinking might not be accessible to all students. To Young and Lambert (2014), critical thinking is a form powerful knowledge and it enables learners to predict, explain and envisage alternatives. Researchers generally concede that critical thinking is distinct from the 'common sense' knowledge we acquire through everyday experience and that the knowledge and skills to think critically is specialised and systematic (Paul, 1997; Tishman, Jay, & Perkins, 1993; Tishman & Palmer, 2006; 1995b; Young & Lambert, 2014).

Given the significance of nurturing the habit of mind in critical thinking that is grounded on subject content for all students, a way forward is to embark on school-based curriculum innovation (SBCI) with an emphasis on infusing critical thinking in across subject content at the national level. Despite the importance of building student capacity on higher order thinking amongst other aspects of engaging the students, Gopinathan and Deng (2006) examined the school-based curriculum enactment in the context of new educational initiatives in Singapore and concluded that schools are overwhelmed with overloaded content, and high-stakes examinations. In addition, schools also face the challenges to build teacher capacity to foster critical thinking in the subject content and persuade teachers to make pedagogical shift from the current outcome-oriented practice to one that is process-oriented. Given the aforementioned issues and educational contexts, this paper aims to (1) examine the state of critical thinking competencies of Singapore secondary school students; and (2) investigate whether there are differences in developing students' critical thinking between the group of schools that infused critical thinking in selected subject areas and the group of schools that infused critical thinking across subjects.

Critical Thinking and Curricular Policies Initiatives

Global challenges in the new millennium which are interconnected and complex are demanding future-ready learners to possess increasing critical thinking competencies. Critical thinking has its root and spirit of intellectual activities. Dewey (1019/1933) defined critical thinking as “reflective thought” which involves suspending judgment, maintaining a healthy skepticism and exercising an open mind. Siegel (2010) highlighted four significant reasons for critical thinking: (1) as the only way in which students are treated with respect as persons; (2) as a fundamental educational ideal involves education’s generally recognized task of preparing students for adulthood to be able independent and self-directed; (3) as a means to learn subject matters; and (4) as a way of good thinking, and reasoned deliberation in order to nurture the citizenry that is sufficiently critical. Critical thinking is the intellectual disciplined process of actively and skillfully drawing inferences, recognizing assumptions, evaluating argument, reasoning with information or observation, and interpreting logically (Watson & Glaser, 2002). Such purposeful mental act serves as a guide to belief and action (Paul, 1997). To Paul (2015), critical thinking is not only a set of skills and competencies, rather it is the dispositions and habits of mind. Hence, critical thinking consists of elements of thought that can be analysed, the universal intellectual standards that can be used to assess the quality of critical thinking and the intellectual traits that can be nurtured. The scholars also investigate whether critical thinking is domain generic or specific. It is found that the instructors need to be well versed in critical thinking and foster classrooms and environments that help promote the use of critical thinking and be able to effectively evaluate the quality of critical thinking among students in order to enable students learn and effectively apply critical thinking skills (refer to Hess II, 2011 for review).

In Singapore, there is realization that learning is not just the mastery of subject content, for example, in a survey involving 2,156 parents found that only 2 per cent of the respondents felt that children need to be "exam smart" in order to fare well in the future economy and that critical thinking and complex problem solving skills are the top three skills they thought would be most in demand in future economy (Yahya, 2017). Hence, building the learners’ capacity to critically make sense of the information and generating ideas is essential to parents and educators. Critical thinking in schools has received a push from a plethora of curricular policies and initiatives aimed to broaden educational goals, starting from the mid-1990s. Under the overarching framework of Thinking Schools, Learning Nation (1997) (TSLN), and the Desired Outcomes of Education (1998), some of these include: the critical thinking initiative (1997), the IT-Masterplan (1998-2002; 2003-2008; 2009-2014), National

Education (1998), Innovation and Enterprise (2004), Teach Less Learn More (TLLM) (2004), the Twenty-first Century Competencies (2004), and the Assessment policy (2008). These initiatives have implications to the choice of knowledge to be incorporated in the curriculum and taught in schools.

With the aim to nurture the potential of all learners, the Ministry of Education has continuously reviewed the educational system and put in place mechanisms that extend learner outcomes beyond high-stake examination performance. One attempt involved creating multiple pathways that favors the development of talents and a deeper focus on building a passion for learning (Heng, 2012; Shanmugaratnam, 2005). In this light, the TLLM policy initiative promoted the school-based curriculum innovations and injected fluidity in the system by promoting customization, choice and autonomy (Shanmugaratnam, 2005). Under the TLLM policy, the MOE trimmed the syllabi with the aims to maintain the rigor of learning, reduce student workload and encourage teachers to promote critical thinking among students (Minsitry of Education, 2017). While all schools are encouraged to embark on school-based curriculum innovation to engage the learners, the MOE also implements the Integrated Programme (IP) which allows the university bound students to skip the GCE 'O' Levels. The IP is a 6-year seamless programme aiming to engage the learners in broader learning experiences. Without the high-stakes examination, the IP schools are responsible to optimize the time freed up from preparing the GCE'O' Levels to stretch students and provide greater breadth in the academic and non-academic curriculum. The progress of these students is monitored by school-based assessments. In view of the large scale curricular policy interventions, it is timely to investigate how teachers have adjusted curriculum and instruction to foster critical thinking among students and to what extent the system has achieved the broaden goals of education by engaging students on critical thinking.

An Ecological Understanding of School-based Curriculum Innovation (SBCI)

Although Singapore has a centralised curriculum, the schools are given the flexibility to customize curriculum or pedagogy to increase student engagement (Shanmugaratnam, 2005). School-based curriculum innovation has become a mechanism for school improvement. Curriculum innovation is a process-based intervention (Mourshed, Chijioke, & Barber, 2010) that involves multiple processes and stakeholders. It is complex. While Singapore has consistent strong performance in international benchmarking tests, policymakers and parents would like to see curricula and pedagogies shift from content mastery to deep learning and acquisition of 21st-century competencies (Shanmugaratnam, 2005; Yahya, 2017). This is especially challenging for teachers who are accustomed to implementing curriculum (Gopinathan & Deng, 2006; A. Koh, 2002; Lim, 2014). Since innovation requires novel practices, tools or technologies, and knowledge and ideas (Cohen & Ball, 2007), embarking on the school-based curriculum innovation demands teachers to deliberately re-conceptualise the curriculum and rethink their pedagogical practice (L. S. Tan & Ponnusamy, 2014a). Hence, we argue that only if teachers or programmes were to subscribe to the philosophy of critical thinking and deliberately infusing critical thinking in their classroom practices is an act of curriculum innovation. Hence, the scale and fidelity of the curriculum innovation matter.

Curriculum innovation takes place in contextualized situations and engages teachers in authentic, complex teaching and learning problems (Borko, 2004; Bound & Middleton, 2003; Leadership and Teacher Development Branch, 2005; Putnam & Borko, 2000). Lieberman and Mace (2008) highlight that teacher learning is the key to educational reform, and Berliner (1992) also points out that teacher expertise is contingent on the teachers' capacity to reframe classroom practices. The context of SBCI calls for teachers to infuse critical thinking in the teaching requires teachers to be involved in an iterative, dialectical process of practical knowledge, teacher knowledge, and complex problems. The key to professional learning therefore involves having school leaders and teachers in the inquiry process with evidence from classroom practices and students as feedback loops (Timperley, Wilson, Barrar, & Fung, 2007). Inevitably, teacher learning in promoting critical thinking in curriculum innovation takes place in the discourses that frame the development of school-based curriculum centered on a professional inquiry process. On the ground, teachers are attempting to strike a fine balance between old and new pedagogies in varying degrees and contexts (Hung, 2017; C. Tan, 2017). However, there are always tensions in finding ways to differentiated curriculum and instruction for critical thinking.

We also argue that the ecology of the school shapes its curriculum leadership and the innovation itself in the curriculum innovation process. Broadly speaking, schooling is embedded in three layers of context- societal, institutional, and instructional. Scholars such as Doyle (1996), Deng, Gopinathan, and Lee (2013) clarify that pervasive questions around all curriculum thinking, discussion and action occur at three distinct levels: (1) societal, where the issues centre on policies at the intersection between schooling, culture and society; (2) institutional or programmatic, where the issues centre on the specification of subject content for schools and programmes, with their core and elective course requirements or expectations, subject specifications, and the construction of appropriate content for classroom coverage within these subjects; and (3) instructional or classroom, where the issues centre on the elaboration of the programmatic curriculum and its connection to the worlds of schools and classrooms in their real-world contexts. Curriculum innovation involves curricular thinking, discussion and action at the programmatic and instructional levels. As such, curriculum leaders deal with issues that surround school history, student profile and programmes. From the ecological perspective, curriculum innovation, whether it is mandated or not, has multiple interfaces at the societal, institutional and instructional levels. Hence, we argue that when implementing curriculum innovation, it is pivotal to understand the ecology of the system in addressing the knowledge gaps, such as understanding the learning needs of the students in order to provide adequate intellectual challenge.

Horng and Loeb (2010) point out that the role of instructional leadership in principals is limited in bringing about change to the curriculum since principals are often held accountable for student performance (Heck & Hallinger, 2005). Ideally speaking, principals who work their way up from being classroom teachers before they are placed on the leadership track such as the case of Singapore, would have had experiences in leading curricular change. Although the literature seems to suggest shared curriculum leadership between school leaders and teachers is the way to go, such shared curriculum leadership could be a double-edge sword as one is dependent on the other. Two studies conducted in Singapore could illustrate this point. In a study, L. S. Tan and Ponnusamy (2014b) found that when curriculum innovation is anchored and led by the school principal, it has multiplying effects on the contextual structures such as the stability of curriculum leaders; and when adopted as a sociocultural lens to elaborate the curriculum, it facilitates greater curriculum innovation. The adoption of a deep and pliable curriculum vision, such as the “thinking curriculum” or the “connected curriculum”, provides a frame to drive the reframing and re-contextualising of the curriculum making process and modify pedagogical practice (L. S. Tan & Ponnusamy, 2014a, 2014b). In another study documented school-based curriculum innovation that do not espouse such a curriculum vision remains ambiguous and lead to teachers to fall back on the familiar benchmark, the high-stakes examinations, as a pragmatic and utilitarian lens towards curriculum and pedagogical practice (E. Koh, Ponnusamy, Tan, Lee, & Ramos, 2014). Such situations may largely be put down to a lack of unpacking, elaboration and scaffolding of the ideas for curriculum and instruction (Cohen & Ball, 2007) in the school-based curriculum innovation the schools wish to achieve. Several studies on the state of infusing critical thinking in Singapore showed mixed findings suggest teachers encountered roadblocks in the curriculum innovation process. While Lim (2014) found the ubiquitous emphasis on critical thinking as a technical skill that students learned in Singapore classrooms, C. Tan (2017) documented teachers enact the curricular policy initiative by making sense of, negotiating, influencing and capitalising on their unique conditions to achieve their goals and juggle multiple demands. Hence, successful school-based curriculum innovation depends much on high quality curriculum leadership (E. Koh et al., 2014; L. S. Tan & Ponnusamy, 2014b) and the outcomes of curriculum innovation should be examined.

The Contexts of Curriculum Innovations in Singapore

The curriculum innovations in our research can be best understood as the need to heighten the significance of nurturing critical thinking that taking place against the backdrop of an exam-oriented culture. In light of this, the curriculum innovations formally designate and provide teachers with opportunity, autonomy and recognition to experiment with and tackle the syllabus in a less conventional way, and even go further with it, to improve student engagement and deepen their learning.

The curriculum innovations in our research generally fall into one of the two categories. The first category usually focuses on a single subject area, is at the department level and is short-term, lasting less than two terms. The Lyo and Merly innovations fall under this category. Meanwhile, the second category of innovation has a broad scope and permeates all subjects, is at the whole-school level and pervades the curriculum throughout academic year. The Singa and the IP innovations fall under this category. Described below are the curriculum innovations.

Study 1: Comparisons of critical thinking competencies between subject-specific and whole-school curriculum innovation

Lyo Secondary School features a 15-lesson Science-based curriculum innovation that seeks to enhance the engagement and learning of students by providing exposure to the knowledge and real-life applications of Life Science. This level-wide innovation exposes students to topics ranging from the preparation of media for bacteria culture, to forensics Science DNA fingerprinting and bioinformatics. The hands-on learning experience not only deepens students’ knowledge of Life Science, but also illustrates how such knowledge is being applied in the real world. Lyo Secondary School is chosen to be part of Study 1 as critical thinking can be fostered in discussing the real life scientific issues.

Merly Secondary School features two innovations regarding languages – DW and BL. DW is a curriculum innovation that integrates drama into the teaching and learning of English and Literature, focusing on the fundamentals of theatre. The five-week innovation culminates in a performance-based task. The main aim of DW is to increase students' confidence in using English Language. By exposing students to drama, the programme can help them become more at ease and confident with the language. The second innovation, BL, is a programme that aims to promote critical thinking skills in students by harnessing the power of technology. Discussions and work in Chinese Language are integrated into an online environment.

Singa School offers a 6-year arts and academic curriculum, with students skipping the GCE 'O' Levels examination. In addition to specialised training in Dance, Music, Theatre or Visual Arts, students also undergo an academic curriculum largely typical to that of other schools. Many of their arts teachers are practising artists who offer students insights into the creative perspectives of real-life arts practitioners.

Study 2: Comparisons of critical thinking competencies between programmes after the removal of high-stakes examination

Study 2 involved a group of schools that offer the dual programmes, the 4-year Express programme that culminates in the GCE "O" Level Examination, and the 6-year seamless IP programme that allows students to skip the GCE "O" Level Examination and enter directly into the next level of education, with the time previously allocated to exam preparation now spent on greater breadth in the academic and non-academic curriculum. In addition to changes in the curriculum, students from the IP programme participate in a variety of enrichment programs that Express programme students generally do not. These programs allow IP students opportunities to associate with and be mentored by people from different fields in industry and institutes of higher learning, to conduct research and explore a topic in greater depth, and to learn more about current affairs and different cultures. We view the 6-year IP Programme as an innovation and the 4-year Express Programme as the standard programme - this means the curriculum innovation in the Express Programme is an add-on component rather than mandated.

Following the TSLN vision, frameworks such as TLLM and 21st Century competencies and student outcomes, all the personnel in-charge stated or discussed critical thinking as an essential features of their programmes despite some curriculum innovations we studied in schools seemingly unrelated to critical thinking. Moreover, regardless the academic programme, we argue that infusing critical thinking in curriculum and instruction should be made available to all students, despite of their academic performance. This argument can be justified by Young and Lambert (2014) inquiry on "entitlement to knowledge" for students where schools "offer students ways of relating to knowledge that is new to them and new in how this knowledge relates to their experiences" (pp. 20-21). As critical thinking is one of the key deliverables in Singapore education, and due to the highly stratified academic streams, in Study 1, we use purposeful sampling in choosing a range of schools to investigate the infusion of critical thinking in curriculum innovation across school contexts, rather than a particular school context, is crucial in understanding accessibility of critical thinking as one of the 21st Century competencies to all students regardless of the school contexts.

Overview of the Present Research

Despite of the explicit curricular policies related to promoting critical thinking in Singapore schools, we could not locate empirical quantitative study that shows the state of critical thinking competencies. Given the inconsistent findings between teachers' desire to foster critical thinking (C. Tan, 2017) and the weak pedagogical enactment in the classroom (Lim, 2014), we hypothesise that critical thinking competencies among Singapore secondary school students are weaker as compared to international counterpart. Also, currently there is no existing quantitative evidence of Singapore students' critical thinking competencies. Next, we purposefully select a number of curriculum innovation structures and contents to examine the level of competency in critical thinking. Finally, since the high-stake examination always takes the blame of indoctrinating students to regurgitate information, we expect the removal of high-stake examination to boost the critical thinking competencies. Three research questions guide the analyses of the studies: (1) what is the state of critical thinking competencies among secondary school students in Singapore in relation to their US counterparts? (2) how the innovations which students attended affect the development of their critical thinking competencies? (3) does the IP students improve critical thinking competencies more than Express students? is an additional question for Study 2. The selection of distinctive academic profiles and curriculum innovations in Study 1 and 2 allows policymakers, educators and researchers to have an in-depth understanding of the state of critical thinking competencies among secondary students who are exposed to critical thinking in different school settings.

Study 1

Method

Participants, Context, and Procedure

Study 1 involved three schools that differed in their student academic profiles and curriculum innovations. A total of 247 students from three secondary schools were involved in Study 1. Students (21 boys and 74 girls) from Singa School attended an arts-anchored program with a strong focus on the arts, music and dance; Students (37 boys and 35 girls) from Merly School participated in either one of two innovations – drama-related or technology-related. While the sample students from the 3rd school, Lyo, came from 2 different academic streams – the Express (13 boys and 24 girls) and Normal (Academic) (NA) (21 boys and 22 girls), they attended the same life science curriculum innovation though this innovation was less intensive for students in the NA program. The average age of all students in this study when they first took the WGCTA in Sec 1 was 14.38 years. Students from both the Express and NA stream sit for the GCE "O" Levels; the difference is that the former takes the exam at the end of 4 years, while the latter learns at a slower pace and takes it at the end of 5 years. In light of this difference, we separated them into 2 groups for analysis- Lyo Express and Lyo NA. The breakdown of the student self-report PSLE score for each school and its respective programme can be seen in Table 1. Students from this sample have a wide range of PSLE scores.

The Measures

Primary School Leaving Examination (PSLE)

The Primary School Leaving Examination is the first national high-stakes examination that a primary school student will sit for at the end of their final year in Primary 6. Students sit for tests in four subjects—English Language, Mother Tongue, Mathematics, and Science—and obtain an aggregated total score. The PSLE score is a key consideration when secondary schools assess the students' application to join them. The PSLE total score can be seen as a measure of a student's general academic ability.

Watson-Glaser Critical Thinking Assessment – UK Version (WGCTA)

The Watson-Glaser Critical Thinking Appraisal is an internationally used test on critical thinking comprising of 80 items in five dimensions. The five subtests measure the following ability: (a) *drawing inferences* which is the ability to evaluate the validity of inferences drawn from a series of factual statements; (b) *recognizing assumptions* which is the ability to identify unstated assumptions or presuppositions in a series of assertive statements; (c) *argument evaluation* which is the ability to determine whether certain conclusions necessarily follow from the information in given statements or premises; (d) *deductive reasoning* which is the ability to weigh evidence and deciding if generalisations or conclusions based on the given data are warranted; and (e) *logical interpretation* which is the ability to distinguish between arguments that are strong and relevant and those that are weak or irrelevant to a particular question at issue. The five subtests are designed to measure different, though interdependent, aspects of critical thinking. Each subtest has a maximum score of 16, and the maximum possible score for the test is 80. The stability of test scores over three months between testing period (test-retest reliability) reported in the manual was 0.73. The correlations between the dimensions of the WGCTA, its total score, and PSLE can be found in Table 1.

Research Design and Procedure

Participating students and their parents were required to acknowledge their consent by signing on consent forms in accordance with ethics and the institutional review board. This was a cohort study. In 2013, the 247 Secondary 1 students from the three schools sat for a number of tests and surveys, one of which was the WGCTA which was attempted using paper-and-pencil (Singa in 2nd quarter; Merly in 3rd quarter; Lyo in 4th quarter). The differences in timing were due to logistical and other issues. In the last quarter of 2014, these same 247 students when they were in Secondary 2) sat for the same set of tests and surveys, including the WGCTA. This WGCTA post-test was for the purpose of understanding the impact of the different schools' innovations on critical thinking.

Table 1. *Descriptive Statistics and Comparisons for PSLE scores and Critical Thinking Total Scores*

			Study 1				Study 2					
		US Sample	Singa	Merly	Lyo NA	Lyo Exp	SentosaIP	SentosaExp	MarinaIP	MarinaExp	IstanaIP	IstanaExp
							PSLE Scores					
	n	1676	95	72	43	37	75	116	97	86	99	92
	M	-	228.37	202.69	195.33	233.91	252.47	241.05	255.38	248.42	256.84	248.42
	SD	-	17.86	11.01	6.05	4.448	6.29	9.4	3.77	7.56	3.52	7.56
							WGCTA Scores					
Sec 1	*M*	-	41.22	37.25	38.26	46.32	46.93	42.29	47.18	45.06	49.86	45.54
Age	*SD*	-	9.21	6.48	7.22	7.54	7.37	6.06	6.21	5.94	6.42	5.75
12-13	*d**	-	0.86	0.48	0.57	1.35	1.42	0.98	1.45	1.24	1.71	1.29
Sec 2	*M*	-	47.18	42.68	41.91	51.05	-	-	-	-	-	-
Age	*SD*	-	6.37	6.13	6.19	7.77	-	-	-	-	-	-
13-14	*d**	-	1.45	1.01	0.93	1.8	-	-	-	-	-	-
Sec 3	*M*	**32.3**	-	-	-	-	52.64	50.25	54.18	51.01	53.15	50.16
Age	*SD*	**10.44**	-	-	-	-	8.17	7.93	6.86	6.39	6.97	7.01
14-15	*d**	-	-	-	-	-	1.96	1.74	2.13	1.82	2.03	1.74

*. Effect size of mean difference, using pooled SD, compared to the US sample of 1676 Grade 9 (Age 14-15) students. All t-tests conducted were significant at $p < .001$.

Note. Other benchmark data from US samples: **Grade 10 (Age 15 - 16)**: $N = 1950$, $M = 36.3$, $SD = 11.65$. **Grade 11 (Age 16 - 17)**: N = 1844, M = 39.1, SD = 11.89. **Grade 12 (Age 17 - 19)**: N = 1636, M = 39.5, SD = 11.89.

Table 2. *Correlation Table of Critical Thinking Scores – Study 1 and Study 2*

	PSLE	***Infer***	***Assum***	***Eval***	***Deduct***	***Intprt***	***Total***	*Infer T2*	*Assum T2*	*Eval T2*	*Deduct T2*	*Intprt T2*	*Total T2*
PSLE	-	.245**	.091*	.116**	.287**	.156**	.320**	.218**	.018	.184**	.207**	.066	.224**
Infer	.468**	-	.136**	.118**	.223**	.141**	.583**	.235**	.139**	.129**	.149**	.071	.250**
Assum	.191**	.170**	-	.081	.193**	.053	.519**	-.003	.106*	.105*	.078	.053	.119**
Eval	.010	.026	.070	-	.181**	.100*	.483**	.165**	.120**	.191**	.145**	.120**	.252**
Deduct	.278**	.299**	.108	-.016	-	.156**	.609**	.171**	.019	.124**	.283**	.096*	.220**
Intprt	.190**	.186**	.076	-.079	.263**	-	.582**	.096*	.023	.117**	.123**	.155**	.165**
Total	.400**	.476**	.442**	.278**	.674**	.611**	-	.234**	.141**	.235**	.274**	.181**	.356**
Infer T2	.447**	.436**	.089	.119	.267**	.100	.334**	-	.124**	.306**	.265**	.153**	.627**
Assum T2	.138*	.150*	.214**	-.035	.101	.132	.163**	.193**	-	.171**	.065	.126**	.596**
Eval T2	.254**	.229**	.112	.091	.110	.069	.162*	.205**	.122*	-	.269**	.075	.610**
Deduct T2	.440**	.341**	.179**	.133*	.264**	.325**	.352**	.412**	.183**	.143*	-	.212**	.563**
Intprt T2	.389**	.240**	.083	-.003	.231**	.318**	.267**	.268**	.249**	.175**	.297**	-	.506**
Total T2	.531**	.464**	.208**	.101	.320**	.297**	.420**	.665**	.564**	.499**	.675**	.649**	-

Note. Correlation coefficients for the Study 1 schools are shown on the bottom left, while coefficients for the Study 2 schools are shown on the top right.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Results

Students from the Singaporean schools scored significantly higher than students from a US benchmark sample

Independent t-tests were conducted to compare students' scores to a US benchmark sample of students who were slightly older. This US sample (data taken from the WGCTA-UK Manual) was used because it was the sample which ages were most similar to the Singaporean sample. The results (Table 1) show that mean scores from individual Singaporean schools from Study 1 at Sec 1 & Sec 2 were significantly higher ($p < .001$) than their US counterparts. Even though the Singaporean sample students (aged 12-13 and 13-14) were younger than the comparison US sample (aged 14-15), they scored significantly higher. Effect sizes of the mean difference in Sec 1 ranged from medium to very large ($d = .48$ to 1.35), while in Sec 2 the effect size was even larger ($d = .93$ to 1.80). Further descriptive statistics for Study 1 by school and t-tests comparing the Sec 1 to Sec 2 scores can be found in Table 3.

Table 3. *Descriptive Statistics and Comparisons Across Schools*

School			Sec 1		Sec 2					
		n	*M*	*SD*	*M*	*SD*	*t*	*df*	*p*	*d*
Singa	Inference	94	6.93	2.28	7.02	2.40	.344	93	.732	0.04
	Assumption	95	9.97	2.50	10.54	2.71	1.724	94	.088	0.22
	Deduction	95	7.79	2.06	8.34	2.30	1.698	94	.093	0.25
	Interpretation	90	9.10	2.97	10.57	2.19	4.077	89	**.000**	0.56
	Evaluation	79	9.53	3.01	10.92	2.44	4.284	78	**.000**	0.51
	Total	95	41.22	9.21	47.18	6.37	6.551	94	**.000**	0.75
Merly	Inference	72	4.53	2.06	5.67	2.20	3.819	71	**.000**	0.53
	Assumption	72	9.03	2.16	9.94	2.04	2.746	71	**.008**	0.43
	Deduction	72	8.21	1.95	8.28	2.02	.215	71	.830	0.04
	Interpretation	71	8.13	2.37	8.82	2.21	1.778	70	.080	0.30
	Evaluation	63	8.54	2.69	9.84	2.43	2.925	62	**.005**	0.51
	Total	72	37.25	6.48	42.68	6.13	5.586	71	**.000**	0.86
Lyo (Express)	Inference	37	7.49	2.30	7.62	2.46	.317	36	.753	0.05
	Assumption	37	10.46	2.55	11.14	2.65	1.296	36	.203	0.26
	Deduction	37	8.54	2.08	9.81	2.45	2.774	36	**.009**	0.56
	Interpretation	35	10.80	2.37	11.46	2.29	1.782	34	.084	0.28
	Evaluation	32	10.69	2.90	11.91	2.13	2.121	31	**.042**	0.48
	Total	37	46.32	7.54	51.05	7.77	4.130	36	**.000**	0.62
Lyo NA	Inference	43	5.23	2.33	5.14	1.82	-.249	42	.804	-0.04
	Assumption	43	9.07	2.09	10.07	2.13	2.209	42	**.033**	0.47

Deduction	43	8.26	2.28	8.23	2.22	-.053	42	.958	-0.01
Interpretation	42	8.74	2.37	8.81	1.98	.170	41	.866	0.03
Evaluation	35	8.80	3.34	9.43	2.09	1.065	34	.294	0.23
Total	43	38.26	7.22	41.91	6.19	2.578	42	**.014**	0.54

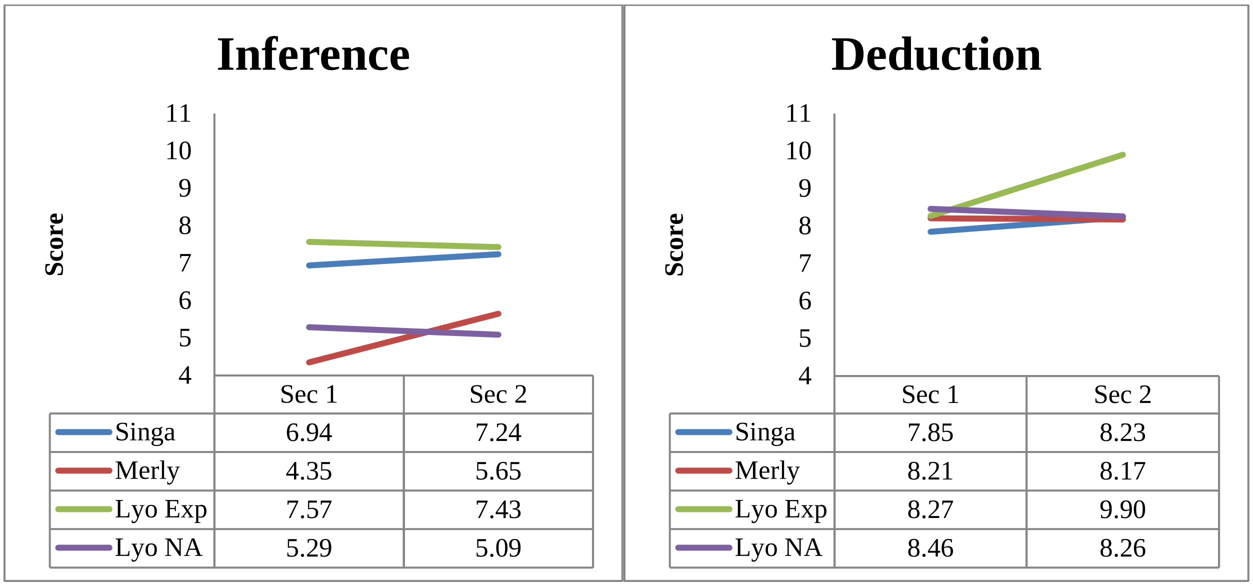

Figure 1. Interaction Graph for Innovation by Level for Inference and Deduction.

Focus on the curriculum innovations can lead to specific development in a dimension of critical thinking

In order to explore whether students from the different schools would show differences in how their critical thinking scores changed over time, a mixed 4 x 2 ANOVA with Innovation (Singa, Merly, Lyo Exp, Lyo NA) as a between-subjects variable and Level (Sec 1 vs Sec 2) as a within-subjects variable was conducted to test if there was any significant interaction between Innovation and Level for the five WGCTA sub-scales and total score (as shown in Figure 1). Results indicated that there was a significant interaction for 2 of the measures – Inference, $F(3,202) = 3.522$, $p = .016$ and Deduction, $F(3,202) = 2.828$, $p = .040$. Examination of the interaction graphs (Figure 1) showed a clear and interpretable pattern for Deduction, but not for Inference. Post-hoc paired t-tests revealed that while students from Lyo Express showed a significant increase in Deduction score from Sec 1 to Sec 2 ($p = .093$), students from Singa (p

= .009), Merly (p = .830) and Lyo NA (p = .903) did not. This provided further evidence of the significance of the interaction.

The different pre-test timings would normally affect the validity of the results (Singa taking the test earliest, Merly second, and Lyo being latest), however the special pattern of the results allow us to reach our conclusion in a valid manner. This is because all the Time 2 measures in 3 schools took place one year later. Despite students in Lyo Express is academically strongest among the three schools, Lyo Express did not show advantage in the Time 2 measure over other sub-scales except on the deductive reasoning. Lyo NA, though academically compatible to Merly, the scores were not significant. Thus, the result of controlling the timing for WGCTA tests would only further emphasize the interaction, seen in Figure 1's deduction graph, leaving our conclusion valid.

Our interpretation of this result is that the science-based curriculum innovation at Lyo Secondary significantly improved students' deduction abilities to the extent it was detectable by our analysis. However, this improvement was only seen for students in their Express programme, but not their 5-year Normal Academic programme.

Study 2

While the 3 schools in Study 1 had vastly different curriculum innovations, and comprised of a diverse range of students with moderate to moderately high academic abilities (PSLE scores), Study 2's schools had more similar profiles with each conducting both an Express and IP programme, and comprising of high ability students. This allowed for a larger sample to examine how the innovations of the IP programme might affect critical thinking in comparison to the Express programme. The innovation of the IP programme was a very different type compared to those innovations in Study 1. While the Singa innovation was an all-encompassing arts-based curriculum, the Merly and Lyo innovations were generally short to medium-term modular programs that could replace or be integrated into existing lesson activities. Comparatively, the IP programme is expected to be all-encompassing curriculum and pedagogy that were used. The analyses we conducted were similar to that of Study 1.

Method

Participants, Context, and Procedure

Participants consisted of a total of 565 students from three single-gender secondary schools which had both an Integrated Programme and Express Programme. Two of the schools were for females (Marina School, n = 183; Istana School, n = 191), while the third school was for males (Sentosa School, n = 191). For the participants from each school, about half attended the IP programme, while the remaining attended the Express programme. For all 3 schools, this was the first time that they were conducting the IP programme for Secondary 1 students.

The breakdown of the student self-report PSLE score for each school and its respective programme can be seen in Table 1. Students from these 3 schools comprised the top 15% of the cohort by PSLE score and displayed a narrower range of PSLE scores. Nevertheless, t-tests showed that students from the IP programme had significantly higher mean PSLE scores than students from the Express programme for all 3 schools ($p < .001$).

Research Design and Procedure

Participating students and their parents were required to acknowledge their consent by signing on consent forms in accordance with ethics and the institutional review board. All these participants were part of another larger study that sought to understand the impact of curriculum innovation on 21st Century Competencies such as creativity, critical thinking, self-directedness, and attitudes to learning.

This was a cohort study. In the first quarter of 2013, the 565 Secondary 1 students from the three schools sat for a number of tests and surveys, one of which was the WGCTA which was attempted using paper-and-pencil. Two years later in the first quarter of 2015, these same 565 students (now in Secondary 3) sat for the same tests, including the WGCTA. This WGCTA post-test was for the purpose of understanding the different impacts of the IP and Express programmes on critical thinking. Descriptive statistics for each dimension of the WGCTA are shown below in Table 4.

Table 4. *Descriptive Statistics and Comparisons Across Schools and Programmes*

		Express									IP								
			Time 1		Time 2							Time 1		Time 2					
	Dimension	*n*	M_1	SD_1	M_2	SD_2	*t*	*df*	*p*	*d*	*n*	M_1	SD_1	M_2	SD_2	*t*	*df*	*p*	*d*
Overall	Inference	294	6.70	2.35	7.62	2.58	4.82	293	**.000**	0.37	271	7.73	2.41	8.53	2.48	4.58	270	**.000**	0.33
	Assumption	294	9.97	2.19	10.55	3.28	2.53	293	**.012**	0.21	271	10.46	2.57	11.02	3.18	2.51	270	**.013**	0.20
	Evaluation	294	9.41	2.85	11.41	2.31	10.20	293	**.000**	0.78	271	10.32	2.83	11.72	2.29	6.77	270	**.000**	0.55
	Deduction	294	8.25	2.00	9.40	2.41	6.77	293	**.000**	0.52	271	8.68	2.11	10.01	2.40	7.73	270	**.000**	0.59
	Interpretation	294	9.79	2.09	11.46	2.10	11.39	293	**.000**	0.80	271	10.90	2.30	12.10	2.12	7.21	270	**.000**	0.54
	Total	294	44.12	6.09	50.45	7.21	13.82	293	**.000**	0.95	271	48.09	6.74	53.38	7.29	10.65	270	**.000**	0.75
Sentosa School	Inference	116	6.01	2.48	7.46	2.78	4.62	115	**.000**	0.55	75	7.12	2.50	8.24	2.75	2.94	74	**.004**	0.43
	Assumption	116	9.53	2.42	10.73	3.23	3.18	115	**.002**	0.42	75	9.85	3.05	10.33	3.75	0.97	74	.334	0.14
	Deduction	116	8.41	2.09	9.51	2.47	3.83	115	**.000**	0.48	75	8.71	2.24	10.07	2.72	3.65	74	**.000**	0.55
	Interpretation	116	9.43	2.08	11.03	2.30	6.73	115	**.000**	0.73	75	10.88	2.30	12.27	2.32	3.92	74	**.000**	0.60
	Evaluation	116	8.91	3.23	11.53	2.11	8.13	115	**.000**	0.98	75	10.37	2.85	11.73	2.33	3.42	74	**.001**	0.53
	Total	116	42.29	6.06	50.25	7.93	10.23	115	**.000**	1.14	75	46.93	7.38	52.64	8.18	5.41	74	**.000**	0.73
Marina School	Inference	86	7.21	2.52	7.73	2.34	1.46	85	.149	0.22	97	7.84	2.23	8.81	2.46	3.5	96	**.001**	0.42
	Assumption	86	10.37	2.09	11.09	2.57	2.00	85	**.049**	0.31	97	10.45	2.32	11.63	2.31	3.39	96	**.001**	0.51
	Deduction	86	8.21	1.86	9.16	2.26	3.26	85	**.002**	0.46	97	8.41	2.17	9.78	2.37	4.75	96	**.000**	0.60
	Interpretation	86	9.80	2.09	11.59	2.03	6.71	85	**.000**	0.87	97	10.56	2.48	11.84	2.08	4.29	96	**.000**	0.56
	Evaluation	86	9.47	2.33	11.43	2.23	5.73	85	**.000**	0.86	97	9.92	2.84	12.11	1.94	7.00	96	**.000**	0.92
	Total	86	45.06	5.94	51.01	6.39	7.41	85	**.000**	0.97	97	47.18	6.21	54.18	6.86	8.85	96	**.000**	1.07
Istana School	Inference	92	7.10	1.76	7.73	2.56	1.99	91	**.049**	0.29	99	8.08	2.44	8.47	2.26	1.48	98	.142	0.17
	Assumption	92	10.14	1.87	9.80	3.81	-0.79	91	.433	0.12	99	10.92	2.33	10.95	3.35	0.09	98	.931	0.01
	Deduction	92	8.09	2.02	9.49	2.48	4.66	91	**.000**	0.62	99	8.93	1.93	10.18	2.17	5.03	98	**.000**	0.61
	Interpretation	92	10.23	2.03	11.89	1.79	6.27	91	**.000**	0.87	99	11.25	2.09	12.22	2.01	4.36	98	**.000**	0.47
	Evaluation	92	9.99	2.70	11.25	2.63	3.68	91	**.000**	0.47	99	10.68	2.78	11.32	2.52	1.83	98	.070	0.24
	Total	92	45.54	5.75	50.16	7.01	6.18	91	**.000**	0.72	99	49.86	6.42	53.15	6.97	4.43	98	**.000**	0.49

Results

Students from both IP and Express Programmes from the 3 Singaporean schools scored significantly higher than the US benchmark

Independent t-tests were conducted to compare students' scores to a US benchmark sample of students who were slightly older. The results (Table 1) show that mean scores from individual Singaporean schools from Study 2 at Sec 1 & Sec 3 were significantly higher ($p < .001$) than their US counterparts. Effect sizes of the mean difference in Sec 1 ranged from very large to extremely large (d = .98 to 1.71), while in Sec 2 the effect size was even larger (d = 1.74 to 2.13). Further descriptive statistics for Study 2 by school and t-tests comparing the Sec 1 to Sec 3 scores can be found in Table 4.

Express students generally showed greater improvement than IP students

In order to investigate the effect of Programme (IP vs Express) on critical thinking scores, a mixed 2 x 2 ANOVA with Programme (IP vs Express) as a between-subjects variable and Level (Sec 1 vs Sec 3) as a within-subjects variable was conducted to test if there was any significant interaction between Programme and Level for the 5 WCGTA sub-scales and total score. Results indicated that the interaction was significant for 2 sub-dimensions – Evaluation, $F(1, 563) = 4.51$, $p = .034$ and Interpretation, $F(1, 563) = 4.68$, $p = .031$. T-tests (Table 4) had earlier revealed that the changes in scores from Sec 1 to Sec 3 were all statistically significant for both programmes. The raw increase in Evaluation score for the IP was 1.40, compared to 2.00 for the Express. The raw increase in Interpretation score for the IP was 1.20, compared to 1.67 for the Express.

The 2 interaction graphs are shown in Figure 2. While the graphs clearly show that the Express students have a larger increase in Evaluation and Interpretation than IP students, the effect is comparatively smaller compared to the earlier interaction finding in Study 1. The observation, that Express students generally showed a greater than IP students (Table 4), and the result of a significant interaction for the dimensions of Evaluation and Interpretation were counterintuitive. Because of the nature of the programmes, we had expected that IP students would show a greater increase in critical thinking ability. More will be discussed in the below section.

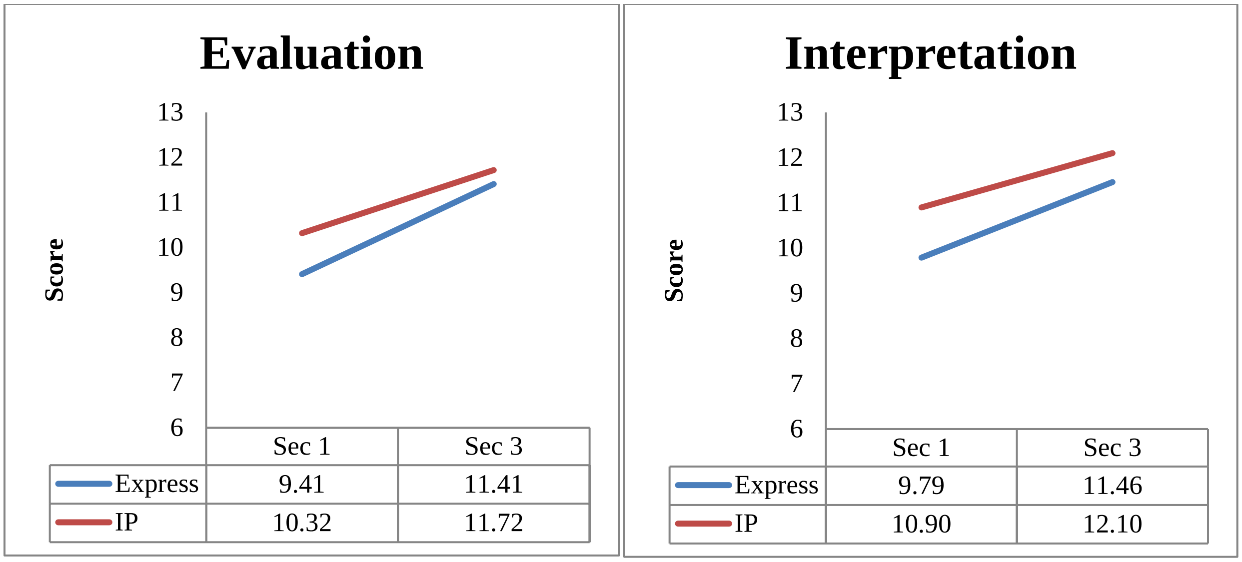

Figure 2. Interaction Graph for Programme by Level for Evaluation and Interpretation.

General Discussion

In the present research, two studies were conducted to measure critical thinking competencies of Singapore secondary students in a number of school settings. Results from both studies provided evidence on critical thinking competencies as one of the student outcomes of curriculum innovation in specific instructional programmes ranging from typical schools, specialized school to IP schools that housed both Express and IP students. While we acknowledge that there might be other confounding factors that might affect the validity of this research (other school programs, activities prior to students taking the test etc.), we were able to obtain results that generally addressed each of our two stated main objectives.

Firstly, while it is widely known that Singaporean students generally show a higher level of math and science scores than American students, our analyses show this is also true for their critical thinking competencies. In both Study 1 and 2, the critical thinking tests administered on the same cohort with repeated measure not only provided empirical evidence for Singapore student critical thinking scores, but also the comparative advantage of Singapore students to that of the US samples. Despite the claims on direct teaching with limited infusion of critical thinking skills in Primary 5 and Secondary 3 classrooms (Hogan et al., 2013), the lack of critical pedagogy (A. Koh, 2002) and the critique of weak enactment of pedagogy in critical thinking (Lim, 2014), our analyses show that even though the Singaporean sample students were younger than the comparison US sample in both Study 1 and 2, they scored significantly higher ($p < .001$) in critical thinking tests. Besides the PSLE being a foundation for teaching critical thinking skills, regardless of the academic programme, Singapore students continued to grow in their critical thinking competencies. Surprisingly, for those who chose to stay within the standard curriculum and proceed with the second high-stakes examination which is the GCE ‘O’ Level showed greater growth in their critical thinking competencies in Study 2 when compare with the IP students.

Secondly, we examined the five dimensions of critical thinking, namely *drawing inference, recognizing assumptions, argument evaluation, deductive reasoning,* and *logical interpretation,* and found evidence of an interaction between Innovation and Level for the deduction WGCTA sub-scale. The Lyo School’s curriculum innovation, focusing on life science, resulted in a higher score, over and above, that of other curriculum innovations for the dimension of deductive reasoning. Pertinent to the scientific process, present in their life science programme, is the use of deduction in which reasoning starts out with a hypothesis, tests evidence, and then examines the possibilities to reach a specific, logical conclusion. We believe that it is this use of the scientific process which contributed to developing students’ deduction abilities. Despite being involved in the same curriculum innovation, Lyo NA students did not show the same pattern as Lyo Express students in deductive reasoning. This finding, however, does not inform us whether deductive thinking is not prevalent in another subject domain. It does not imply some disciplines are more appropriate for fostering students’ critical thinking competencies than others. Although all five critical thinking competencies exit in all subject domains and each competency is specific in each discipline, curriculum innovations with a focus on certain dimension of critical thinking could lead to specific development in a dimension of critical thinking. No doubt teaching critical thinking in a domain-specific, with deliberate effort and structured process, has impact on students’ capacity to apply critical thinking (Hatcher, 2006; McKown, 1997), studies showed that the instructor needs to be well versed in critical thinking and foster classrooms and environments that help promote the use of critical thinking (Sungur & Tekkaya, 2006). They also need to effectively evaluate the quality of critical thinking among students in order to enable students learn and effectively apply critical thinking skills (Colucciello, 1997; Schumm, Webb, Tuerk, Jones, & Ballard, 2006). Hence, teacher’s choice of focus and pedagogical effectiveness are the keys to infuse critical thinking in the curriculum and instruction.

Further analysis of course materials revealed that there was a reduction of materials used for Lyo NA and that there were also more open-ended questions in the materials for Lyo Express as compared to Lyo NA. In contrast, taking the whole-school approach in the arts-anchored curriculum, Singa did not focus on deductive reasoning. In addition, Merly's curriculum innovations focus on expository writing in the learning of Chinese Language and building confidence in speaking English Language did not help in developing deductive reasoning. This might due to the design of the course materials adopted by teachers in innovating the curriculum. Research in Israel on the improvement of higher-order thinking skills showed that the intervention group improved 40% compared to 4% in control group and there were differences according to the type of school (Vidergor, 2017). Hence, if curriculum innovation is a practical intervention on the part of teacher, the innovation could design whether it would privilege specific critical thinking skill or be more comprehensive in all five skills as reported here.

Next, in Study 2, the question is whether the innovation of the IP program facilitates the development of critical thinking competencies over and above the standard academic programme. Previously in their qualitative study, Cheong and Cheung (2008) found lower secondary school students exhibited minimum critical thinking skills during the online discussion, our analyses actually showed the contrary - Express students showed a greater increase in 4 out of the 5 dimensions of critical thinking scores compared to the IP students. Two of these increases, *drawing inference* and *argument evaluation*, were statistically significant. There are several possible explanations for these findings. Firstly, the IP innovation was a nascent development; schools without prior working experiences in engaging high ability students would need some time to deliberate and re-configure their pedagogies. As this is the first batch of IP students, the current findings might be preliminary. Secondly, some of the IP enrichment programmes were made available to the Express students, resulting in some substantial benefit to them too. Thirdly, it is very possible that the high-stakes GCE 'O' Level examination in recent years requires critical thinking. This requirement drives teachers to focus on critical thinking competencies of the students. Lastly, the differing levels of item difficulties of the WGCTA instrument might pose a challenge in interpreting the results. The critical thinking scores among IP students were already higher than the Express students in both Time 1 and 2. It might be possible that the remaining test questions that IP students answered wrongly are comparatively very much harder than the ones that they got the answers right, and this might be a result of a ceiling effect that prevented IP students' scores from increasing further. On the other hand, the Express students caught up in terms of their scores for each of the dimensions as there were room for improvement. Hence, we find some evidence to say that the Express programme has substantial strengths relating to the development of critical thinking, but as of now, further research would need to be conducted on the IP before we arrive at conclusions on its contribution to critical thinking.

All the findings in this present research donate three levels of understandings on the state of critical thinking competencies among Singapore students: (1) In both our studies, Singapore students who are younger than the US sample score higher than the US sample who are either equivalent or older in age; (2) the focus of curriculum innovation might lends itself to certain critical thinking sub-scales, thus deliberate efforts are needed in designing curriculum to develop different aspects of critical thinking competencies; and (3) the Express programme appears to have substantial strengths relating to the development of critical thinking.

The development of critical thinking competencies is a deliberate effort in designing and implementing a differentiated curriculum and instruction. Hence, this present research documented the state of critical thinking competencies among Singapore secondary students in different school contexts and curriculum innovations.

Although the strength of the two studies presented in this paper is having the research funding to conduct critical thinking tests over time, the findings of our studies are limited in the following areas: (1) the curriculum innovations of the participating schools are diverse in a number of subjects. The use of WGCTA in measuring critical thinking taught in different subject areas is limiting; and (2) curriculum innovation in school is a complex process and the innovations might develop at different phases. The measurement of student outcome such as the critical thinking competencies should be interpreted with caution.

Conclusion

This paper examines the state of critical thinking competencies among secondary school students in Singapore in relation to their US counterparts; the curriculum innovations bring about the development of their critical thinking competencies; and whether the IP students improve critical thinking competencies more than Express students. In examining the state of critical thinking competencies among secondary school students in the contexts of curriculum innovations, our findings contribute to a deeper understanding of Singapore secondary school students' level of critical thinking competencies in comparison to the US samples. Given the multiple settings and contexts of curriculum innovations involved in the present research, our findings advanced our understanding on the complexities in fostering critical thinking as one of the outcomes of the related educational policies such as the TSLN, TLLM and the 21st Century Competencies. Under the Singapore high-stakes examination system, most teachers claim that the teaching of critical thinking within curriculum time is challenging. The IP is an experimentation of whether the removal of high-stakes examination at the secondary level necessitates teachers to teach critical thinking rigorously. Our findings suggest that educational policies alone may not promote the desired pedagogical shift if teachers are not well versed in teaching critical thinking and design learning environment for students to apply critical thinking in learning. Hence, pedagogical change is the outcomes of a combination of complex sociocultural elements at play.

Moreover, critical thinking competencies can be taught and improved within a high-stakes examination system if the items in the examination require students to use critical thinking skills. The international researchers and practitioners can draw at least two implications from the analyses of this paper. That only curricular that are rigorously designed to foster critical thinking competencies reap the intended student outcome. In addition, the removal of high-stakes examinations is a necessary but insufficient condition to foster critical thinking competencies among students. Future investigation on critical thinking competencies among Singapore Secondary students could focus on the enablers and inhibitors of curriculum innovations; and how teachers have adjusted curriculum and instruction to foster critical thinking and to what extent the system has achieved the broaden goals of education by engaging students on critical thinking.

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