A Project entitled

Comparative study of STEM Education in curriculum, pedagogy, and assessment between Hong Kong and Singapore

Submitted by

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Declaration

I, *Yuen Ho Lung* declare that this research report/ project report represents my own work under the supervision of *Assistant Professor, Dr XIONG Weiyan*, and that it has not been submitted previously for examination to any tertiary institution.

YUEN Ho Lung

01/04/2024

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Abstract

Since 2015, the Hong Kong Curriculum Development Council (2015) has promoted STEM education to cultivate more STEM talents. However, the market development and demand for STEM talents are insufficient. The innovation and technology industry contributed only 1.7% to Hong Kong's GDP in 2017. The Government of HKSAR (2022) noted that Hong Kong's innovation and technology R&D expenditure is low. Secondly, the Legislative Council Secretariat (2020) found that Hong Kong students feel that traditional science subjects have no future and do not consider taking them. As a result, graduates from STEM programs have limited employment prospects, and university STEM departments fail to attract the best students. Therefore, this study reviewed the relevant government policies and institutional practices to identify and analyze the similarities and differences in STEM Education curriculum, pedagogy and assessment in Hong Kong and Singapore, focusing on higher education levels. Through this comparison, this study aims to understand better how each region approaches STEM Education and identify their respective systems' strengths and weaknesses. This will provide valuable insights that can be used to improve the development and effectiveness of STEM Education in Hong Kong and Singapore. This study attempts to identify best practices and potential areas for improvement, thereby informing STEM Education policy and practice.

Keywords: STEM, STEM Education, curriculum, pedagogy, assessment

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SECTION 1: Background

Introduction

Science, technology, engineering, and mathematics (STEM) Education is essential today due to a growing demand for STEM professionals (Khine, 2015; Lee & Kim, 2019). Many countries such as Singapore emphasise STEM Education to prepare students to meet future challenges (Khine, 2015; Lee & Kim, 2019).

Mullis et al. (2020) stated that grade 4 and grade 8 students in Hong Kong and Singapore had the top performance in Science and Mathematics from 2003 to 2019, according to the results from the Trends in International Mathematics and Science Study (TIMSS) (see Figure 1). Hong Kong's performances, however, fluctuated compared with steadily rising Singapore. It is valuable to compare the similar levels of education systems between Hong Kong and Singapore.

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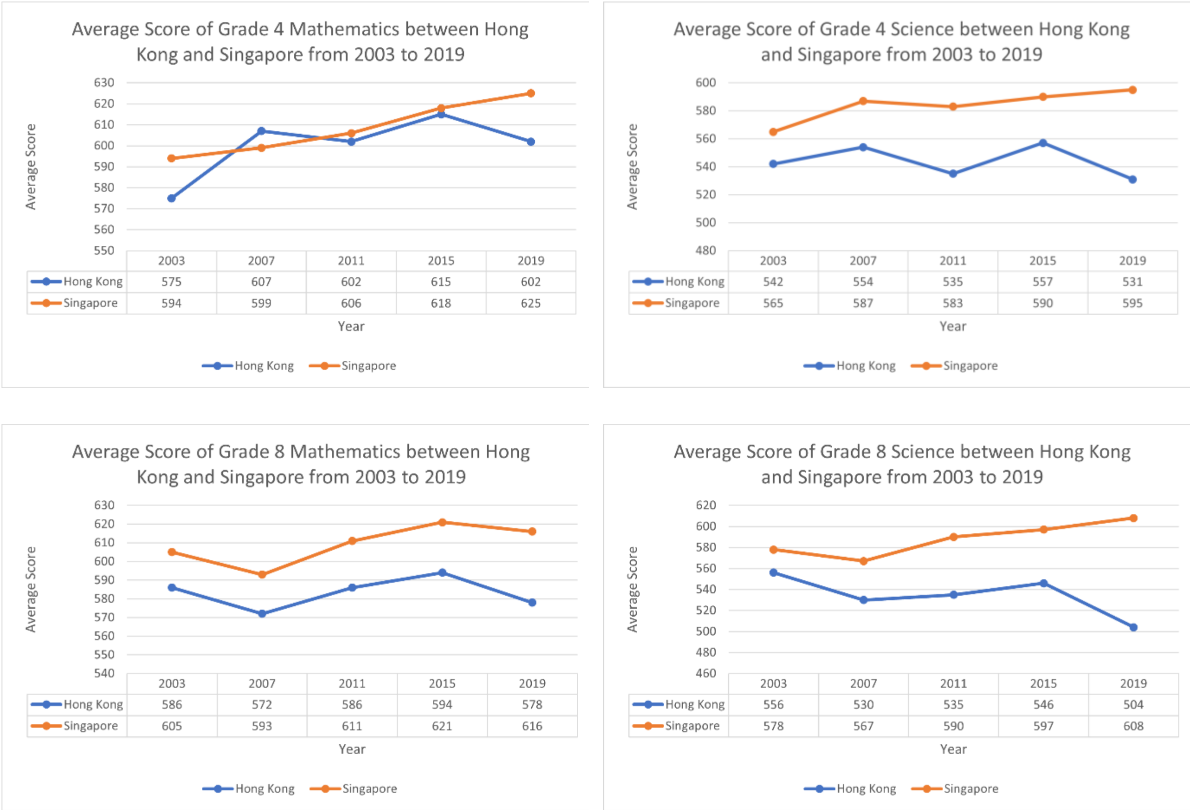
Figure 1

Grade 4 and Grade 8 Average Scores in Mathematics and Science from 2003 to 2019



Note: Figures were created by the author based on the data of Mullis et al. (2020).

Hong Kong and Singapore, which have been ranked third and fourth in the Global Financial Centres Index (GFIC) for a long time, have been competing for the position of financial centres in the Asia-Pacific region (Mainelli & Wardle, 2023). As mentioned by BBC News (2019), with similar colonial backgrounds, languages, transparent and efficient legal systems, large pools of well-educated professionals, and world-class infrastructure such as airports and harbours, Hong Kong and Singapore are robust and similar in terms of economic strength due to their efficient business environments and many years of trading experience and partnerships.

Hong Kong and Singapore have been influenced by British colonialism for many years. Hong Kong and Singapore are multi-religious societies, with their resident's enjoying freedom

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of religion and being influenced by Eastern and Western cultures (Zheng et al., 2016). This has led to similarities in education policies, teaching methods and student development in the two places, which facilitate comparative studies. Therefore, Hong Kong and Singapore are the subjects of this study because of their similarities in terms of ambitious standards in education, economic strength, and cultural background.

Research Objectives and Questions

This study identifies and analyses the similarities and differences in STEM Education curriculum, pedagogy and assessment in Hong Kong and Singapore. Through this comparison, this study aims to understand better how each region approaches STEM Education and identify their respective systems' strengths and weaknesses. This will provide valuable insights that can be used to improve the development and effectiveness of STEM Education in Hong Kong and Singapore.

This research provides a framework for the larger theoretical and practical question of improving STEM Education globally. As the demand for STEM professionals grows, we must prepare students with the skills and knowledge they need to succeed. By examining the approaches to STEM Education adopted in Hong Kong and Singapore, this study attempts to identify best practices and potential areas for improvement, thereby informing STEM Education policy and practice. The research questions are mentioned below.

1) What are the differences in developing the STEM Education curriculum in Hong Kong and Singapore?
2) What are the differences in the pedagogy of STEM Education in Hong Kong and Singapore?
3) What are the differences in the assessment of STEM Education in Hong Kong and Singapore?

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Definition of Key Terminologies

STEM Education

The term STEM Education originated from English and referred to the acronym for the four disciplines of Science, Technology, Engineering, and Mathematics (Gonzalez & Kuenzi, 2012). It was first coined by Rita Colwell, the director of the National Science Foundation in the US in the 1980s (Marshall, 2015). STEM Education combines two different but related subjects, such as Science, Technology, Engineering, and Mathematics, for cross-curricular education, teaching, and learning (Gonzalez & Kuenzi, 2012). However, it has various expressions of STEM Education globally during its development so that STEM Education would have different definitions in different regions.

Curriculum

The board's definition of curriculum is a growing path requiring an individual to overcome several obstacles or tasks (Eisner, 1994). Marsh (2009) stated that even experts in the field have many different definitions of curriculum, while the curriculum is all the learning planned by the school and is the school's responsibility. To fulfill the purpose of the curriculum, Morris and Adamson (2010) suggested that the essential elements of the curriculum include content, assessment, teaching methods, and learning objectives to achieve the aims of the curriculum. Moreover, Morris and Adamson (2010) defined five curriculum orientations: academic rationalism, social and economic efficiency, child-centred (progressivism), social reconstruction and orthodoxy/ideological transfer.

Pedagogy

Mortimore (1999) said that "pedagogy" is often debated, and various definitions have been proposed. Murphy and Gipp (2004) discovered that the most common approach is to define it as the study of teaching methods, which is teaching and learning, how teachers ensure

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that students follow the curriculum and what students do to know or be able to do what they could not do before (Westwood, 2008). Greenfield (1984) and Puntambekar and Hübscher (2005) mentioned that Vygotsky's social constructionist theory of learning emphasizes that scaffolding, which has five characteristics including providing support, serving as a tool, extending the scope of the student's work, allowing the student to perform tasks that would otherwise be impossible and using to assist students selectively, and Belland (2013) also mentioned that the role of the teacher is to identify students' recent development areas and support their learning by providing guidance and formative feedback.

Assessment

Berry (2008; 2010) defined assessment as the deliberate and systematic gathering of information by teachers and students and its analysis and interpretation to improve teaching and learning activities. Assessment functions include selection and placement, accountability, diagnosis and learning support. Selection and placement are the process of determining which students can attend college or are assigned to different classes. Accountability determines whether students are achieving learning outcomes appropriate to their grade level. Diagnosis is identifying the cause or problem of learning difficulties. Monitoring student progress in the classroom provides feedback on student progress. Moreover, there are three main approaches to assessment, which are Assessment of Learning (AoL), Assessment for Learning (AfL) and Assessment as Learning (AaL). AoL provides valid, reliable, and quantitative evidence to judge how much students have learnt. AfL is timely feedback on what, how and how well students have learnt and the effectiveness of learning and teaching strategies. AaL promotes self-learning, where students discover satisfactory performance through self-assessment and mutual assessment.

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SECTION 2: Literature Review

The curriculum of STEM Education

STEM education dates to the 1960s when it was thought that all college students should learn programming and computational theory (Grover & Pea, 2013). One of the main goals is to develop computational thinking, which applies not only to STEM disciplines but also to languages and the humanities. Togyer (2013) stated that computational thinking refers to the thought processes involved in solving problems and finding solutions so that information-processing agents can effectively execute those solutions. It consists of understanding aspects of computing in the world around us and applying the tools and techniques of computer science to understand and reason about natural and artificial systems and processes (The Royal Society, 2012).

In addition, Deming and Noray (2018; 2020) stated that the job market is recently shifting towards industries that require a strong STEM foundation because of advancing Information Technology. Many high-paying and high-demand jobs, such as technology, engineering, and data analysis, require proficiency in STEM subjects. By providing a STEM education, individuals can better meet the demands of the job market and secure well-paying careers. Moreover, Deming and Noray (2018, 2020) also asserted that STEM-related skills are rapidly changing, and people should equip themselves to adapt to the changing employment landscape and acquire new skills as needed. STEM education provides a solid foundation for lifelong learning and continuing professional development.

Pedagogy of STEM Education

Honey et al. (2014) defined STEM as completing tasks in complex presentations or situations requiring students to use knowledge and skills from multiple disciplines. Honey et al. (2014) mentioned advocates believe that in solving real-world problems can lead to greater

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integration of STEM disciplines. Daugherty and Carter (2017) mentioned each STEM discipline's unique content, techniques, and contributions to solving some of humanity's most challenging problems. Interdisciplinary STEM learning simulates real-world problem-solving. Hence, the primary pedagogy of STEM in schools is project- and problem-based learning. Mehta et al. (2016) suggested that there are seven elements that teachers and schools should have in place for good STEM teaching and learning, including ownership of the learning process, student-centred pedagogy, the structure and culture of the classroom, student collaboration, fostering student creativity, the teacher as a facilitator and experiential learning.

Assessment of STEM Education

Thomas et al. (1999) mentioned that project-based learning (project) is a long-term, interdisciplinary, student-centred approach to learning that incorporates real-world problems and practices. It explores complex issues by fostering abstract intellectual tasks that promote genuine understanding and the construction of knowledge. In project, students engage in meaningful exploration, judgement, interpretation, and synthesis of information. Otherwise, Savery (2006) mentioned that problem-based learning (PBL) originated in the 1960s. It encourages students to develop a deeper understanding of a particular topic through problem-solving, usually in small groups and without a single correct answer. The method enables students to research, integrate theory and practice, and apply knowledge and skills to develop viable solutions to specific problems.

Meuller (2023) indicated that project and PBL are authentic assessments requiring students to perform real-world (authentic) tasks that demonstrate meaningful application of essential knowledge and skills. Wiggins and McTighe (1998) recommended that the GRASPS model, which contains goal, role, audience, situation, products, and standards, apply to the model well and can have a better authentic assessment.

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SECTION 3: Methodology

This study aims to conduct comparative research on STEM education in terms of curriculum, pedagogy and assessment between Hong Kong and Singapore. To achieve the research objectives, the following research methodology has been adopted.

Research Design

A qualitative research design was adopted to gain an in-depth understanding and utilized Bereday's Comparative Method to compare STEM education in Hong Kong and Singapore. (Bereday, 1964) In the Findings have shown the description and interpretation the STEM Education in two places while the discussion & conclusion have integrated juxtaposition and comparison to show the similarities and differences in curriculum development, pedagogy and assessment. Lastly based on the discussion and the limitations in Hong Kong while drawing lessons from Singapore to give recommendations for Hong Kong.

Data Collection

This study collected data from various sources, including government and non-government reports, documents, news media reports, and academic studies. These sources provide information on Hong Kong and Singapore's STEM education policies, initiatives, and developments.

In addition, additional secondary data such as interviews, and open-ended questionnaires from previous studies and the Internet were collected. These data include the views of various stakeholders such as students, teachers, government officials, citizens, and STEM-related industries.

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Data Analysis

The qualitative data collected was analysed using thematic analysis. This approach helps identify and extract themes and patterns related to STEM education in terms of curriculum, pedagogy, and assessment.

In the juxtaposition and comparison stage, the qualitative data was integrated to understand the research questions comprehensively.

Limitations

The limitations of this study include data availability and reliability, potential bias in secondary research data, and generalisability of results. The endeavours have been taken to ensure the reliability and trustworthiness of the data and mention these limitations in the research report. Through the above research methodology, this study can conduct a comprehensive comparative study to gain insights into the similarities and differences between Hong Kong and Singapore regarding curriculum, pedagogy, and assessment of STEM education. This will provide valuable information for Hong Kong while drawing lessons from Singapore.

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SECTION 4: Findings

Development of STEM Education Curriculum

Hong Kong

The Education Bureau (EDB) of Hong Kong (2016) launched the report “Promotion of STEM Education - Unleashing Potential in Innovation”, looking forward to the promotion of STEM education in schools to strengthen science, technology, and mathematics education to cultivate diverse talents in related disciplines and enhance Hong Kong’s international competitiveness with goals include:

1. To prepare students to become lifelong learners of science, technology, and mathematics, helping them meet the challenges of the 21st century.
2. From a macro perspective, cultivate diverse talents with different knowledge and skill levels to enhance Hong Kong’s international competitiveness and contribute to national development.
3. To allow students to establish a solid knowledge base and enhance their interest in science, technology, and mathematics; strengthen their ability to synthesize and apply knowledge and skills; and cultivate their creativity, collaboration, and problem-solving abilities.
4. Cultivate talents/experts in STEM-related fields to promote the development of Hong Kong.

To supplement STEM education, EDB updated the curriculum related to the science, technology, and mathematics education learning areas in primary and secondary schools in 2017. Legislative Council Panel on Education (LCPE) (2023) mentioned that EDB had renamed STEM education to STEAM Education, which is based on STEM Education and its curriculum development and integrates with the Arts.

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LCPE (2023) mentioned optimizing curriculum, popularising science, and innovative technology learning, and strengthening innovative technology learning in primary and secondary schools. To popularise innovation and technology learning, EDB has added more innovation and technology learning elements to the curriculum at the essential education stage, including modules on Coding Education for Upper Primary and Artificial Intelligence for Junior Secondary to cultivate students' interest and ability in learning innovation and technology. In addition, the updated secondary school information and communication technology subject has added innovative technology topics.

LCPE (2023) mentioned that it will clarify the learning focus of STEAM education. To clarify the learning objectives of STEAM education more clearly in primary and secondary schools and the learning expectations for students at different learning stages, the STEAM Education Standing Committee is formulating the "STEAM Education Handbook". The main contents include the purpose of STEAM education, The learning objectives and content at different learning stages, and suggestions and summaries of the school-based curriculum of STEAM education.

According to Hong Kong Education City (HKEdCity) (2024a), 49 major community partners promote STEAM education, mainly government agencies, NGOs, and post-secondary institutions. EDB (2016) To bring into play the harmonious effect of the community, EDB will strengthen cooperation with cooperative institutions from various departments, including government agencies and STEAM-related groups, to promote different plans and build on the strengths of each institution to complement each other's deficiencies.

Singapore

Teo and Choy (2021) mentioned that STEM education is gaining attention in Singapore and worldwide as interdisciplinary knowledge and skills are valued in modern times to meet

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the needs of the fourth industrial revolution. The arrival of the fourth industrial revolution highlights the importance of digitalization and technology in human lives and communities.

Prime Minister Lee Hsien Loong states that developing STEM capabilities is necessary to sustain Singapore's economic growth (Lee, 2015). Honorary State Counselor Goh Chok Tong (Yong, 2017) stated, "We must push bright young students towards STEM." Education Minister Chan Chun Sing (2022) said, "Understand the importance of STEM and inculcate science based on empirical data and logical thinking approach. We want our citizens to possess all these traits, even if they are not in a STEM field or consider themselves STEM enthusiasts. In addition, we want our citizens to be curious to explore and experiment, create, and innovate, and be open to innovative ideas with an open attitude. This will be our competitive advantage in the future, using STEM to build tomorrow's challenges and find solutions."

Teo & Choy (2021) mentioned that although there is currently no clear written STEM curriculum framework, to achieve what ministers said. Teng (2018) reports that Applied Learning Program (ALP) has been rolled out in all secondary schools. the Singapore Ministry of Education (MOE) wholeheartedly supports STEM Inc's initiatives because STEM Inc supports STEM ALP in secondary schools. STEM Inc's mission is to nurture the future of STEM in Singapore, as the global STEM industry suffers from a shortage of quality labour. Therefore, the goals of STEM Inc are:

1. Motivate students to take STEM-related courses;
2. Increase students' desire to pursue STEM careers by exposing them to real-world industries;
3. Enhance professional STEM career image.

STEM Inc (2023b). Designed: Cities and urban landscapes, Emerging technologies, the future of transportation, health and food science, and sustainability are themes in secondary

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school design. Teo and Choy (2021) cite these selected themes as responding to the potential impact of Singapore's STEM economy. STEM Inc (2023c) and Statista Research Department (2023) stated that 64 secondary schools offer STEM ALP, accounting for 47.0% of the 136 selected STEM ALP secondary schools.

To develop STEM and STEM education further academically through research, meriSTEM@NIE (2023a) is a STEM education research centre that advocates the integration of STEM disciplines and education and promotes the forefront of STEM education research and teaching. meriSTEM@NIE Singapore is uniquely positioned to promote interdisciplinary STEM education research and disseminate empirical research findings, programs, and curricula relevant to Singapore and beyond. Their mission is to improve the quality of STEM literacy through interdisciplinary collaborations in research, teaching, and outreach so that future generations of educators and learners can use relevant STEM knowledge and skills to cope with current and current challenges for themselves and others. Therefore, meriSTEM@NIE has three primary responsibilities:

1. Leading STEM Education Research:

   meriSTEM@NIE Singapore's core business is to provide leadership in STEM education research in Singapore through partnerships with researchers, academics and industry across STEM disciplines and education.

2. Promote research-based STEM education:

   The National Institute of Education, meriSTEM@NIE Singapore, contributes to the country's education services by delivering STEM education programs and curricula based on solid and rigorous STEM education research.

3. Inspiring evidence-based STEM education promotion:

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meriSTEM@NIE Singapore's research and professional work will inspire new and existing partnerships and community outreach to enhance the overall quality of STEM-literate citizens.

To further enrich students' learning experiences, STEM Inc (2023a) 's Industry Partner Program (IPP) creates early exposure to real-world STEM industries and careers. STEM Inc (2023d) stated that IPP can help students gain exposure to real-world STEM-related careers and a deeper understanding of industry developments and challenges. For partners, the program enables them to correct industry misconceptions and raise the profile of STEM professions. STEM Inc (2023e) mentioned that 37 organizations, mainly companies in STEM-related industries, cooperate with STEM ALP secondary schools to conduct IPP.

Pedagogy of STEM Education

Hong Kong

EDB (2016) indicated that the pedagogy principles for promoting STEAM education are:

1) Learner-cantered:

   Arrange STEAM-related learning activities to promote students' ability to learn to learn. Schools should meet students' interests and needs, encourage learning and teaching, and evaluate strategies.

2) Provide a learning experience:

   When all students can learn, they can access STEAM-related learning opportunities outside the classroom, which are essential learning experiences.

LCPE (2023) mentioned resource support. The STEAM Education Centre has advanced maker spaces and relative equipment to support schools in supporting STEAM education, including organizing teacher professional development courses and student activities.

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LCPE mentioned (2023) that Quality Education Fund (QEF) has established the “QEF e-Learning Ancillary Facilities Programme” to support the necessary facilities for e-learning and cooperate with STEAM education. The programme aims to develop, enrich, and provide e-learning facilities by promoting in-depth cooperation among various sectors, such as building a learning and teaching resource-sharing platform.

LCPE (2023) mentioned that the STEM Education Center continues to organize territory-wide student competitions, which are themes related to 3D printing, drones and robot programming.

LCPE (2023) mentions professional training has been provided for different roles in school. For STEAM personnel and teachers, EDB strengthened professional training for teachers, enhanced the professional capabilities of school leaders and STEAM education, and established a team of teachers that can keep up with the development of innovation and technology. and for school principals and curriculum leaders to have "STEAM Education Intensive Training" to strengthen their professional capabilities in planning STEAM education.

LCPE (2023) mentions strengthening teachers’ professional energy in using digital technology. STEAM education and e-learning complement each other. EDB is currently compiling the “Framework of Essential Skills on Information Technology in Education for Teachers”. The framework stipulates the general skills required for the application of information technology in teaching, including barriers to information literacy and STEAM education’s e-teaching skills and other content help teachers understand and master the effective use of e-teaching in the classroom to promote interactive learning in different learning areas/goals.

LCPE (2023) mentions providing employment flexibility for schools. EDB issued a circular, “Providing Employment Flexibility for Aided Primary Schools to Promote STEAM Education”

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in 2022 to recruit staff with STEAM specialist qualifications to assist schools in implementing and promoting STEAM education.

LCPE (2023) mentions school-based support for STEAM education. EDB often provides appropriate school-based support services to primary and secondary schools to assist schools in planning school-based curricula for STEAM education. Students can participate in relevant support programs based on their development priorities and school student learning application needs. The plan provides on-site support to participating primary and secondary schools to assist schools in establishing STEAM. Moreover, QEF launched the "Dedicated Funding Programme for Publicly-funded Schools" to allow schools to apply for funding for school-based curriculum design and student support measures, including developing school-based STEAM education.

LCPE (2023) mentioned arranging for scientific and technological experts to come to school for support. EDB actively arranges science and technology experts to go to schools to support STEAM education. For example, Hong Kong Institution of Engineers has launched a latest support program for primary and secondary schools, "Engineers on Campus", to discuss specific engineering topics, such as engineering in daily life, art and entertainment engineering. Smart Life arranges for engineers to enter the school and work with teachers to design different learning activities to enhance student's interest and motivation in STEAM learning.

LCPE (2023) mentions EDB's gifted education to cultivate and nurture local talented students, including students enhanced with STEAM, so that they can fully demonstrate their strengths and expand Hong Kong's talent pool. In addition to providing professional support to schools and teachers, EDB will continue to strengthen collaboration with The Hong Kong Academy for Gifted Education (HKAGE) and post-secondary institutions on cross-cutting

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talent development programmes. Provide systematic and specialized enrichment training for specially gifted students in primary and secondary schools outside the school.

LCPE (2023) mentioned that HKAGE is a nonprofit organization whose mission is to provide systematic, coherent, and specific off-campus training courses for students with outstanding talents, practice gifted education and promote related concepts to support teachers and parents. HKAGE provides expert or scholar guidance for students with extraordinary potential in STEAM to conduct academic creations or research inventions on different learning themes. In addition, EDB continues to work with HKAGE to arrange specific training for students participating in national and international competitions so that gifted students can unleash their STEAM potential.

Singapore

According to MOE (2023a), ALP helps students to Academic knowledge and skills are connected to the real world. ALP aims to help students realize the relevance and value of their learning and develop stronger motivation and purpose in acquiring knowledge and skills. ALP is untestable and emphasizes applying knowledge and thinking skills, expanding imagination, and applying it to natural social and industrial environments.

STEM Inc (2023b) mentioned that ALP courses are taught practically, fun, and engagingly, stimulating students' enthusiasm for STEM. STEM Inc's curriculum helps students learn STEM subjects cohesively by integrating subject teaching into a cohesive learning paradigm. STEM ALP courses focus on creating solutions to real-life problems. Students either work on several small projects or develop an extensive project. STEM Inc's courses involve applications in electronics, programming, engineering design and robotics. Teo & Choy (2021) mentioned that when a school starts STEM ALP and seeks help from STEM Inc, officials from

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MOE and curriculum experts from STEM Inc will provide consultation and customize the curriculum package to meet the school's and students' needs.

To continue stimulating students' interest in STEM, STEM Inc (2023f) organizes STEM Co-op Club as an extracurricular activity to hone their STEM skills while developing entrepreneurial skills for co-op joint ventures. STEM Inc supports STEM ALP school teachers in running the STEM aspect of the STEM Co-op Club by providing a library of one-time activities and projects for members to choose from. The National Co-operative Federation of Singapore supports the entrepreneurial aspect of STEM Co-op Clubs by advising members to start and sustain co-operatives with social causes.

Teo and Choy (2021) mentioned that STEM Inc also promotes partnerships between schools and industry through IPP, allowing STEM professionals to volunteer as student project mentors and provide curriculum support. STEM Inc (2023f) helps schools establish connections with STEM-related industries through IPP, among which STEM Ambassadors are STEM professionals who volunteer to mentor or oversee student project work in schools. STEM companies will begin introducing them to schools. It helps schools continue to connect with STEM industry partners as the STEM Inc consulting team that facilitates schools and individual STEM ambassadors will be introduced to schools.

In Teaching Qualifications and Professional Development in STEM ALP, Teo & Choy (2021) mentioned STEM educators from STEM Inc. They will be assigned to a school for three years to formulate, implement, revise, and finally hand over the STEM ALP curriculum to the school. During this period, schoolteachers can preview, conduct professional development, and co-teach STEM courses with STEM educators to gain experience in STEM course production. STEM Inc (2023f) to improve the STEM teaching qualifications of schoolteachers, STEM Inc

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provides teacher training to help develop professional knowledge and keep teachers up to date with the latest STEM skills and knowledge.

Teo and Choy (2021) mentioned that STEM Inc is responsible for teacher professional development, established STEM to build a community of practice for connections and sharing, and organized student competitions. This partnership model and ongoing support enable the sustainability of STEM education efforts. STEM Inc (2023f) Forced STEM Community of Practice, a platform for teachers to connect, share and meet teachers from other schools in STEM ALP teaching. On this platform, teachers can:

1. An inter-school network for teachers from exact teaching fields to share and learn from each other,
2. Teachers may conduct STEM industry visits and contacts in specific teaching areas and
3. Training courses may be held for teachers from specific teaching areas.

According to MOE (2023b), two-quarters of Independent Specialist Schools (SIS) provide specialized education to students with talent and genuine interest in mathematics, science, and applied learning. These schools are NUS High School of Mathematics and Science (NUS High School) and School of Science and Technology (SST).

MOE (2021) mentioned that NUS High School offers a 6-year NUS High School Diploma course, which suits talented students and a strong interest in science and mathematics. NUS High School (2024a) offers Singapore’s only school-based gifted education program to develop talents in mathematics and science. NUS High School’s modular curriculum allows for personalized pace, depth, and scope, including further subject-based acceleration, emphasizing critical thinking, problem-solving, research and excellence in science and technology. NUS High School (2024b), the central da Vinci program, can enhance students’ abilities in STEM fields.

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NUS High School (2024c) mentioned that the Da Vinci Project is their key course. It complements the courses that cultivate students' scientific thinking and aims to cultivate multidisciplinary research, innovation, and entrepreneurial skills. Students receive structured courses during their first four years to prepare them for a research project in their senior year.

At the foundation level, the department has designed structured modules that provide training in problem-solving skills and inter- and multi-disciplinary research. Students are also offered elective modules in Design & Engineering and Science Communication.

To prepare our students for research work, all students are required to take the Research Methods module. Students can also conduct more straightforward research projects under the guidance of teachers. From their third year, they can also participate in a mentorship program to conduct research with partner organizations.

Students begin their senior research project during the specialization period. All student research will be presented for project presentation at the annual NUS High School Research Conference. Students are always encouraged to interact with local and international peers and exchange ideas through oral and poster presentations at local and overseas science fairs and conferences.

SST (2024a) is to build a globally connected institution dedicated to transforming learning, and its mission is to cultivate passionate innovators who apply scientific and technological knowledge guided by the humanistic spirit to create a better world.

SST (2024b) mentioned that applied learning methods guide SST's teaching and learning process. These methods deliver lessons in relevant real-life contexts to ensure the learning experience is coherent, challenging, and aimed at developing students' full capabilities and talent. In SST, applied learning methods include active learning, relational learning, authentic learning, integrated learning, community-centred, learner-centred, and process-centred.

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SST (2024c) offers a range of applied subjects to suit varying interests for admission to recognized junior colleges or polytechnics. Applied subjects offered by SST include Biotechnology, Computer+, Design Studies and Electronics. Students can also take two applied subjects.

In pursuit of innovation, SST (2024d) created their unique curriculum. The Changemaker Program for junior secondary school students aims to develop a changemaker mentality, innovative attitudes, and qualities. The program combines the principles, knowledge and skills of art, design, media and technology, innovation and entrepreneurship, and information and communications technology. Students are taught how to apply the SST ChangeMakers' process is an integral part of the innovation process that improves people's lives.

The program takes students through all project stages, from conceptualization to market launch, including planning, design, prototyping and developing a business plan. In addition, the program collaborates with industry professionals to provide students with insights into practical applications in various fields and provide mentorship on selected projects.

ChangeMakers program provides a comprehensive learning experience that equips students with the essential skills and knowledge to succeed in today's innovation-driven economy. By teaching students how to think creatively and critically and design and develop prototypes, the program prepares them to face future challenges confidently.

Assessment of STEM Education

Hong Kong

LCPE (2023) mentioned that teachers implement cross-disciplinary learning activities such as project learning, thematic learning, designs, and inventions, which shows that schools will integrate STEAM learning activities into the classroom. Learning and teaching of existing

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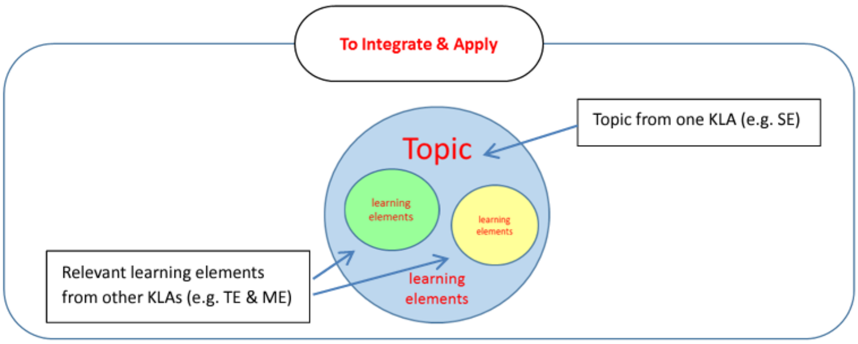
courses, rather than just treating STEAM as extracurricular activities. Schools also add learning elements from different learning areas according to school conditions, such as adding arts elements to guide students to use what they learn in mathematics and science and technology classes to design some Aerotech products for the elderly to facilitate daily life and improve the design of the products—moreover, aesthetics to further develop students' creative thinking.

EDB. (2016) suggested the model of blocking STEAM education learning activities. The focus of STEAM is to strengthen students' ability to integrate and apply knowledge and skills in various learning areas of science, technology, and mathematics education and across learning areas. The following are two suggested approaches to promote STEAM education learning activities:

Figure 2

Approach 1: Thematic Learning Activities (EDB, 2016)



Note: Establish thematic learning activities based on the theme of one learning area to allow students to integrate learning elements related to other learning areas.

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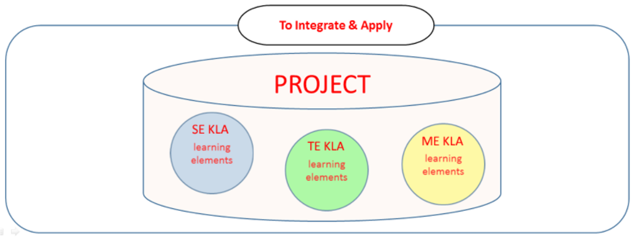
Figure 3

Approach 2: Project Learning (EDB, 2016)

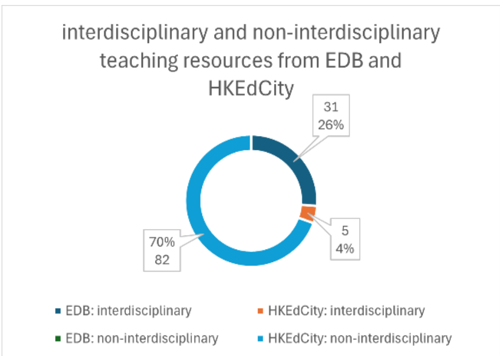


Note: Establish project learning allows students to integrate relevant learning elements from different learning areas.

Based on the above recommendations, EDB (2023) and HKEdCity (2024b, 2024c, 2024d & 2024e), EDB and HKEdCity provided 31 and 87 STEAM education learning and teaching resources, respectively, of which 46 and 72 were designed for primary and secondary schools, respectively. All teaching resources are developed under the learning objectives of the curriculum document. EDB and HKEdCity provide 31 and 5 interdisciplinary studies, respectively.

Figure 4

Interdisciplinary and non-interdisciplinary teaching resources from EDB and HKEdCity



Note: Figures were created by the author based on the data of EDB (2023) and HKEdCity (2024b, 2024c, 2024d & 2024e).

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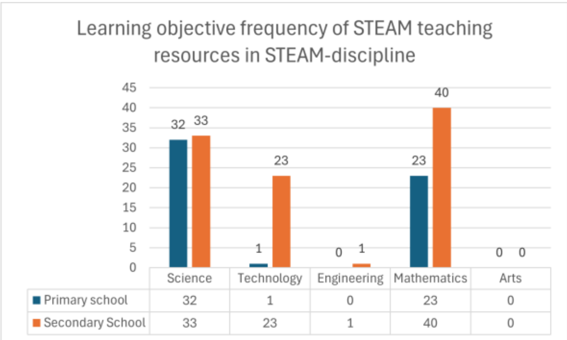
The learning objectives with no Arts are mostly mathematics, followed by science, then information technology, and at least engineering. Most teaching resources are thematic and project learning, which provide sufficient learning background, prior knowledge, and student learning process, allowing students to learn, think, apply, and clarify specific learning goals.

Figure 5

Learning objective frequency of STEAM teaching resources in STEAM-discipline



Note: Figures were created by the author based on the data of EDB (2023) and HKEdCity (2024b, 2024c, 2024d & 2024e).

EDB's STEAM Examples: Games of Computer Images and Data Encoding

Computer graphics and data coding games are thematic learning related to "data representation" in information and communication technology courses. They are suitable for junior secondary school students who have the following prerequisite knowledge:

1) mutual conversion between binary digits.
2) finding out the Mean, median and mode of ungrouped data.
3) Understanding the concept of weighted average

and learning how to:

1) apply binary number knowledge to convert between text, images, and numeric data,
2) select appropriate text Coding methods.

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3) Apply mathematics to solve daily life problems.

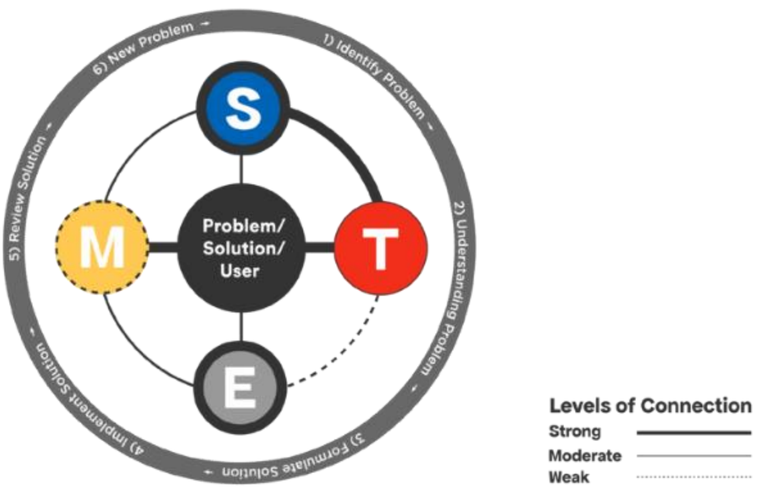
The learning process lasts for about 30 minutes in two classes. It is recommended to divide it into two stages, with students in groups of two to four, with guiding questions and tasks to guide students to complete the learning objectives and reflective questions for students to interact with the group discussion.

Singapore

meriSTEM@NIE (2023b) proposes that problem-centred STEM quartet is rooted in a complex, enduring, and expanding question, explored through a convergent and divergent process.

Figure 6

Problem-Centric STEM Quartet (Tan et al. (2019))



Note: The process of inquiry involves: 1) Identifying the problem, 2) Understanding the problem, 3) Developing solutions, 4) Implementing solutions, 5) Checking the solution, and 6) Finding a new problem.

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Subject-specific learning outcomes, also known as vertical learning. They will also draft and plan cross-cutting connections between these disciplines. The thickness of the lines in the graph shows how closely each discipline is related to the other.

Zhang Taiao et al. (2021) mentioned the problem-centred STEM quartet, that is, metaknowledge: students can think creatively about diverse ways to solve problems collaboratively, and the beneficiaries of their outcomes and outputs are learners can explore alternatives and develop a range of solutions from which to choose. However, its limitation is that it may lead to a wide range of solutions that may not be practical unless tested and evaluated.

Mainstream school STEM ALP example: Tampines Secondary School

As mentioned by MOE (2023c), Tampines Secondary School (TPSS) is a mainstream school in Singapore that adopts STEM ALP, with the theme of sustainable development and creative engineering as interdisciplinary real-world problem-solving.

TPSS (2024) mentioned that in section 1, students gain hands-on learning experience with upcycling and drones before forming a junior technology startup team to solve problems related to “water” or Real-world challenges associated with the theme of “water” and “technology”.

In the second session, students will gain hands-on learning experience building a solar-powered toy car and learn to code using Microbits before forming junior tech startup teams to solve real-world challenges related to “energy” or “ageing”.

All ALP sessions are held in the Maker Hub equipped with 3D printers, laser cutters and electronics kits. The group repair activities after the exam further stimulated students’ interest in hands-on production.

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During this period, TPSS has designed an online learning platform for students to conduct e-learning. Students can study and find general information on their topics. Also, TPSS provides designated e-books for students to self-study and provides guidance content throughout the ALP process.

Students who form Junior Tech Startup teams to solve real-life problems must undergo real-world assessments to complete their assignments in approximately five weeks. The Junior Tech Startup Assessment Guide has five roles: Dreamer, Designer, Maker, Thinker, and Presenter. Students must play and take responsibility for themselves. It guides students to conceive an innovative solution to a real-world problem and present it as a prototype based on their topic.

After completing their work, groups will be graded based on the general analysis rubric found in the e-book.

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SECTION 5: Discussion & Conclusion

Comparison: Curriculum Development

According to Table 1, Regarding the aims of STEM/STEAM Education in Singapore and Hong Kong, most of the aims stipulated in the official documents drafted by the prominent education organizations in both regions are remarkably similar. In the scope of the learning in the classroom, for instance, both aimed to develop students' interest and skills in STEM/STEAM-related subjects through projects. The aims in the scope of social development are to nurture lifelong learners and to meet the job market demands in the long run. Job-related skills include creativity, cooperation, and problem-solving skills to cope with the increasingly complex social and employment environment.

Table 1: Similarities and Differences of Curriculum Development between Hong Kong and Singapore

Curriculum Development / Regions		Hong Kong	Singa-pore
Aims of STEM Education	a) Develop students' interest and skills in STEM-related subjects	✔	✔
	b) Nurture lifelong learners	✔	✔
	c) Meet the job market demands in the future	✔	✔
	d) Motivate students to pursue STEM careers	✔	✔
	e) Cultivate skills in creativity, cooperation, and problem-solving skills	✔	✔
Teaching content	a) Academic disciplines	✔	✘
	b) Coding, innovation and technology programs	✔	✘
	c) Cities and urban landscapes	✘	✔
	d) Emerging technologies	✘	✔
	e) The future of transportation	✘	✔
	f) Health, and food science	✘	✔
	g) Sustainability	✘	✔
Further development	a) Clarify the definition and aims of STEM education	✔	✘
	b) Clarify the learning objectives and content at different learning stages	✔	✘
	c) Provide suggestions and summaries of the school-based curriculum of STEM education	✔	✔
	d) Provide leadership in STEM education research	✘	✔
	e) Inspire partnerships to enhance the quality of STEM-literate citizens	✘	✔
Cooperation Networks	a) Government Organizations	✔	✔
	b) Non-Government Organizations	✔	✘

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	c) Tertiary institutions	✔	✔
	d) Related Industries	✖	✔

In contrast, there are differences between these regions in teaching content, actions on further development and orientation of cooperation network. In terms of teaching content, Hong Kong and Singapore are academic rationalism and social and economic efficiency respectively (Morris & Adamson, 2010). STEAM education in Hong Kong is academic rationalism, which focuses on subject knowledge, skills, and values of academic disciplines. Hong Kong is a STEAM education that combines arts and STEM, and advocates STEAM education, while in recent years, it has updated each curriculum document, developed coding programs, and focused on innovation technology education. In contrast, Singapore's STEM education is social and economic efficiency, which focuses on developing problem-solving knowledge and skills in the essential use of STEM that are valuable and relevant to future employment (Morris & Adamson, 2010). Singapore emphasizes thematic teaching contents, which are the fields of national needs in future. In further developments in STEM Education, Hong Kong will launch "STEAM Handbook" to direct and clarify the definition and aims of STEM education to designate the learning objectives and content at different learning stages, while MeriSTEM@NIE will be the research leadership of STEM Education in Singapore to provide leadership in STEM education research and inspire partnerships to enhance the quality of STEM-literate citizens, while Hong Kong tended to cooperate with non-government organization to promote STEAM and Singapore tended to cooperate with STEM-related industries through IPP to engage students gain exposure to real-world STEM-related careers and a deeper understanding of industry developments.

Comparison: Pedagogy

According to Table 2, In terms of the Main approaches of pedagogy and teaching quality, both places are similar. Both places emphasize pedagogy approaches including Student-centred pedagogy to let students have experiential learning and ownership of the

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learning process which the teacher as a facilitator to foster student creativity.(Mehta et al. 2016) Moreover, both places also have teacher professional training in STEM ability, provide support from STEM experts and recruit teaching staffs with STEM specialist qualifications to ensure and enhance the teaching quality in STEM.

Table 2: Similarities and Differences of Pedagogy between Hong Kong and Singapore

Pedagogy / Regions		Hong Kong	Singa-pore
Main approaches of pedagogy	a) Ownership of the learning process	✔	✔
	b) Student-centred pedagogy	✔	✔
	c) Fostering student creativity	✔	✔
	d) Teacher as a facilitator	✔	✔
	e) Experiential learning	✔	✔
Hardware for STEM	a) STEM-related teaching equipment	✔	✔
	b) E-learning equipment	✔	✖
Teaching quality	a) Teacher professional training in STEM ability	✔	✔
	b) Teacher professional training in digital technology	✔	✖
	c) Support from STEM experts	✔	✔
	d) Teaching staff with STEM specialist qualifications	✔	✔
Catering to learning diversity	a) Catering general students	✖	✔
	b) Catering students with strong abilities in STEM	✔	✔
	c) Catering gifted students in STEM	✔	✔

In contrast, there are differences in e-learning development and catering learning diversity between Hong Kong and Singapore. Although both places have provided STEM-related teaching equipment from STEM Education Center in Hong Kong and STEM Inc in Singapore, Hong Kong also emphasizes the importance of e-learning, such as providing e-learning facilities for schools and holding teacher professional training in digital technology, to support STEAM Education. Moreover, Singapore has all-rounded approaches to catering to learning diversity. In Singapore, STEM Inc provides STEM ALP for all students to learn the foundation of STEM, and it also provides Co-op Club as extracurricular activities and IPP as intern for strong abilities and interest in STEM to have in-depth knowledge and exposure to real-world STEM industries and careers. Also, Singapore has independent schools, which are NUS High School and SST, for gifted students to have study communities and environment,

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which can be more comprehensive with systematic and complementary support for students. In Hong Kong, it is optional to conduct STEAM Education activities for all students, but STEM Education Center provides various extracurricular activities for students with strong interest in STEAM and HKAGE provides individualized education for nurturing students who are gifted.

Comparison: Assessment

According to Table 3, in terms of assessment types in STEM Education, both places apply AoL and AfL to assess students' learning outcomes and competencies. (Berry 2008; 2010) Otherwise, Singapore has promoted more AaL to assist students to develop their STEM ability. Singapore provides rich learning contexts and resources in STEM education assessment, such as the Maker Hub and online learning platforms to support students' learning and assessment process. (Berry 2008; 2010)

Table 3: Similarities and Differences of Assessment between Hong Kong and Singapore

Assessment / Regions		Hong Kong	Singa-pore
Assessment Type	Assessment of Learning	✔	✔
	Assessment for Learning	✔	✔
	Assessment as Learning	✖	✔
Assessment Model and Examples: GRASPS Model	Goal	✔	✔
	Role	✖	✔
	Audience	✖	✔
	Situation	✖	✔
	Products	✔	✔
	Standards	✔	✔

In terms of interdisciplinary educational models, Singapore adopted more practical educational models in the assessment. Singapore proposed a problem-centred STEM quartet, emphasizing students' exploration, and learning through solving complex real-world problems with a guiding process for teachers to design the assessment. In contrast, Hong Kong emphasizes project-based and thematic-based learning to acquire the learning objectives of the courses in each subject, where students apply what they learn. According to the examples from

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Hong Kong and Singapore, both have clear learning goals, the product of the learning outcome and standards for outcome, example of Singapore has a real problem in the world as a situation, and students have five different roles that they have to take the duties and show their STEM product to peers and teachers which is lacked in Hong Kong example. Therefore, Singapore is more closely aligned to the GRASPS framework which is more effective and real in authentic assessment to increase the learning effectiveness. (Wiggins & McTighe 1998).

Limitation

STEAM education in Hong Kong is school-based, diversified and focused on teachers' professional development and training. Hong Kong has established a STEM Education Centre to provide training and resource support to help teachers improve their STEAM teaching capabilities. However, Hong Kong has its shortcomings. For example, Hong Kong's STEAM education may suffer from insufficient funds and resources. This limits the development and innovation of schools and teachers in implementing STEAM education. Although the government provides an average of 370,000 HKD in one-time funding to each school, involving a total of 290 million HKD, to pay for wireless network fees, purchase mobile computer equipment and strengthen e-learning support, more than 70% of teachers still think there is a lack of hardware equipment and teaching materials for STEAM education after funding (Hong Kong Federation of Education Workers, 2017). Only 89 secondary schools will benefit from the "Secondary Schools Information Technology Enhancement Project". Only a few schools can receive funding from the Professional School Development Program and the Thematic Network Program of the Quality Education Fund.

Second, more information on STEAM education curriculum design and teaching guidelines is needed. Although the development of STEAM education in Hong Kong is school-based, more information is still required on STEAM education curriculum design and teaching guidelines. A survey by the Hong Kong Federation of Youth Groups (2018) shows that more

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than 70% of secondary schools believe that STEAM education hours are insufficient, and the development of interdisciplinary STEAM education faces challenges; there are currently inadequate reference examples for the development of STEAM education; and the educational policy is unclear. These issues make implementing STEAM in schools challenging because the curriculum still needs to mature.

Third, STEAM education fails to attract students to value STEAM. Government statistics (2022) show that the total number of STEAM-related bachelor's degree courses increased from 8,165 in the 2016/17 academic year to 8,494 in the 2020/21 academic year, an increase of 329 students. Although STEAM-related places should increase, the Legislative Council Secretariat Research Group (2020) found that local students do not consider taking traditional science subjects because they do not see a future for these subjects. The innovation and technology industry contributed only 1.7% to Hong Kong's GDP in 2017. The Government of HKSAR (2022) noted that Hong Kong's innovation and technology R&D expenditure is low. Many high-achieving students abandon STEM studies in college and graduate into more attractive fields such as medicine, business, and law. The Joint Universities Admissions Systems (2021) statistics show the median admission scores for three popular departments: the University of Hong Kong and the Chinese University of Hong Kong.

Recommendations

Drawing lessons from Singapore, it is suggested that Hong Kong establish "STEAM Inc" as a dedicated organization for STEAM education in Hong Kong. STEAM Inc's work includes coordinating and promoting STEAM education, establishing regional centres, developing, and updating curriculum, providing teacher training and support, organizing competitions, and implementing industrial cooperation programs to inspire and attract students to participate in STEM education.

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First, STEAM Inc can coordinate, lead, and promote STEAM education through curriculum development, teaching material updates and STEAM education guidelines to ensure a certain level of STEAM education development in primary and secondary schools in Hong Kong. Refer to STEM Inc in Singapore and meriSTEM@NIE, which attracts some outstanding university department teams and non-governmental organizations that operate STEAM Inc and provides funding resources to allow these organizations to establish regional centres in their areas to provide teaching resources to nearby secondary schools based on their characteristics. The current services of the “STEM Education Centre” can be integrated and operated as a regional centre into the STEAM Inc.

Secondly, STEAM Inc can set up expert courses to support and train teachers to better implement and promote S TEAM education in schools and communities. STEAM Inc. can recruit experts from colleges and universities, education circles and STEAM-related industries and establish a team of experts to be responsible for regular updating and development of teaching materials and training of teachers so that schoolteachers can receive assistance and can conduct better STEAM teaching and education in schools. In addition, STEAM Inc can regularly organize STEAM innovation competitions in developed curriculum areas and set up project study awards for students and teaching awards for teachers to promote interdisciplinary teaching and learning.

Finally, STEAM Inc can implement IPP to attract more students interested in STEAM subjects and careers. STEAM Inc can coordinate and co-organize IPP in Hong Kong with companies in the STEAM industry. This can create opportunities for students to have early exposure to real-world STEAM industries and careers, stimulating their enthusiasm for STEAM subjects and thus inspiring them to take STEAM-related courses. At the same time, exposing students to real-world industries enhances the image of professional STEAM careers and increases their desire to pursue STEAM careers.

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Conclusion

Hong Kong and Singapore have similarities in promoting STEAM education, including emphasizing subject foundations, cultivating creativity and collaboration skills, improving teachers' professional capabilities, and establishing cooperative relationships with industry and communities. However, there are also differences between the two places, such as the orientation of curriculum development, implementation measures, ways of promoting STEAM education, and methods of assessing students. STEM education in Hong Kong faces insufficient resources, immature curriculum design and teaching guidelines, and challenges in attracting students.

To improve the situation, it is recommended that Hong Kong learn from Singapore's practice and establish a dedicated organization, STEAM Inc, to coordinate and promote STEAM education, provide training, and resource support, and cooperate with industry to promote STEAM education. This can strengthen the development of STEAM education in Hong Kong and improve students' STEAM learning outcomes and career development opportunities. It is hoped that through this, Hong Kong students can reach a higher level in STEAM subjects and STEAM education and achieve higher achievements internationally; it is also expected that top STEAM-related talents and experts can be cultivated to contribute to the development of Hong Kong and its contribution to a strategic position in national development.

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