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A study of the alignment of learning targets and assessment to generic skills in the new senior secondary mathematics curriculum in Hong Kong

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ABSTRACT

Education reform is now a worldwide phenomenon, and many countries are interested in the issue of alignment. The mathematics curriculum of the new three-year senior secondary (NSS) curriculum in Hong Kong aims to develop the proficiency of students or learners to think critically and creatively, to inquire and reason mathematically, and to use mathematics to formulate and solve problems in mathematical contexts as well as in daily life. Nine generic skills are expected to be developed through the acquisition of the mathematical knowledge and concepts. The Hong Kong Diploma of Secondary Education (HKDSE) Examination serves as the only public examination in the NSS. Presumably, it is expected that the HKDSE Examination aligns well with the curriculum expectations. In this article, we investigate and judge the alignment between such expectations and the HKDSE Examination. Our research findings show that there is a lack of learning strategies and collaboration and self-management capabilities acquired as expected from the learning targets, nor examined through the assessments in the current NSS Mathematics Education. Public examination is indeed not a good venue to access some generic skills. This clearly shows that there exist certain degrees of imbalance in the acquisition of the generic skills through the current NSS Mathematics Education. We suggest a revision of the general curriculum and assessment structure, an introduction of new forms of assessment, and an increase in the diversity of assessment as means for alleviating the aforementioned problems. We believe that the experience in Hong Kong would be of interest to other parts of the globe.

Introduction

The unprecedented changes in the worldwide economic structure and the knowledge-based economy in the 21st century pose new challenges for the way people think and live (Education Commission, 2000). This leads to the education reform worldwide and the launching of the new Hong Kong three-year senior secondary curriculum (NSS) in 2009. In the NSS, Mathematics is a core subject. The mathematics curriculum at the NSS aims to meet the aforementioned challenges by developing the proficiency of students or learners to think critically and creatively, to inquire and reason mathematically, and to use mathematics to formulate and solve problems in mathematical contexts as well as in daily life (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). Nine generic skills[1] are expected to be developed through the acquisition of the mathematical knowledge and concepts. They can be considered as both process skills and learning outcomes in the Mathematics Education Key Learning Area (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). These skills form a basis for one to build the capabilities for learning how to learn, so that they can apply them to pick up advanced knowledge as well as solving problems encountered in their daily lives.

Knowledge generation requires strong generic skills, or higher-order thinking skills (HOTS), including analytic reasoning, problem solving, and writing, and education serves as a vehicle for nurturing students by teaching generic skills and measuring the progress with respect to the desired goals (Benjamin et al., 2012). To fulfill the rationale and overall curriculum aims of the NSS

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[1] Generic skills are skills, qualities, and trait that an individual needs to develop for personnel development (Hamzah & Abdullah, 2009).

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0191-491X/

Mathematics Education, the curriculum serves as a means for students to foster generic skills, together with thinking abilities and positive attitudes towards the learning of mathematics (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). Thus, the development of generic skills for students is a central theme in such education. A properly aligned curriculum helps learners master these generic skills in the most balanced, efficient, and effective manner through the acquisition of mathematical knowledge and concepts (expressed in the form of learning targets). Not only does aligning assessments with generic skills encourage students to adopt a deep approach to learning, but also teachers to give more credence and value to pedagogy as described in the curriculum document. Both students and teachers can hence find an effective linkage between the performance in assessment and approaches in teaching and learning that assists students to develop the knowledge and skills for acquiring new information and solving real-life problems. Therefore, an objective of this work is to investigate the alignment of the intended generic skills to the curriculum and assessment.

Educational assessment refers to all activities that can be employed to assist learners to learn effectively and gauge the learning progress (Black & Wiliam, 1998). The Hong Kong Diploma of Secondary Education (HKDSE) Examination (Hong Kong Examinations and Assessment Authority, 2011b) serves as the only public examination in the NSS. The HKDSE Examination is a standards-referenced, standardised test to evaluate the performance of learners reported against a set of pre-defined level descriptors. Presumably, it is expected that the HKDSE Examination aligns well with the curriculum expectations that can yield a positive backwash effect[2], which can in turn offer incentives to learners to acquire what they are expected to learn in the curriculum. The learner perspective of the curriculum is hence defined by assessment (Ramsden, 2003). However, a misalignment may mean that the assessed performance of a learner does not properly reflect the extent of what he/she is expected to learn and acquire (e.g., the underlying generic skills) during the study. This results in a negative backwash so that learners would not pick up those knowledge and skills in the curriculum that are expected not to be assessed. This in turn defeats the learning goal. Therefore, there is a need to investigate and judge the alignment between the curriculum expectations and the HKDSE Examination. This also helps discover deficiencies and thus search for remedies to improve the efficiency and effectiveness of the NSS so as to benefit the learners.

In the literature, some international studies on assessing generic skills have been reported, such as (Benjamin et al., 2012; Ito, 2014). (Benjamin et al., 2012) advocated that Collegiate Learning Assessment (CLA) is an effective standardised, performance-based assessment for accessing HOTS across all domains. By employing CLA, students are asked to solve problems encountered in scenarios that are typical in the real world. (Ito, 2014) gave an account of the Progress Report on Generic Skills (PROG), which is an assessment tool similar to CLA for measuring learning outcomes of college students in Japan. The study confirmed a weak correlation between PROG and grade point average (GPA). It also found that PROG might fail to measure some generic skills and needed to be complemented by other assessment techniques. Both studies have shown that generic skills can be identified and measured. Though the studies were focused for higher education, the inferences made could be applicable to secondary education as well. Our work aims to investigate the alignment between assessment and the generic skills embodied within the curriculum. It offers an effective framework on how an alignment study of assessment to a set of generic skills can be conducted. This bridges the gap between what concepts and knowledge learners have picked up and what generic skills they have ultimately acquired from the learning process.

Our contributions

The focus of this work is to study the assessment alignment of the HKDSE Mathematics Examination with the acquisition of the nine generic skills expected for the NSS Mathematics Education. In other words, we investigate whether the intended generic skills are covered in the curriculum and assessment. Therefore, the curriculum is studied from the curriculum policy designers' perspectives, which may differ from the doers' perspectives (Cooper & Dunne, 1998). The investigation is carried out in two phases. In the first phase, we analyse the extent to which these generic skills can be acquired based on the stated learning targets. Some deficiencies and inconsistencies among the learning targets with respect to the generic skills are identified, and possible remedies are then suggested.

In the second phase, we evaluate the assessment questions in the first HKDSE Examination in 2012 by finding out whether these questions reflect an appropriate balance in the acquisition of the captioned nine generic skills. Based on the findings, several recommendations are suggested for improving the efficiency and effectiveness of the NSS Mathematics Education.

We will investigate the efficiency and effectiveness of the NSS Mathematics Education by examining four basic questions:

- Are the nine generic skills properly reflected in the learning targets in the NSS Mathematics Curriculum Framework? What are the deficiencies?
- Can the assessment questions in the HKDSE Examination reflect an appropriate balance in the acquisition of the generic skills? What are the limitations?
- What are the possible remedies to alleviate these deficiencies and limitations?
- What are the implications of the experience in Hong Kong for other parts of the world?

This study should contribute to better understanding of alignment theory. In alignment theory, it is hypothesised that agreement in education components implies coherence and efficiency for an education system. The degree of alignment is generally judged on subject-specific knowledge or skills. However, there are limitations in the method of studying alignment when alignment is established in the context of transferable skills, such as generic skills, as they may be achieved through learning various subjects and cannot be assessed directly. In other words, the attainment of generic skills inferred from the assessment does not necessarily mean that they are acquired through the curriculum. Yet, as inferred from our findings in the Findings section, the existence of some generic skills not assessed in the assessment reveals inconsistency or misalignment of learning targets and assessment to generic skills in the NSS Mathematics Education curriculum. This inference is applicable to transferable skills in general.

Organisation of the paper

The rest of this paper is organised as follows. First, we present a literature review on curriculum alignment. We then give a comprehensive overview of the evolution of the Hong Kong education system and mathematics curriculum, and discuss the NSS Mathematics Education as the background for this research.

[2] The backwash effect, also known as washback effect, is a phenomenon describing the impact of assessment on learning and teaching that learners tend to acquire and teachers incline to teach on what they consider to be examined (Elton, 1987; Prodromou, 1995). Backwash effect is positive when the assessment results in favourable changes in learning and teaching strategies, matching a variety of teaching-learning situations with different educational aims (Biggs, 1996).

Afterwards, we describe the research methods employed in this study, and show the research findings regarding the alignment of the learning targets and assessments to the nine generic skills. Further discussion of the research findings, and some open issues and challenges are given. Finally, we summarise and conclude the article.

Related work on curriculum alignment

Alignment is a process to determine the match between curriculum standards and assessments (Council of Chief State School Officers, 2002; Webb, 2007). It refers to how well policy documents in a system cooperatively guide instruction and eventually student learning (Webb, 1997). Moreover, it indicates the degree of agreement between content standards for a specific subject area and the assessment(s) employed to measure student achievement of these standards (Bhola, Impara, & Buckendahl, 2003). Therefore, alignment studies allow researchers to systematically study various components of an educational system so as to compare their contents and make judgments about their degrees of concurrence (Martone & Sireci, 2009). This gives directions for future reforms and improvements.

Forms of alignment

Webb (1997) suggested that agreement among components in an educational system could be aligned in two different forms: horizontal alignment and vertical alignment. For horizontal alignment, standards, frameworks, and assessments work together in an educational system and mainly at the policy level. This differs from vertical alignment, in which the elements among different strata in an educational system (such as textbook content, classroom instruction, professional development, and student outcomes) are aligned with each other and with factors external to the educational system (including national standards, public opinion, and work force). The relationship between horizontal alignment and vertical alignment in an educational system is illustrated in Fig. 1.

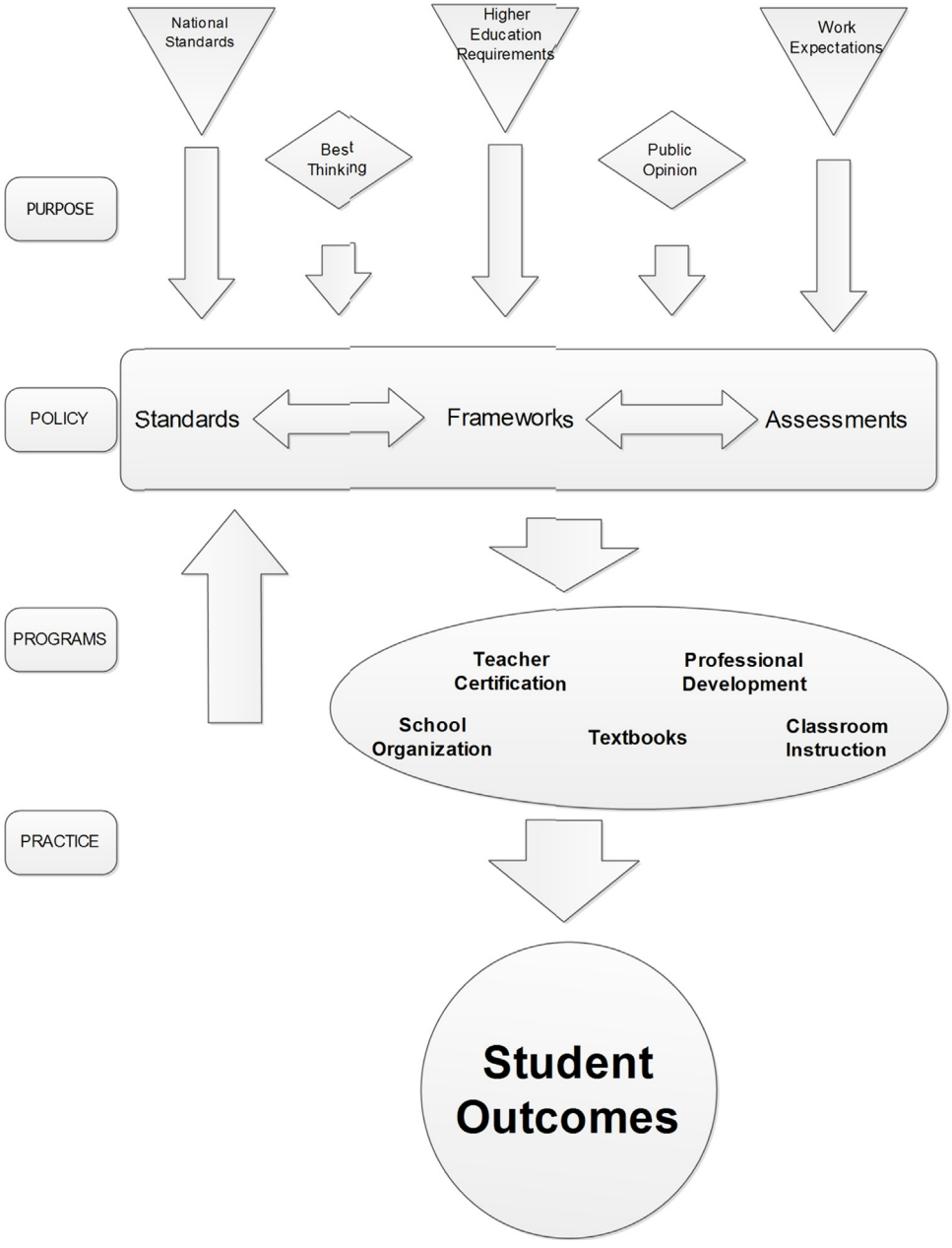

Fig. 1. An illustration of horizontal alignment and vertical alignment within an educational system (Webb, 1997, P. 6).

In this study, we conduct the alignment of the learning targets (in the curriculum framework) and assessments to the set of generic skills in the NSS Mathematics Education. According to Fig. 1, the learning targets and assessments fall into the policy category, whereas the set of generic skills can be classified into the purpose category. Our analysis examines the degree to which the development of generic skills can be achieved through these learning targets and assessments. Thus, the work studies the vertical alignment for the NSS Mathematics Education. Since the acquisition of such skills is central to the education reform in Hong Kong, it is critical and timely for this investigation to gauge whether the policy for the NSS Mathematics Education is properly aligned with its purpose.

Alignment methods

In the literature, there are three most common alignment methods, namely, the Webb methodology, the Surveys of Enacted Curriculum (SEC) methodology, and the Achieve's protocol (Bhola, Impara, & Buckendahl, 2003; Martone & Sireci, 2009).

Webb (1997, 1999, 2002, 2007) developed a comprehensive, two-stage methodology to study the degree of alignment between assessments and standards. In the first stage, reviewers code the depth-of-knowledge (DOK) levels of the standards. In the second stage, reviewers code the DOK levels of assessment items with respect to the curriculum standards or objectives. Findings with the attainment of the specified acceptable levels are then reported based on four different criteria, namely, the categorical concurrence, DOK consistency, range of knowledge correspondence, and balance of representation.

Porter and Smithson developed the SEC alignment methodology (Porter, 2002) to quantitatively measure and compare the degrees of alignment for standards, assessments, and instruction across schools of different regions employing various instructional materials and practices. Reviewers categorise and indicate the degree of emphasis (say, cognitive demand) of each topic in standards, assessments, curriculum, or instructional practices in a content matrix. An alignment index can then be computed for the sake of comparison on the degree of alignment. In contrast to the Webb approach, the SEC method evaluates the alignment between standards and assessments by mapping them to a common framework, rather than directly with each other (Webb, 2007).

The Achieve's protocol (Rothman et al., 2002) devised an alignment protocol for determining the alignment of assessments to standards, based on four different criteria: content centrality, performance centrality, challenge, and balance and range. The alignment analysis is conducted by a group of experts making nuanced yet systematic judgments on whether assessment items and intended objectives correspond fully, partially, or do not correspond to each other. Reaching consensus among reviewers in the analysis of the Achieve's protocol makes it distinctive from the other two approaches (Webb, 2007).

In this study, we follow an approach similar to Achieve's protocol for the investigation of the alignment study in the NSS Mathematics Education. The content centrality component is conducted by comparing each learning target and assessment item to the generic skills involved. The challenge component is carried out by examining whether a set of learning targets and assessment items together expresses the set of generic skills as expected. The balance and range component is done to offer a quantitative and qualitative evaluation of the alignment of learning targets and assessment to generic skills. Since the depth of each skill involved is quite difficult to be quantified, the performance centrality component of the protocol is not implemented. We believe that the approach fits the nature of the study best, since we are not assessing DOK or mapping standards and assessment to a common framework, and it is simpler and easier to administer.

Evolution of the Hong Kong education system and mathematics curriculum

In this section, a comprehensive overview of the Hong Kong education system and the evolution of the mathematics curriculum in Hong Kong is introduced. Interested readers can refer to (Wong, 2010; Tam et al., 2014) for details.

Hong Kong has begun to offer a six-year free and compulsory primary education (Grades 1–6) starting from 1971. The education was extended to the first nine years in 1979, including the six years of primary education and the first three years of secondary education (Grades 7–9). More than 90% of students continued their school education for two more years (Grades 10–11) and then took the Hong Kong Certificate of Education Examination (HKCEE). General Mathematics was a core subject, and 25% of the more mathematically oriented students also took Additional Mathematics as an elective subject for HKCEE. Those who performed well in HKCEE could further attend the two-year matriculation class (Grades 12–13), followed by taking the Hong Kong Advanced Level Examination (HKALE) for university admission. Pure Mathematics (Advanced Level), Applied Mathematics (Advanced Supplementary Level or Advanced Level), and Mathematics and Statistics (Advanced Supplementary Level) were elective subjects for HKALE. Since the 2008–2009 school year, free education has been extended to 12 years. The Hong Kong three-year senior secondary curriculum (NSS) has also been launched in 2009, so that students in Hong Kong receive a six-year secondary education, instead of three years of junior secondary, two years of senior secondary, and two years of matriculation. The Hong Kong Diploma of Secondary Education (HKDSE) Examination serves as the public examination for the NSS. The NSS Mathematics Education will be discussed in the NSS Mathematics Education section.

In the early 1990s, the Target Oriented Curriculum was proposed to offer a clear set of learning targets to teachers and schools in order to develop lively and effective methods to teaching, learning, and assessment. Due to criticisms by teachers and academics, a holistic review of the mathematics curriculum was conducted, leading to the new primary and secondary mathematics curricula released in 2002 and 1999 and carried out in 2002 and 2001, respectively. Higher-order thinking skills (HOTS) are incorporated into the content-based learning dimensions of the mathematics curriculum such that students can develop HOTS through the acquisition of various mathematical knowledge. This has further led to the overall curriculum aims of the Mathematics Education Key Learning Area following the education reform initiated in 1999. The curriculum was further restructured and the contents of each syllabus redesigned. Thus, the two mathematics curricula at the two-year senior secondary and the four mathematics curricula at the two-year matriculation were reorganised to form the new NSS Mathematics Curriculum, which is to be discussed below.

NSS Mathematics Education

The NSS Mathematics Curriculum aims to help learners develop the ability to think critically and creatively, to communicate with others and express their ideas and opinions clearly and logically in mathematical language, to manipulate numbers, symbols, and other mathematical objects, to appreciate structures and patterns, and to appreciate the aesthetic nature and cultural aspects of mathematics (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). Such process skills and learning outcomes are collectively known as *generic skills*. In the next subsection, these generic skills will be described, followed

by a discussion of the curriculum and assessment framework for NSS Mathematics.

Generic skills

To enable learners to learn how to learn, a total of nine generic skills have been identified (Curriculum Development Council, 2002). They are Collaboration Skills, Communication Skills, Creativity, Critical Thinking Skills, Information Technology Skills, Numeracy Skills, Problem-solving Skills, Self-management Skills, and Study Skills. These generic skills are embedded in the learning and teaching of mathematical concepts. They assist learners to develop the abilities on the acquisition and mastery of mathematical knowledge and concepts (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). Interested readers can refer to (Curriculum Development Council, 2002; Leung, Leung, & Zuo, 2013) for details.

Curriculum and assessment framework

The NSS Mathematics Curriculum (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007) comprises two parts, namely, the Compulsory Part and the Extended Part. All students must study the Compulsory Part, and can choose up to one of the two modules from the Extended Part during their NSS studies. The Mathematics curriculum is structured in order to cater for different needs, interests, and orientations for learners in a flexible manner. According to (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007), the curriculum serves as "a continuation of the existing Mathematics Curriculum at the junior secondary level", and has been developed "on the direction set out in the Mathematics Education Key Learning Area Curriculum Guide (Primary 1—Secondary 3)" (Curriculum Development Council, 2002), where "students' knowledge, skills, positive values and attitudes are further extended". In this paper, the results of the Compulsory Part and the Extended Part will be reported separately.

The Hong Kong Diploma of Secondary Education (HKDSE) serves as the public assessment of students studying the NSS curriculum, and offers a common end-of-school credential for further study, work, and training. HKDSE aims to foster learning, monitoring learner progress, and certification and selection. The HKDSE Examination employs standards-referenced reporting of assessments (Hong Kong Examinations and Assessment Authority, 2011a).

Compulsory Part

The Compulsory Part serves as a foundation for all learners in NSS Mathematics. It consists of topics in three different strands: (1) Number and Algebra, (2) Measures, Shape and Space, and (3) Data Handling (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). Moreover, a Further Learning Unit is introduced to help learners learn to integrate and apply knowledge and skills acquired in these three strands for solving problems in mathematical and real-life contexts. To meet the diverse needs of learners, its contents are grouped into Foundation Topics and Non-Foundation Topics. The Foundation Topics correspond to a set of coherent topics on basic concepts and knowledge, whereas some in-depth or advanced topics are covered in the Non-Foundation Topics.

The HKDSE Mathematics Compulsory Part Examination consists of two papers, namely, Papers 1 and 2 (Hong Kong Examinations and Assessment Authority, 2009). Each paper consists of two sections, namely, Sections A and B. Section A (two-third of the marks awarded to the paper) consists of questions on the Foundation Topics of the Compulsory Part as well as the Foundation Part of the Secondary 1–3 Mathematics Curriculum (Curriculum Development Council, 1999), whereas Section B (one-third of the marks) comprises questions on the Compulsory Part as well as both the Foundation Part and the Non-Foundation Part of the Secondary 1–3 Mathematics Curriculum. Paper 1 (65%) consists of conventional questions, whereas all questions in Paper 2 (35%) are equally weighted multiple-choice questions. Students are expected to attempt all questions.

School-based assessment (SBA) in Mathematics has been advocated for the Compulsory Part to enhance the validity of the overall assessment, and to test candidates' ability to think critically and creatively, conceptualise, investigate and reason mathematically, communicate with others, and express their views clearly and logically in mathematical language (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). However, there are a number of concerns raised by teachers, students, and parents about SBA for HKDSE, including workload, fairness, reliability and validity, and teacher-friendliness of assessment procedures, that may hinder the effectiveness of SBA to learning. The proposal of including a SBA element in HKDSE Mathematics was put on hold, and it has recently been announced that it is cancelled (Curriculum Development Council, Hong Kong Examinations and Assessment Authority, & Education Bureau, 2013).

Extended Part

The Extended Part extends learners to be exposed to a horizon in mathematics beyond the Compulsory Part, so that they can acquire more advanced mathematical knowledge and skills (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). There are two modules, namely, Modules 1 and 2, for students to choose from. Module 1 (Calculus and Statistics) offers learners intuitive concepts, related basic skills, and useful tools of calculus and statistics, and emphasises applications rather than mathematical rigour for widening learners' perspectives on mathematics. Module 2 (Algebra and Calculus) nurtures learners with a solid foundation in algebra and calculus, and focuses on the understanding of mathematics for further studies. Both modules assume the knowledge in the Compulsory Part and the Secondary 1–3 Mathematics Curriculum. In each module, some basic concepts and knowledge needed but not included in the Compulsory Part are covered as part of the Foundation Knowledge. A Further Learning Unit is also introduced for enhancing the learners' abilities to inquire, communicate, reason, and conceptualise mathematical concepts.

The HKDSE Mathematics Extended Part Examination consists of one paper for each module. The papers are divided into two equal-weighted sections, namely, Sections A and B. Section A comprises short questions, while Section B is made up of long questions. Students are expected to attempt all questions.

Research methods

The objective of this research study is to investigate the alignment of the learning targets in the NSSS Mathematics Curriculum Framework and assessment questions in the HKDSE Mathematics Examination to the acquisition of the nine generic skills expected for the NSS Mathematics Education. In the next subsection, the study plan will be discussed, followed by a discussion of the data analysis methods and the alignment coding process employed in this research study.

Study plan

The study is carried out in two phases. In the first phase, we analyse to what extent these generic skills can be acquired based

on the stated learning targets in the curriculum. The learning units[3] which align with these learning targets are also identified. The purposes of this phase are three-fold. First, we can infer from the findings whether or not the generic skills can be acquired across the learning targets. Some inconsistencies and deficiencies of the learning targets with respect to the generic skills are identified. Second, the findings can help us identify misalignments between the learning targets and the learning units in the curriculum. Third, possible remedies can be suggested for the deficiencies, inconsistencies, and misalignments identified.

In the second phase, the assessment questions in the first HKDSE Examination in 2012 are evaluated by finding out whether the captioned nine generic skills have been embodied in these questions. The purposes of this phase of the study are also three-fold. First, we can infer from the findings whether and to what extent the generic skills are embodied in these assessment questions. Second, the findings can help us identify the balance and range of the generic skills involved in the sets of the assessments under study. Third, several recommendations can be suggested for improving the efficiency and effectiveness of the HKDSE Mathematics Examination.

Data analysis

In this study, an analysis to investigate the vertical alignment of the learning targets and assessments to the set of generic skills expected for the NSS Mathematics Education is performed. An approach similar to the Achieve's protocol (Rothman et al., 2002) is followed when carrying out the alignment study. Yet, the depth of each skill involved is quite difficult to be quantified, so that the performance centrality component of the protocol is not implemented.

A learning target and an assessment item correspond fully to a generic skill whenever the involved skill is acquired and/or involved directly[4] during the NSS study and involved when answering the assessment item, respectively. A learning target and an assessment item correspond partially to a generic skill whenever the involved skill at the NSS level may be or may not be acquired during the study, and may be or may not be involved when answering the assessment item, respectively. A learning target or an assessment item does not correspond to a generic skill otherwise.

This judgement is inevitably subjective, and so prior to the main data analysis, a review with consensus judgments based on inter-rater reliability for the alignment analysis has been conducted. First of all, the first author of this paper prepared a set of examples on determining whether assessment items are related to a certain generic skill as exhibited in Appendix A. Next, the third author was explained the level of judgement based on the set of examples. Ten assessment questions selected from the practice papers[5], some of which were multipart questions, were then rated by both the first and third authors. The authors then discussed on the disagreements on judging some assessment items. Disagreements between the two authors were identified, and fine-tuning on the level of judgement was made until consensus has been reached. The first author then rated all the assessment items in the 2012 HKDSE Examination papers. Finally, the first author rechecked all findings before publication. Meanwhile, the second author oversaw the alignment analysis in order to ensure that it has been properly conducted.

Alignment coding process

In determining an alignment relationship, we use the symbols "✓", "✓", and " " to indicate that a learning target or an assessment item in question corresponds fully, partially, and does not correspond to a certain generic skill, respectively. Some examples for Communication Skills are also exhibited as follows (and a full set of examples is shown in Appendix A):

Example 1 ( ): (HKDSE Sample Paper CP 1 Q.2) Make b the subject of the formula $a(b + 7) = a + b$.

The logical presentation on the derivation of equalities is pre-assumed and not considered as part of Communication Skills being learnt at this level.

Example 2 (✓): (HKDSE Sample Paper CP 1 Q.4a) The marked price of a handbag is $560. It is given that the marked price of the handbag is 40% higher than the cost. Find the cost of the handbag.

A candidate is expected to *define* an unknown x for the required cost before solving for x, or write down an expression for the cost directly.

Example 3 (✓): (HKDSE Sample Paper CP 1 Q.5) In a football league, each team gains 3 points for a win, 1 point for a draw and 0 point for a loss. The champion of the league plays 36 games and gains a total of 84 points. Given that the champion does not lose any games, find the number of games that the champion wins.

A candidate is expected to *define* some unknown(s) before formulating and solving linear algebraic equation(s).

In some cases, certain concepts taught in the Secondary 1–3 Mathematics Curriculum may be utilised in answering an assessment item. The symbol "4.3.x (S1–S3)" denotes that certain concepts covered in Chapter 4.3.x of the Secondary 1–3 Mathematics Curriculum (Curriculum Development Council, 1999) are applied in answering the assessment item, where x is 1 or 2 or 3. Any learning units which may or may not be employed in answering an assessment item are surrounded by a pair of square brackets when indicated in a table.

Findings

Our research findings are grouped into two different sets. The first set of results studies how well the learning targets in the NSS Mathematics Curriculum Framework align to the generic skills, whereas the second set of results investigates whether assessment in the HKDSE Examination strikes an appropriate balance in the acquisition of the generic skills.

Alignment of learning targets to generic skills

Tables 1–3 present the alignment of the learning targets in the NSS Mathematics Curriculum to the generic skills. For each learning target, a set of learning units that matches its description is identified. Learning targets which are more complex are broken down into multiple sub-targets, each of which a set of the

[3] A learning unit is a topic of concepts and knowledge that learners are expected to acquire.

[4] This work focuses on the alignment analysis of the generic skills acquired and/or involved directly during the NSS study. Those lower-level generic skills inherently applied in the assessments are not included. For example, understanding an assessment question is generally not considered that Communication Skills are involved at the NSS level.

[5] The provision of practice papers is two-fold. It helps teachers and students become familiar with the format and requirements of the HKDSE Examination (Hui, 2011). It also assists the Hong Kong Examinations and Assessment Authority to rehearse the development of question papers and marking schemes, and the marking procedure.

Table 1
Alignment of learning targets of Compulsory Part to generic skills.

Learning targets	Learning units	Collaboration skills	Communication skills	Creativity	Critical thinking skills	Information technology skills	Numeracy skills	Problem-solving skills	Self-management skills	Study skills
Extend the concepts of numbers to complex numbers	1.8–1.9						✓			
Investigate and describe relationships between quantities using algebraic symbols	2.1, 6		✓				✓			
Generalise and describe patterns in sequences of numbers using algebraic symbols, and apply the results to solve problems[6]	(1) 7.1–7.6 (2) 7.5–7.7		✓	✓			✓	✓		
Interpret more complex algebraic relations from numerical, symbolic and graphical perspectives	2.2–2.4, 3.4, 5.1, 8–9		✓				✓	✓		
Manipulate more complex algebraic expressions and relations, and apply the knowledge and skills to formulate and solve real-life problems and justify the validity of the results obtained[7]	(1) 1.1–1.7, 3.1–3.3, 4, 5.2–5.4 (2) 3.5–3.6, 6.1, 6.3, 7.7 (3) –		✓	✓	✓	✓	✓	✓		
Apply the knowledge and skills in the number and algebra stand to generalise, describe and communicate mathematical ideas and solve further problems in other strands	18		✓	✓		✓	✓	✓		
Use inductive and deductive approaches to study the properties of 2-dimensional shapes	10.1–10.5		✓	✓			✓	✓		
Formulate and write geometric proofs involving 2-dimensional shapes with appropriate symbols, terminology and reasons	10.6		✓	✓	✓		✓	✓		
Inquire into and describe geometric knowledge in 2-dimensional space using algebraic relations and apply this knowledge in solving related problems	11–12		✓	✓			✓	✓		
Inquire and describe geometric knowledge in 2-dimensional space and 3-dimensional space using trigonometric functions and apply the knowledge in solving related problems	13		✓	✓		✓	✓	✓		
Interconnect the knowledge and skills in the measure, shape and space strand and other strands, and apply them to formulate and solve 2-dimensional and 3-dimensional problems using various strategies	18		✓	✓		✓	✓	✓		
Understand the measures of dispersion	16.1–16.4					✓	✓			
Select and use the measures of central tendency and dispersion to compare data sets	16.5–16.7		✓	✓	✓	✓	✓	✓		
Investigate and judge the validity of arguments derived from data sets	17		✓		✓					✓
Acquire basic techniques in counting	14			✓		✓	✓	✓		
Formulate and solve further probability problems by applying simple laws	15		✓	✓		✓	✓	✓		
Integrate the knowledge in statistics and probability to solve real-life problems	15.5, 16.6, 17.2–17.3, 18		✓	✓		✓	✓	✓		
Number of targets aligned	N/A	0/0/17	14/0/3	12/0/5	4/0/13	7/2/8	16/0/1	13/0/4	0/0/17	1/0/16

[6] This learning target is divided into two sub-targets: (1) generalise and describe patterns in sequences of numbers using algebraic symbols, and (2) apply the results to solve problems.

[7] This learning target is broken down into three sub-targets: (1) manipulate more complex algebraic expressions and relations, (2) apply the knowledge and skills to formulate and solve real-life problems, and (3) justify the validity of the results obtained.

Table 2
Alignment of learning targets of Module 1 to generic skills.

Learning targets	Learning units	Collaboration skills	Communication skills	Creativity	Critical thinking skills	Information technology skills	Numeracy skills	Problem-solving skills	Self-management skills	Study skills
Apply binomial expansion for the study of probability and statistics	1					✓	✓	✓		
Model, graph and apply exponential functions and logarithmic functions to solve problems	2.1–2.3		✓			✓	✓	✓		
Understand the relationships between exponential and logarithmic functions and hence apply the two functions to solve real-life problems[8]	(1) – (2) 2.3–2.4		✓	✓		✓	✓	✓		
Recognise the concept of limits as the basis of differential and integral calculus	3.1–3.2						✓			
Understand the idea of differentiation and integration through consideration of concrete phenomena	3.3–3.4, 7.1, 8.1									
Find the derivatives, indefinite integrals and definite integrals of simple functions	4–5, 7.2–7.4, 8.2–8.4						✓	✓		
Understand the concepts of probability, random variables, and discrete and continuous probability distributions	10–13			✓			✓	10.2, 11, 13.2–13.3		
Understand the fundamental ideas of statistical reasoning based on the binomial, Poisson, geometric and normal distributions	14–20		✓	✓		✓	✓	✓		
Use statistical ways of observing and thinking, and then make inferences[9]	(1) 21.1–21.2 (2) 21.3–21.4, 22–23		✓	✓	✓	✓	✓	✓		
Develop the ability to think mathematically about uncertainty and then apply such knowledge and skills to solve problems	24		✓	✓	✓	✓	✓	✓		
Number of targets aligned	N/A	0/0/10	5/0/5	5/0/5	2/0/8	5/1/4	9/0/1	7/0/3	0/0/10	0/0/10

corresponding learning units is determined. For each entry relating a learning target to a generic skill in a table, the symbols "✓", "✓", and " " indicate an alignment relationship that a captioned learning target corresponds fully, partially, and does not correspond to a certain generic skill, respectively. Therefore, we can infer how generic skills are reflected in each learning target. Each entry with respect to a generic skill in the last row of each table shows the three numbers of learning targets aligned fully, partially, and not corresponded to the generic skill, respectively. For a generic skill, a larger sum of the first two numbers indicates that the skill is reflected in more learning targets in the NSS Mathematics Curriculum Framework.

The alignment results for the Compulsory Part are exhibited in Table 1. Four generic skills, namely, Communication Skills, Creativity, Numeracy Skills, and Problem-solving Skills, are expected to be acquired as stipulated in most learning targets. Information Technology Skills are involved in many learning targets. Critical Thinking Skills are developed in a few learning targets, specifically, on justifying the results in the Number and Algebra Strand, formulating geometric proofs, and comparing and investigating data sets. It seems that two generic skills, namely, Collaboration Skills and Self-management Skills, are not involved in any learning targets. It may be inferred that the learning targets of the curriculum focus more on assisting learners in developing Communication Skills, Numeracy Skills, and thinking skills (mainly on the Problem-solving Skills and Creativity), but pay little

[8] The learning target is decomposed into two sub-targets: (1) understand the relationships between exponential and logarithmic functions, and (2) apply the two functions to solve real-life problems.

[9] The learning target is subdivided into two sub-targets: (1) use statistical ways of observing and thinking, and (2) make inferences.

Table 3
Alignment of learning targets of Module 2 to generic skills.

Learning targets	Learning units	Collaboration skills	Communication skills	Creativity	Critical thinking skills	Information technology skills	Numeracy skills	Problem-solving skills	Self-management skills	Study skills
Rationalise surd expressions	1						✓			
Understand the principle of mathematical induction	2		✓	✓	✓		✓	✓		
Expand binomials using the binomial theorem	3					✓	✓			
Understand simple trigonometric functions and their graphs	4.1, 4.3						✓	4.2		
Understand important trigonometric identities and formulae involving compound angles	4.4–4.5						✓			
Understand the number *e*	5						✓			
Understand the concepts, operations and properties of matrices and the inverses of square matrices up to order 3	12–13			✓			✓			
Solve systems of linear equations	14		✓	✓			✓	✓		
Understand the concept, operations and properties of vectors	15–16						✓			
Apply the knowledge of vectors to solve problems in 2-dimentsional space and 3-dimensional space	17		✓	✓			✓	✓		
Understand the concept of limits as the basis of differential and integral calculus	6						✓			
Understand the concepts and properties of derivatives, indefinite integrals and definite integrals of functions	7.1–7.2, 9.1–9.2, 10.1–10.2, 10.6						✓			
Find the derivatives, indefinite integrals and definite integrals of simple functions	7.3–7.4, 9.4–9.6, 10.3–10.5			✓			✓	✓		
Find the second derivatives of functions	7.5						✓			
Apply the knowledge of differentiation and integration to solve real-life problems	8, 9.3, 11		✓	✓			✓	✓		
Number of targets aligned	N/A	0/0/15	4/0/11	6/0/9	1/0/14	0/1/14	15/0/0	5/0/10	0/0/15	0/0/15

attention to learning strategies (i.e., Study Skills) and collaboration and self-management capabilities (i.e., Collaboration Skills and Self-management Skills).

Table 2 shows the alignment of the learning targets of the Extended Part Module 1 to the generic skills. Two generic skills, namely, Numeracy Skills and Problem-solving Skills, are expected to be acquired as stipulated in most learning targets. Communication Skills, Creativity, and Information Technology Skills are involved in many learning targets. Critical Thinking Skills are developed in a few learning targets, mainly in the Statistics Area. Nevertheless, it seems that three generic skills, namely, Collaboration Skills, Self-management Skills, and Study Skills, are not involved in any learning targets. It can be inferred that the learning targets of the curriculum focus on assisting learners in developing Numeracy skills and thinking skills (mainly on Problem-solving Skills), but pay little attention to learning strategies and collaboration and self-management capabilities. Moreover, our results also show that for the Calculus area and for the concepts of random variables, Communication Skills, Creativity (besides the concepts of random variables), Critical Thinking Skills, and Information Technology Skills, in additional to Collaboration Skills, Self-management Skills, and Study Skills are not involved explicitly.

Table 3 presents the alignment of the learning targets of the Extended Part Module 2 to the generic skills. The learning targets

Table 4
Alignment of 2012 HKDSE (Compulsory Part Paper 1) to generic skills.

Assessment items	Learning units	Collaboration skills	Communication skills	Creativity	Critical thinking skills	Information technology skills	Numeracy skills	Problem-solving skills	Self-management skills	Study skills
1	4.3.1 (S1–S3)						✓			
2	4.3.1 (S1–S3)		✓				✓			
3(a)	4.3.1 (S1–S3)						✓			
3(b)	4.3.1 (S1–S3)						✓			
4(a)	4.3.1 (S1–S3)						✓	✓		
4(b)	4.3.1 (S1–S3)		✓		✓		✓	✓		
5	4.3.1 (S1–S3)		✓	✓			✓	✓		
6(a)	8.1		✓				✓			
6(b)	4.3.1 (S1–S3)									
7(a)	16.2–16.3		✓				✓	✓		
7(b)	16.2–16.3		✓	✓	✓		✓	✓		
8(a)	4.3.2 (S1–S3), 10.2		✓	✓			✓	✓		
8(b)	4.3.2 (S1–S3)		✓	✓	✓		✓	✓		
9(a)	4.3.1–4.3.2 (S1–S2)		✓				✓	✓		
9(b)	4.3.2 (S1–S3)		✓				✓	✓		
10(a)	4.3.3 (S1–S3)					✓	✓	✓		
10(b)(i)	4.3.3 (S1–S3)						✓	✓		
10(b)(ii)	4.3.3 (S1–S3)		✓	✓	✓		✓	✓		
11(a)	6.3		✓				✓	✓		
11(b)	4.3.2 (S1–S3), 6.3		✓				✓	✓		
12(a)	4.3.2 (S1–S3)						✓			
12(b)(i)	4.3.2 (S1–S3)						✓	✓		
12(b)(ii)	4.3.2 (S1–S3)		✓	✓	✓	✓	✓	✓		
13(a)	4.3		✓				✓			
13(b)(i)	4.3.2 (S1–S3), 2.2						✓	✓		
13(b)(ii)	1.1/4, 1.6, 2.2, 4.1		✓		✓		✓	✓		
14(a)(i)	11.2		✓				✓			
14(a)(ii)	11.3, 12.1		✓				✓	✓		
14(b)(i)	12.1, 12.3		✓		✓		✓	✓		
14(b)(ii)	4.3.2 (S1–S3)		✓	✓			✓	✓		
15(a)	16.4, 16.7						✓	✓		
15(b)	16.4–16.7		✓	✓	✓		✓	✓		
16(a)	(14.1, 14.4–14.5, 15.5) or 15.3–15.4			✓		✓	✓	✓		
16(b)	[14.1, 14.4–14.5, 15.5], 15.2			✓		✓	✓	✓		
17(a)	10.5, 12.3		✓				✓	✓		
17(b)	((((1.4, 1.6) or 1.7), 12.4) or (10.1, 12.2)), 12.1		✓	✓			✓	✓		
18(a)	13.4, 13.6		✓			✓	✓	✓		
18(b)(i)	4.3.2 (S1–S3), 13.4, 13.6		✓	✓		✓	✓	✓		
18(b)(ii)	4.3.2 (S1–S3), 13.1, [13.4], 13.6		✓	✓	✓		✓	✓		
19(a)(i)	4.3.1 (S1–S3)		✓			✓	✓	✓		
19(a)(ii)	7.3–7.5, 7.7						✓	✓		
19(b)(i)	4.3.1 (S1–S3), 3.4		✓	✓	✓		✓	✓		
19(b)(ii)	4.3.1 (S1–S3), 3.3, 7.3–7.5, 7.7, 8.3		✓	✓		✓	✓	✓		

have been clearly stated so as to align well to the learning units in the curriculum. The only generic skill that is expected to be acquired extensively as stipulated in all learning targets is Numeracy Skills. Communication Skills, Creativity, and Problem-solving Skills are involved in less than half of the learning targets. Critical Thinking Skills and Information Technology Skills are each developed in just one learning target. It seems that three generic skills, namely, Collaboration Skills, Self-management Skills, and Study Skills, are not involved in any learning targets. It can be inferred that the learning targets of the curriculum focus on assisting learners in mainly developing Numeracy Skills, but pay little attention to learning strategies and collaboration and self-management capabilities.

Alignment of assessment to generic skills

Tables 4–7 exhibit the alignment of the assessment items in the 2012 HKDSE Examination to the generic skills. For each entry relating an assessment item to a generic skill in a table, the symbols "✓", "✓", and " " indicate an alignment relationship that a captioned assessment item corresponds fully, partially, and does not correspond to a certain generic skill, respectively. Therefore,

Table 5
Alignment of 2012 HKDSE (Compulsory Part Paper 2) to generic skills.

Assessment items	Learning units	Collaboration skills	Communication skills	Creativity	Critical thinking skills	Information technology skills	Numeracy skills	Problem-solving skills	Self-management skills	Study skills
1	4.3.1 (S1–S3)						✓			
2	4.3.1 (S1–S3)						✓			
3	4.3.1 (S1–S3)						✓			
4	4.3						✓			
5	4.3.1 (S1–S3)						✓			
6	2.3						✓			
7	8.1						✓			
8	15.2–15.4			✓			✓	✓		
9	4.3.1 (S1–S3)						✓			
10	6.1, 6.3						✓	✓		
11	4.3.1 (S1–S3)						✓	✓		
12	7.1–7.2, 7.5			✓			✓	✓		
13	4.3.1 (S1–S3)		✓		✓					
14	4.3.1 (S1–S3)						✓	✓		
15	4.3.2 (S1–S3)						✓	✓		
16	4.3.2 (S1–S3)						✓	✓		
17	4.3.2 (S1–S3)			✓			✓	✓		
18	4.3.2 (S1–S3)						✓	✓		
19	13.1						✓			
20	4.3.2 (S1–S3), [10.3]			✓			✓	✓		
21	4.3.2 (S1–S3)			✓			✓	✓		
22	4.3.2 (S1–S3)				✓		✓			
23	4.3.2 (S1–S3)						✓	✓		
24	11.2		✓							
25	12.1				✓		✓			
26	12.3				✓		✓			
27	4.3.3 (S1–S3)						✓	✓		
28	4.3.3 (S1–S3)						✓	✓		
29	4.3.3 (S1–S3), 16.4					✓	✓	✓		
30	4.3.3 (S1–S3)				✓		✓			
31	4.4						✓			
32	3.3, 12.1						✓	✓		
33	4.3.1 (S1–S3)						✓			
34	2.3, 9.4				✓		✓			
35	1.9						✓			
36	8.4–8.5				✓		✓			
37	7.1–7.2, 7.5				✓		✓	✓		
38	9.4		✓		✓		✓			
39	13.1				✓		✓			
40	4.3.2 (S1–S3), 13.6			✓		✓	✓	✓		
41	4.3.2 (S1–S3), 10.3, 10.5			✓			✓	✓		
42	1.5, 8.3, 12.4						✓	✓		
43	14.1, 14.4–14.5			✓		✓	✓	✓		
44	15.3–15.4			✓			✓	✓		
45	4.3.3 (S1–S3), 16.2, 16.4–16.5, 16.7				✓		✓			

Table 6
Alignment of 2012 HKDSE (Module 1) to generic skills.

Assessment items	Learning units	Collaboration skills	Communication skills	Creativity	Critical thinking skills	Information technology skills	Numeracy skills	Problem-solving skills	Self-management skills	Study skills
1(a)	1						✓			
1(b)	((1.1 or 1.4), 1.6) (CP), 2.1		✓				✓	✓		
2	[4], (7.2–7.5 or (8.2–8.4, 8.6))		✓	✓			✓	✓		
3(a)	3.3 (CP), 2.2						✓			
3(b)	2.3–2.4		✓			✓	✓	✓		
4(a)	3.3 (CP), 2.2, 4		✓				✓			
4(b)	4, 5.2		✓				✓	✓		
5(a)	2.2, ((7.2–7.3, 7.5) or (8.2–8.3, 8.6))		✓				✓	✓		
5(b)	12.1 (CP), 2.2, 3.4, 6		✓				✓	✓		
5(c)	2.2, 8.2–8.3, 8.5						✓	✓		
6(a)	18.2, 19, 20.1, 20.3, 21.2		✓				✓	✓		
6(b)	19, 21.3, 23		✓			✓	✓	✓		
7(a)	3.3 (CP), 2.3, 16–17		✓			✓	✓	✓		
7(b)	16.2, 17			✓		✓	✓	✓		
7(c)	((10, 16.2) or 16), 17			✓		✓	✓	✓		
8(a)	12, 13.1–13.2		✓	✓			✓	✓		
8(b)(i)	15.1–15.2 (CP)						✓	✓		
8(b)(ii)	10.1 or 10.2		✓		✓		✓	✓		
9(a)	15.2 (CP), 10, 18.2, 19, 20.1, 20.3		✓	✓			✓	✓		
9(b)	10–11			✓		✓	✓	✓		
9(c)	14.2, 17			✓		✓	✓	✓		
10(a)(i)	2.2, 9					✓	✓			
10(a)(ii)	4, 5.2, 9		✓		✓		✓	✓		
10(b)	4.3.1 (S1–S3), 4.2, 8.2, 8.4		✓	✓	✓		✓			
10(c)	8.2, 9, 19		✓	✓		✓	✓	✓		
11(a)	6		✓				✓	✓		
11(b)	3.3 (CP), 2.2, [4], (7.2–7.5 or (8.2–8.4, 8.6))		✓	✓			✓	✓		
11(c)	3.3 (CP), 2.3		✓	✓			✓	✓		
11(d)	((1.1 or 1.4), 1.6) (CP), 4, 5.2, 6		✓				✓	✓		
12(a)(i)	19, 21.3, 22.2		✓				✓	✓		
12(a)(ii)	22		✓				✓	✓		
12(b)(i)	14.2, 17, 18.2, 19, 20.1, 20.3		✓	✓		✓	✓	✓		
12(b)(ii)	10.1, 14.2, 17			✓		✓	✓	✓		
13(a)	2.3, 16–17			✓		✓	✓	✓		
13(b)	2.3, 10, 16.2, 17			✓		✓	✓	✓		
13(c)(i)	15.2, 17			✓		✓	✓	✓		
13(c)(ii)	(14.3–14.5, 15.5) (CP), 2.3, 10.1, 16.2, 17			✓		✓	✓	✓		

we can infer how generic skills are reflected in each assessment item.

Tables 4 and 5 show the alignment of the assessment items in Papers 1 and 2 of the Compulsory Part in the 2012 HKDSE Examination to the generic skills, respectively. For Paper 1, our findings indicate that Communication Skills, Numeracy Skills, and Problem-solving Skills are involved in most assessment items, whereas Creativity and Critical Thinking Skills are needed in answering many assessment items. There are a few assessment items involving the use of Information Technology Skills. Nevertheless, there are three generic skills, namely, Collaboration Skills, Self-management Skills, and Study Skills, which are not needed explicitly.

For Paper 2, our findings clearly demonstrate that Numeracy Skills are involved in answering all but one question. Problem-solving Skills are needed in answering nearly half of the questions, and Critical Thinking Skills and Creativity need to be applied in answering nearly one-fourth of the questions. Communication Skills and Information Technology Skills are needed in a few questions. Similar to Paper 1, Collaboration Skills, Self-management Skills, and Study Skills are not needed explicitly.

Hence, the assessments in the Compulsory Part are oriented to assessing Communication Skills, Numeracy Skills, and thinking skills (i.e., Problem-solving Skills, Creativity, and Critical Thinking Skills), but pay little attention to learning strategies and collaboration and self-management capabilities. This is consistent with what would be derived from the learning targets. As far as the assessment questions are concerned, 49 and 38 out of 90 learning units are not covered in Papers 1 and 2, respectively. One may argue that not all learning units are needed to be covered, and actually it is not feasible to cover each and every unit in one examination. Hopefully, this is not a general trend in the future.

Table 7
Alignment of 2012 HKDSE (Module 2) to generic skills.

Assessment items	Learning units	Collaboration skills	Communication skills	Creativity	Critical thinking skills	Information technology skills	Numeracy skills	Problem-solving skills	Self-management skills	Study skills
1	5–6, 7.1		✓				✓			
2	3		✓				✓	✓		
3	2		✓		✓		✓	✓		
4(a)	4.5 (CP), 9.2						✓			
4(b)	7.2–7.3, 9.2, 9.4		✓				✓			
5	4.3.1 (S1–S3), 4.5 (CP), 6, 7.2–7.3, [7.5], 8.2–8.3		✓				✓	✓		
6(a)	4.3.2 (S1–S3)		✓		✓		✓	✓		
6(b)	7.2–7.3, 8.4		✓				✓	✓		
7(a)	[12,15.2], 15.3, 16.2, 17						✓	✓		
7(b)	((12, 16.2) or 16.1), 17		✓				✓	✓		
8(a)	14		✓				✓	✓		
8(b)	14		✓				✓	✓		
9(a)	9.2, 9.6			✓			✓			
9(b)	13.1 (CP), 4.1, 10.3, 11.2						✓	✓		
10(a)	4.3.2 (S1–S3), ([13.1], 13.4) (CP), 4.3		✓	✓	✓		✓	✓		
10(b)	(8.1, 13.1) (CP), 4.1, 4.3		✓	✓			✓	✓		
11(a)	((1.1 or 1.4), 1.6) (CP), 12		✓				✓	✓		
11(b)(i)	12, 13.1		✓				✓	✓		
11(b)(ii)	13		✓				✓			
11(b)(iii)	13		✓	✓			✓	✓		
12(a)	4.3.2 (S1–S3), 15.1–15.2, 17		✓				✓	✓		
12(b)(i)	4.3.2 (S1–S3)		✓	✓	✓		✓	✓		
12(b)(ii)	4.3.2 (S1–S3), 15.1–15.2, 16.1, 17		✓	✓	✓		✓	✓		
13(a)(i)	13.1 (CP), 4.1, 4.5		✓	✓	✓		✓	✓		
13(a)(ii)	4.1, 4.3, 4.5		✓	✓			✓	✓		
13(b)(i)	4.3.2 (S1–S3), 2.4 (CP)						✓			
13(b)(ii)	4.4, 7.2–7.3, 10.3–10.4		✓	✓			✓	✓		
13(c)	13.1 (CP), ((4.1, 10.1–10.2) or (4.4, 10.3)), 7.2–7.3, 10.4		✓	✓			✓	✓		
14(a)	4.3.2 (S1–S3), 7.2–7.3, 8.1		✓		✓		✓	✓		
14(b)(i)	4.3.1–4.3.2 (S1–S3), (10.5 (CP) or (12.3 (CP), 7.2–7.4))		✓	✓	✓		✓	✓		
14(b)(ii)	4.3.2 (S1–S3), ((12.3 (CP), 7.2–7.3, 10.4) or 4.2), 4.1, 10.2–10.3, 11.1		✓	✓			✓	✓		

Table 6 presents the alignment of the assessment items in the Extended Part Module 1 for the 2012 HKDSE Examination to the generic skills. Our findings show that Communication Skills, Numeracy Skills, and Problem-solving Skills are involved in most assessment items, whereas Creativity and Information Technology Skills are needed in answering many assessment items. Surprisingly, there are only three assessment items requiring Critical Thinking Skills. Yet, three generic skills, namely, Collaboration Skills, Self-management Skills, and Study Skills, are not needed explicitly in answering the assessment items. Furthermore, 14 out of 54 learning units are not involved in the assessment.

In other words, the assessments in the Extended Part Module 1 are oriented to assessing Communication Skills, Numeracy Skills, thinking skills (mainly on Problem-solving Skills and Creativity), and Information Technology Skills, but pay little attention to learning strategies and collaboration and self-management capabilities. This is consistent with what would be derived from the learning targets, except that there are surprisingly few assessment items involving Critical Thinking Skills.

Table 7 exhibits the alignment of the assessment items in the Extended Part Module 2 for the 2012 HKDSE Examination to the generic skills. Our findings show that Communication Skills, Numeracy Skills, and Problem-solving Skills are involved in most assessment items, whereas Creativity and Critical Thinking Skills are needed in answering about half of the assessment items. Yet, four generic skills, namely, Collaboration Skills, Information Technology Skills, Self-management Skills, and Study Skills, are not needed explicitly in answering the assessment items. Furthermore, 7 out of 45 learning units are not involved in the assessment.

Again, the assessments in the Extended Part Module 2 are focused on assessing Communication Skills, Numeracy Skills, and thinking skills (i.e., Problem-solving Skills, Creativity, and Critical Thinking Skills), but pay little attention to learning strategies and

collaboration and self-management capabilities. There are some misalignments between assessment and the learning targets, because Critical Thinking Skills are generally not embodied in the learning targets.

Further discussion

We summarise our findings on the alignment of the assessment to the generic skills as follows:

- Communication Skills, Numeracy Skills, and Problem-solving Skills are mostly involved in the assessments of the Compulsory Part and the Extended Part Modules 1–2.
- Creativity is involved in many assessment items of the Compulsory Part and the Extended Part Modules 1–2.
- Critical Thinking Skills are involved in some assessment items of both the Compulsory Part and the Extended Part Module 2. They are rarely needed in dealing with the assessment items of the Extended Part Module 1. That seems to be in conflict with the curriculum objective that the module is focused on mathematical applications and there should be more opportunities to formulate and evaluate views about these applications.
- Information Technology Skills are more involved in the Extended Part Module 1 than in the Compulsory Part, but they are seldom assessed for the Extended Part Module 2.
- There is a lack of learning strategies (i.e., the Study Skills) and collaboration and self-management capabilities (i.e., Collaborative Skills and Self-management Skills) in the learning targets and the assessment, contrary to what is as expected from the NSS Mathematics Education.
- There are only a few assessment items involving Communication Skills in the Compulsory Part Paper 2, where all questions are multiple-choice questions.

In other words, Communication Skills, Creativity, Numeracy Skills, and Problem-solving Skills are generally involved in the assessments, while learning strategies (i.e., the Study Skills) and collaboration and self-management capabilities (i.e., Collaborative Skills and Self-management Skills) are not examined in HKDSE. Critical Thinking Skills are seldom involved in the assessment items of the Extended Part Module 1, so students are not given the opportunities to formulate and evaluate arguments in the decision-making process in the assessment. Information Technology Skills are generally not needed in assessment for the Extended Part Module 2.

Thus, we can see that there exist certain degrees of imbalance in the acquisition of the generic skills through the current NSS Mathematics Education. There is a lack of learning strategies and collaboration and self-management capabilities embodied in the curriculum or examined through the assessments. Besides, the diversity (in terms of the question format and topic coverage) of assessment items is rather limited, as inferred from both the generic skills involved and the set of learning units examined (or not examined).

Public examination is generally not a good venue to assess some generic skills, such as collaboration. In fact, this concurs with our results that we do not find these in the HKDSE Examination papers, and there is inconsistency or misalignment in the current curriculum for the Hong Kong NSS Mathematics Education. In our views, these skills should be assessed, and school-based assessment (SBA) may be the right venue to do it. It is a pity that the proposal for SBA is shelved. The Hong Kong Education Bureau (EDB) should not bow to pressures on technical difficulties, such as teachers finding it difficult to do or issues of fairness, at the expense of not fulfilling the curriculum intention on these skills. Besides, some generic skills are best achieved through self-directed learning, which is recommended as a guiding principle for effective learning and teaching of NSS Mathematics in (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007). In self-directed learning, open-ended questions are employed to promote students to learn mathematics as well as solve real-life problems. However, public examination is not the venue for assessing self-directed learning, which may be assessed through SBA.

To alleviate the aforementioned problems, we suggest the following recommendations for the Compulsory Part and the Extended Part:

1. Revision of the general curriculum and assessment structure: Generic skills that cannot be examined in the current setting of the assessments can be acquired through the use of appropriate pedagogical strategies. However, there is a lack of motivation to do so in reality because of two reasons. First, there is no learning unit in the curriculum from which learners are clearly expected in acquiring generic skills such as learning strategies and collaboration and self-management capabilities. Second, our analysis shows that these learning strategies and collaboration and self-management capabilities are generally not required in the assessments, and given the examination culture in Hong Kong, if they are not assessed then they will not be taught. Indeed, the examination-oriented learning culture, which is predominant in East Asian societies (Kwok, 2004; Zhan & Wan, 2010), drives the student mode of learning. Hence, there is a need to explicitly incorporate some learning units specifically for learning such skills, and to assess the mastery of such skills in the examination.
2. Introduction of new forms of assessment: It may not be possible for the current form of the written examination to involve Collaborative Skills, Self-management Skills, and Study Skills. New forms of assessment, such as written practical examination and SBA, should be introduced to alleviate such deficiencies. A written practical examination, which can be a separate paper or part of an existing paper, consists of a set of assessment items surrounding the same scenario (in the form of a story discussion). Learners collaborate in solving the problem, and based on the collaboration experience, they produce a collaborative plan for the given scenario as part of the assessment. The assessment items can be set in such a way that Collaborative Skills, Self-management Skills, and Study Skills can then be involved, in addition to other generic skills which are generally needed in the conventional questions.

   In SBA, some assessment tasks can be conducted in the form of group work, so as to encourage cooperative learning and the acquisition of collaboration and self-management capabilities. The use of IT in learning and teaching should also be strongly encouraged, since the information technology skills assessed in the written examinations can only be on the use of scientific calculators. As suggested in (Curriculum Development Council & Hong Kong Examinations and Assessment Authority, 2007), powerful mathematics-related software packages can be utilised so as to support students to understand concepts and construct knowledge, say, by visualisation and exploration of problems. This may also imply the need of advancements of pedagogy and assessment practices. Notwithstanding the concerns in the Compulsory Part section, SBA is still the most viable assessment instrument to promote the acquisition of the generic skills, which are generally not needed in conventional written assessments. In other words, SBA and written assessments are somewhat complementary in learning.
3. Increase in the diversity of assessment items: We find that the assessment items in both the practice paper and the 2012 HKDSE Examination paper are quite similar in terms of question format,

coverage, and the skills involved. This would implicitly encourage rote memorisation. To make learning more effective, assessment items should be set with certain degrees of variations, in terms of question format, topic coverage, and the skills involved, across years.

Although we believe that our work in investigating the alignment of the learning targets and assessments to the generic skills may have shed light on the efficiency and effectiveness of the NSS Mathematics Education, some issues have not yet been studied and are potential research topics. They are listed as follows:

1. Alignment study of assessments to the learning targets and contents in the curriculum standards: This future study will be complementary to our work, so as to find out whether there are horizontal misalignments between curriculum and assessment. This helps us visualise a more complete picture on alignment among the learning targets, curriculum standards, and assessments.
2. Alignment study of classroom instruction and teaching materials to the curriculum standards: Classroom instruction and teaching materials such as textbooks are pivotal in realizing the learner outcomes expected from the curriculum. Studying the effectiveness of this vertical alignment to the curriculum standards will give a full picture of curriculum alignment throughout the system.
3. Follow-up research on examination papers across years: Our research findings are based on the papers from the 2012 HKDSE Examination, the first HKDSE examination, and thus provide important baseline data. It would be valuable to conduct a follow-up study to research any persistent and time-varying trends and inferences across years, especially in terms of the variations of assessment items mentioned above.

Conclusion

Education reform is now a worldwide phenomenon, and many countries are interested in the issue of alignment. Cultural issues could be pivotal to the success of a reform. In this article, we investigate the assessment alignment of the HKDSE Mathematics Examination with the acquisition of the nine generic skills expected for the NSS Mathematics Education. Our findings show that Communication Skills, Numeracy Skills, and Problem-solving Skills are mostly involved in the assessments of the Compulsory Part and the Extended Part Modules 1–2. Creativity is involved in many assessment items of the Compulsory Part and the Extended Part Modules 1–2. Critical Thinking Skills are involved in some assessment items of both the Compulsory Part and the Extended Part Module 2. They are rarely needed in dealing with the assessment items of the Extended Part Module 1. There is more involvement of Information Technology Skills in the Extended Part Module 1 than in the Compulsory Part. Yet, the skills are seldom assessed for the Extended Part Module 2.

Now we re-visit the four questions posed in the Introduction section. Our study shows that the generic skills are not reflected in a balanced manner through the learning targets in the current NSS Mathematics Education. There is a lack of learning strategies (i.e., the Study Skills) and collaboration and self-management capabilities (i.e., Collaborative Skills and Self-management Skills) acquired as expected from the learning targets, nor examined through the assessments in the current NSS Mathematics Education. Public examination is indeed not a good venue to access some generic skills. This clearly shows that there exist certain degrees of imbalance in the acquisition of the generic skills through the current NSS Mathematics Education. In addition, the current NSS Mathematics Education can help learners in the acquisition of certain generic skills, but not all. In other words, we would expect that learners can acquire these nine generic skills in the NSS education as a whole, instead of a single subject, like Mathematics, alone.

To alleviate these deficiencies and limitations, we suggest some revisions to the curriculum and assessment structure, introduction of new forms of assessment, and an increase in diversity of the assessment items as means for alleviating the aforementioned problems.

The predominant examination-oriented learning culture in East Asian societies, such as Hong Kong, drives the student mode of learning. This has coupled with an informal mass tutoring subculture, which is iconed with idol, authoritative tutors and the success stories of their tutored students. Such informal learning alters values in daytime teaching and learning that may work against reform missions and make the education system ineffective (Kwok, 2004). We believe that, probably influenced by Confucian thoughts, East Asian people incline to learn from predecessors or authorities. This differs from Western people who may generally have a stronger motivation on exploration. Hence, the experience in Hong Kong implies that a good education system in one place does not necessarily mean that the system can be directly applicable to another place. Cultural issues should be considered for building or rebuilding an education system so that they can be catalysts, instead of retarders, for aligning components in the system.

The theoretical contribution of this work is three-fold. First, it offers an effective framework on how an alignment study of assessment to a set of generic skills can be conducted. The conventional horizontal alignment analysis based on the mapping from the assessment items to the learning targets in the curriculum does not reveal whether assessment is properly aligned with the generic skills. As far as we know, this is the first work to investigate the alignment between assessment and the generic skills embodied within the curriculum. This bridges the gap between what concepts/knowledge learners have picked up and what generic skills they have ultimately acquired from the learning process.

Second, this is also the first work, to the best of our knowledge, which evaluates the effectiveness of the ongoing education reform in Hong Kong by means of assessment alignment to the generic skills. Because of the backwash effect, it is expected that a properly aligned assessment to the generic skills would assist learners to acquire the generic skills in the most balanced, efficient, and effective manner through the acquisition of the mathematical concepts and knowledge. Hence, this work proposes a new alignment process, which can be applicable to other educational systems as well.

Third, our study makes some contribution to alignment theory as well. In alignment theory, it is hypothesised that the agreement in education components implies coherence and efficiency for an education system. The degree of alignment is generally judged on subject-specific knowledge or skills. However, the method of studying alignment exhibits a limitation when alignment is established in the context of transferable skills, such as generic skills, as they may be achieved through learning various subjects and cannot be assessed directly. In other words, the attainment of generic skills inferred from the assessment does not necessarily mean that they are acquired through the curriculum in the NSS Mathematics Education. Yet, as inferred from our study, the existence of some generic skills not assessed in the assessment reveals inconsistency or misalignment of learning targets and assessment to generic skills in the current curriculum. This inference is applicable to transferable skills in general.

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Appendix A

Examples on determining whether assessment items are related to a certain generic skill are shown as follows. The sample papers and the practice papers for the HKDSE Mathematics Examination are available at http://www.hkeaa.edu.hk/en/hkdse/hkdse_subj.html?A1&1&4_3 and http://www.hkeaa.edu.hk/en/hkdse/hkdse_subj.html?A1&1&4_17, respectively.

(a) Collaborative Skills

Example (✓): Compare and contrast, with example(s), between indefinite integrals and definite integrals on their approaches (derivation method, applicability, and pitfalls) when solving real-life problems. Form a team of 2 persons, divide the task into a number of sub-tasks, and indicate which part(s) each member in the team are involved.

(b) Communication Skills

Example 1 (): (HKDSE Sample Paper CP1 Q.2) Make b the subject of the formula $a(b+7)=a+b$.

The logical presentation on the derivation is pre-assumed and not considered as part of Communication Skills being learnt at this level.

Example 2 (✓): (HKDSE Sample Paper CP 1 Q.4a) The marked price of a handbag is $560. It is given that the marked price of the handbag is 40% higher than the cost. Find the cost of the handbag.

A candidate is expected to *define* an unknown x for the required cost before solving for x, or write down an expression for the cost directly.

Example 3 (✓): (HKDSE Sample Paper CP 1 Q.5) In a football league, each team gains 3 points for a win, 1 point for a draw and 0 point for a loss. The champion of the league plays 36 games and gains a total of 84 points. Given that the champion does not lose any games, find the number of games that the champion wins.

A candidate is expected to *define* some unknown(s) before formulating and solving linear algebraic equation(s).

Example 4 (✓): (HKDSE Sample Paper CP 2 Q.25) In the figure, the two 6-sided polygons show A. a rotation transformation. B. a reflection transformation. C. a translation transformation. D. a dilation transformation.

It is expected that a candidate needs to *interpret* the two polygons in the figure and apply a correct term on transformation for the answer.

Example 5 (✓): Find the coefficient of x^2 in the expansion of $(2x+1)^8$.

A candidate may first *present* the coefficient of a general term and make use of it to derive the required coefficient, or write down an expression of the required coefficient directly.

(c) Creativity

Example 1 (): (HKDSE Sample Paper CP1 Q.2) Make b the subject of the formula $a(b+7)=a+b$.

The derivation does not involve any skills on creativity.

Example 2 (✓): (HKDSE Practice Paper CP 1 Q.7) In Figure 1, BD is a diameter of the circle ABCD. If AB = AC and $\angle BDC = 36^\circ$, find $\angle ABD$.

A candidate is expected to *develop* a solution plan by finding some other angles for solving the problem.

Example 3 (✓): (HKDSE Sample Paper CP 2 Q.44) If 2 girls and 5 boys randomly form a queue, find the probability that the two girls are next to each other in the queue. A. $\frac{1}{7}$ B. $\frac{2}{7}$ C. $\frac{6}{7}$ D. $\frac{1}{21}$

A candidate needs to *construct* cases that correspond to the given event before he/she can compute the required probability.

(d) Critical Thinking Skills

Example 1 (): (HKDSE Sample Paper CP1 Q.2) Make b the subject of the formula $a(b+7)=a+b$.

The derivation does not involve any skills on critical thinking.

Example 2 (✓): (HKDSE Sample Paper CP 1 Q.14c) The stall-keeper claims that since the median and the mean found in (*a*) exceed 50%, newspaper A has the largest market share among the newspapers in city H. Do you agree? Explain your answer.

A candidate is expected to *evaluate* a given claim and *draw* a conclusion about the validity of the claim with respect to the underlying assumptions in random sampling.

Example 3 (✓): (HKDSE Sample Paper CP 2 Q.29) $\{a-7, a-1, a, a+2, a+4, a+8\}$ and $\{a-9, a-2, a-1, a+3, a+4, a+6\}$ are two groups of numbers. Which of the following is/are true? I. The two groups of numbers have the same mean. II. The two groups of numbers have the same median. III. The two groups of numbers have the same range. A. I only B. II only C. I and II only D. II and III only

A candidate is expected to compute and *compare* statistics (mean, median, and range) between two groups of numbers, and then *test* the given three hypotheses.

(e) Information Technology Skills

Example 1 (): (HKDSE Sample Paper CP1 Q.2) Make b the subject of the formula $a(b+7)=a+b$.

The derivation does not involve any skills on information technology.

Example 2 (✓): (HKDSE Sample Paper CP 1 Q.14a) The data below show the percentages of customers who bought newspaper A from a magazine stall in city H for five days randomly selected in a certain week: 62%, 63%, 55%, 62%, 58%. Find the median and the mean of the above data.

A candidate may employ the *statistics mode* of a scientific calculator to compute the mean of the above data, or simply apply the formula to compute the average of the data that does not need to employ a scientific calculator.

Example 3 (✓): (HKDSE Sample Paper CP 2 Q.39) Peter invests \$P at the beginning of each month in a year at an interest rate of 6% per annum, compounded monthly. If he gets \$10000 at the end of the year, find P correct to 2 decimal places. A. 806.63 B. 829.19 C. 833.33 D. 882.18

A candidate needs a scientific calculator to evaluate 1.005^{12}, i.e. in the form of x^y, when finding P.

(f) Numeracy Skills

Example 1 (✓): (HKDSE Sample Paper CP1 Q.2) Make b the subject of the formula $a(b + 7) = a + b$.

The derivation involves some *algebraic manipulations*.

Example 2 (): (HKDSE Sample Paper CP 1 Q.14c) The stallkeeper claims that since the median and the mean found in (a) exceed 50%, newspaper A has the largest market share among the newspapers in city H. Do you agree? Explain your answer.

A candidate is not expected to perform any reasoning and manipulations involving numerical concepts.

Example 3 (✓): The mean score of a class of students in a test is 70 marks. Victor receives 90 marks in the test. A student, Apple, withdraws from the class and her test score is then deleted. If her score equals the mean score of the class, will there be any change in the standard score of Victor due to the class withdrawal? Explain your answer.

A candidate is expected to validate or falsify the claim by considering the change in the standard score due to a score deletion. This may involve a verbal argument with no quantitative information, or a comparison of two expressions involving *algebraic manipulations*.

(g) Problem-solving Skills

Example 1 (): (HKDSE Sample Paper CP1 Q.2) Make b the subject of the formula $a(b + 7) = a + b$.

The derivation does not involve any problem-solving skills for such simple algebraic manipulations.

Example 2 (✓): (HKDSE Sample Paper CP 1 Q.5) In a football league, each team gains 3 points for a win, 1 point for a draw and 0 point for a loss. The champion of the league plays 36 games and gains a total of 84 points. Given that the champion does not lose any games, find the number of games that the champion wins.

A candidate is expected to *devise* a plan to find the required number of games by formulating and *solving* linear algebraic equation(s).

(h) Self-management Skills

Example (✓): Self-evaluate own strengths and weaknesses in mathematics learning.

(i) Study Skills

Example (✓): Discuss with examples the uses and abuses of statistical methods in conducting surveys.

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