THE USE OF SELF-ASSESSMENT TO FACILITATE SELF-DIRECTED LEARNING IN MATHEMATICS BY HONG KONG SECONDARY SCHOOL STUDENTS

YU, TAO,WANG

THE USE OF SELF-ASSESSMENT
TO FACILITATE SELF-DIRECTED LEARNING IN MATHEMATICS
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ABSTRACT

In a world that is constantly changing, the most important skill to acquire is learning how to learn. One of the aims of the education reform in Hong Kong is to help students to develop self-directed learning capabilities, leading to whole-person development and life-long learning. Self-directed learning refers to a process whereby the learner assumes a major responsibility for the initiation, planning, implementation and monitoring of their own learning. In this study, several self-assessment tools, introduced to the teachers, were used by the students in mathematics classrooms in order to facilitate students' self-directed learning. The self-assessment tools included student reflective journals, think boards and mind maps. The purpose of this research is to explore ways to use guided self-assessment to build high quality self-directed learning processes in students, which will assist teachers and schools in producing successful and self-directed learners in mathematics. It also investigated the effectiveness of the intervention to enhance students' mathematics capability. A total of 533 Secondary Three (S3) students in 16 classes from 6 schools took the pre- and post-tests. Out of the 533 students, 315 engaged in self-assessment with teachers' guidance. The students were asked to reflect on what they had learned in class using those self-assessment tools. Pre- and post-tests were administrated before and after the intervention respectively to see if there was a difference in gain between the treatment group and control group. The treatment group made significantly greater gains than the control group (effect size=0.27). Also, 101 samples of student self-assessment work were analyzed to understand the nature of the reflective learning that took place. The analysis showed that many of the components of self-directed learning were found in their self-assessment work. The results tell us that self-directed learning facilitated by self-assessment is a viable pedagogy in mathematics for these S3 Hong Kong students.

On the basis of this research, the use of student self-assessment to facilitate self-directed learning in other settings could be explored in the future. This study will guide future developments of interventions related to self-assessment and self-directed learning to enhance teaching and learning.

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ABBREVIATIONS

ANOVA	Analysis of Variance
EDB	Education Bureau
LPA	Latent Profile Analysis
MOI	Medium of Instruction
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
SDL	Self-Directed Learning
SDLR	Self-Directed Learning Readiness
SRL	Self-Regulated Learner
S3	Secondary Three
TIMSS	Trends in International Mathematics and Science Study

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DECLARATION

The thesis results from my own work and it has not been previously submitted for a degree in this university or any other institution.

STATEMENT OF COPYRIGHT

CHAPTER 1 Introduction to the study

1.1 The Hong Kong education reform

Hong Kong is facing new challenges posed by the knowledge-based and globalized economy in this constantly changing world. The Hong Kong government acknowledged that one of the most important skills Hong Kong students should acquire is learning how to learn. In 2001, the Hong Kong Education and Manpower Bureau (EDB) launched a 10-year reform accepting suggestions from the report, "Education blueprint for the 21st century: Learning for life, learning through life – Reform proposals for education system in Hong Kong", prepared by the Education Commission (2000). It suggested that the curriculum reform should attempt to develop a new culture of learning by shifting from the transmission of knowledge to learning how to learn, through cultivating positive values, attitudes and commitment to life-long learning. Also, all students should be provided with essential life-long learning experiences for whole-person development. For assessment, more emphasis should be put on assessment for learning rather than assessment of learning. Assessment should be use in a formative way in which teachers seek to diagnose student learning difficulties, and provide feedback for students on where they are and where to go next.

The Hong Kong education reform is composed of many initiatives. However, the overarching principle is learning to learn. Therefore, to foster students' self-learning capability is vital. In Hong Kong, for a long time, learning has been examination-driven and scant attention has been paid to "learning to learn" (Education Commission, 2000). The reform is an attempt to counter a strong examination culture,

which is considered to be a product of a meritocratic society with deep roots in Confucianism (Brown, Kennedy, Fok, Chan & Yu, 2009). In this context, high expectations for success and social improvement through examinations play a very significant role in the lives of Chinese families. As pointed out by Gow, Balla, Kember & Hau (1996), in Chinese societies, students in general are hard working and attribute their academic performance more to their effort than to ability. Also, they learn in school so as to fulfil their duties towards their parents. In Asia, there are traditions of rote learning, teacher-directed instruction, rigid national curriculum systems, and centralized administrative structures (Hallinger, 2010). In Hong Kong, public examination is still the primary mechanism for selecting students for a limited number of university places. In Australia and the United States, 82% and 64% of the students respectively can receive government subsidized higher education, but the figure for Hong Kong is only 18%. Therefore, harsh competition among students is inevitable. To make things worse, the student population has decreased rapidly in recent years and that means some schools are under the threat of closing down. Schools need good results to attract students. Therefore, for some teachers, assessment for learning is fine, but helping students to get good grades in public examinations is a matter of life and death for their careers. While acknowledging the use of summative assessment in the past, the EDB now calls for an increased adoption of formative assessment in schools, stressing the need to place emphasis on supporting student learning processes rather than on reporting achievement (Berry, 2011). In fact, many researchers have provided evidence that learners who take charge of their own learning, and habitually engage in self-assessment and self-regulation in learning, are also better achievers (Mok, 2010). Hong Kong and many other Asian countries, which are predominated by strong examination culture, have started reforms in their education and assessment systems in order to prepare their students to face new challenges. Studies such as PISA and

TIMMS show that although Hong Kong, Japan and Korea have high academic performance, they have low country means in academic self-concept (Ou, 2009; Wilkins, 2004, as cited by Mok, 2010). Research has told us that the competitive assessment is affecting both students' current learning as well as students' motivation for further learning. It is important for places in Asia like Hong Kong, Japan, Korea, Singapore and Taiwan to redesign pedagogy so that more emphasis is put on using assessment as a tool for learning rather than simply to record attainment, and for the purposes of selection.

This study, draws from a project funded by the EDB to promote assessment for learning, and will explore ways in which assessment can be used to promote self-directed learning. In particular, how student self-assessment can help Hong Kong students to improve meta-cognition and self-directedness in mathematics learning, and how teachers can use student self-assessment to diagnose students' learning problems as well as misconceptions in mathematics. It is hoped that this study would provide useful references and inform wider research for Asian countries to implement alternative assessment practices which inform learning, and a pedagogy which creates self-directed learners.

1.2 Mathematics education in Hong Kong

The Programme for International Student Assessment (PISA) is an internationally standardised assessment that was jointly developed by participating countries and administered to15-year-olds in secondary schools (PISA, 2012). It assesses students'

ability in applying knowledge in science, mathematics and reading to solve problems. The PISA results of Hong Kong students have been quite good over the years. In 2006, Hong Kong ranks third out of 57 countries, behind Taiwan and Finland, in mathematics scores (with no significant differences). Also, in the Trends in International Mathematics and Science Study (TIMSS) administered to secondary two students (around 13 or 14 years old), in 2007, Hong Kong ranks fourth out of 56 countries in mathematics (Trends in International Mathematics and Science Study, 2012). Hong Kong students have achieved highly and consistently in international mathematics achievement tests.

The study by Ho (2010) on PISA 2000+ to PISA 2006 revealed that the achievement gap of students from different socio-economic backgrounds in Hong Kong is relatively small, whereas the between-school variance is relatively high compared with other countries. Although the situation on between-school variance had improved slightly over the years, the decrease in between-school variation may be related to the change of the five-banding system to a three-banding system in secondary school enrolment after 2000. Students are grouped into 3 bands instead of 5 bands according to their ability levels, with about 33% of students in each band. This academic segregation in school intake could explain the high proportion of between-school variance.

Although Hong Kong has done well in the international mathematics achievement tests such as PISA and TIMSS, the Hong Kong and other East Asian mathematics classrooms have been observed to be very traditional. The curricula are content oriented and examination driven. Instruction is teacher dominated and student directed activities are not common. Students are encouraged to memorize mathematical facts,

complete lots of exercises and learn by rote, but mostly without thorough understanding. Both teachers and students are under constant pressure to perform well in high-stake examinations, and students do not seem to enjoy their study (Leung, 2001).

1.3 Outline of this study

1.3.1 Research aims

This study aims to address the following themes with regard to self-directed learning in mathematics in the Hong Kong secondary school context:

1. The pedagogical usefulness of student self-assessment activities to facilitate self-directed learning in mathematics for intervention in Hong Kong secondary classes.

2. The extent to which one can equip students and teachers with the capacity, knowledge and attitude for using student self-assessment to facilitate self-directed mathematics learning.

1.3.2 Significance of the study

It has been argued that students are facing the new challenges of the 21st century induced by globalization, the information explosion and international competition

(Cheng, Chow & Mok, 2004). Many believe that higher order skills or so-called 21st century skills are fundamental to the success of knowledge workers (Galarneau & Zibit, 2007). Therefore, learning goals including cultivating critical thinking, developing generic skills, seeing things from multiple perspectives, collaborating with others and a commitment to life-long learning may become more important. At present, in many parts of Asia and particularly in Hong Kong, one can make the case that the mode of classroom teaching and learning, and the deployment of learning time are largely content-oriented and teacher-centred. Teaching-to-the-test and rote-learning are not uncommon. Emphasis is often on factual knowledge which is easier to teach and test objectively (Lee, 1991) and much time is allocated to preparing for examinations and memorizing facts out of context rather than developing high order thinking skills and appropriate attitudes to life-long learning. Shepard (1997) points out that the teaching-to-the-test literature has repeatedly shown that practice with familiar formats reduces the likelihood that students will be able to use their knowledge when they encounter problems posed in even slightly different ways. In contrast, it is suggested that students should learn how to extend their knowledge and apply it in new situations. They should be able to use insights from previous lessons to generate new knowledge rather than just within the narrow perimeters of a given lesson or set of content. Reid (1994) argued that students can only build up knowledge through active participation. The conventional teacher-centred approach of teaching puts students in a passive position. Learning is effective only when learners can relate what they already know to what they are going to acquire. It is likely that students cannot internalize their knowledge and apply it in other situations if such knowledge is acquired merely by rote-learning (Law, 2005). Moreover, Glasersfeld (1989) argues that learning is a constructive activity. Knowledge cannot be reduced to a stock of retrievable ‘facts’ but concerns the ability to create new results. In Piaget’s

terminology, it is operative rather than figurative. Glasersfeld (1991) also argues that for a student to feel the intellectual satisfaction of having solved a problem, the solution should result from his or her own management of concepts and operations rather than being supplied from outside. A major focus of learning should be on learning how to learn, think and create. The learning can be student-directed and can be a discovering and reflecting process. As pointed out by Glasersfeld (1995), the insight into why a result is right, and understanding the logic in the way it was produced, gives the student a feeling of ability and competence that is far more empowering than any external reinforcement. Students should be given the chance to think their own way through problems and acquire the confidence that they can solve them, so that the students will be more likely to be motivated to tackle more problems. Therefore, the traditional teacher-centred paradigm should be changed to a more student-centred orientation. In such a paradigm shift, some educators suggest that the nature of instruction inevitably has to change (Cheng, Chow & Mok, 2004). Grow (1991) and Pintrich (1995) also points out that self-direction can be taught and teachers must adapt their pedagogical approaches to match students' self-directedness in order to increase students' abilities in self-directed learning. I agree that, in principle, teachers can change their pedagogy to enhance students' self-directedness. This study will explore how student self-assessment with teachers' guidance plays out in the context of self-directed learning in mathematics in representative classrooms. Mathematics is chosen in order to narrow the scope of the study.

The findings from this research will help to gain insights into using student self-assessment tools to contribute to creating high quality self-directed learning process designed to assist teachers and schools in producing successful and self-directed learners in mathematics.

CHAPTER 2 Literature review

2.1 Self-direct learning

Self-directed learning (SDL) is a process in which an individual, with the support of others, diagnoses learning needs, sets learning goals, identifies learning resources, consciously selects and implements learning strategies, monitors and evaluates learning outcomes (Knowles, 1975). Cave (1975) suggests that SDL is the cooperative effort among individuals to plan and manage learning, in order to achieve development of self, society, and workplace. SDL is also the learning model of an individual learning, including self-understanding of the inward deliberate changes and the external changes on management (Brookfield, 1986). Some authors categorized self-directed learning as a *process* of learning in which people take the primary responsibility or initiative in the learning experience (Knowles, 1975; Tough, 1979). Guglielmino (1977) categorizes self-directed learning as a *personal attribute* of the learner, and suggested that a self-directed learner is aggressive, independent, and with strong perseverance in learning; has a sense of responsibility for their own learning; likes to face challenges and is not deterred by difficulties; has capacity for self-teaching; has strong curiosity; has strong self-efficacy; can use basic learning skills; can manage time for learning; is able to develop an overall plan, enjoys learning, and is goal directed. Bruce (2001) also notes that student autonomy has been associated with increased intrinsic motivation, confidence in one's own abilities and academic achievement.

The type of learning in which learners are active agents, both physically and mentally, in their quest for new knowledge and skills (Zimmerman, 2001) has been characterized variously as “self-regulated”, “self-controlled”, “self-reinforced” and “self-directed”. Authors writing about SDL in different academic contexts, and varying approaches based on different theoretical foundations, agree on at least one point. Learners are seen as active participants in all aspects of the learning process, whether meta-cognitive, affective or behavioural (Zimmerman & Martinez-Pons, 1988, as cited by Hrimech, 1995). At the meta-cognitive level, learners plan, organize, teach themselves, and assess their own learning at different stages of their learning process. At the affective level, they perceive themselves as efficient, autonomous and intrinsically motivated. At the behavioural level, they create structure, and seek better strategies to facilitate the learning process.

Candy (1991) makes an interesting point that with regard to self-directed learning, learner autonomy would seem to be subject to constraints, since teachers have considerable control over the space in which learning occurs, and learner control is variable and occurs only where it is delegated by teachers. Thus, tensions exist for learners who are expected to be responsible for their own learning and to be self-directed, whilst at the same time being controlled by a particular teaching methodology and the need to master specific subject matter.

Many self-directed or self-regulated learning models and theories have been developed over the years. Mok and Cheng (2001) offer the following model of the components and dynamics of the development of self-directed learning (Figure 2.1):

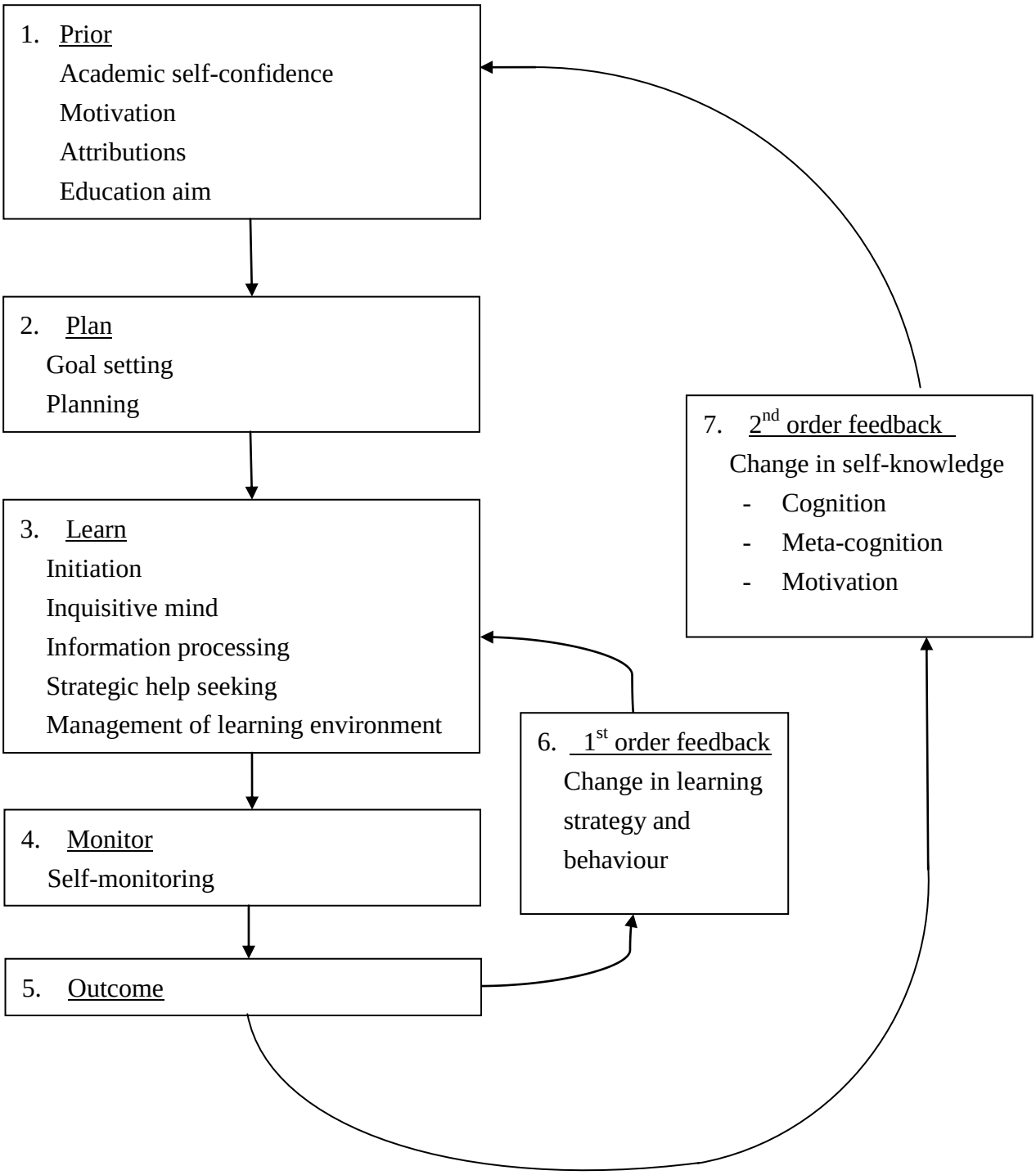


Figure 2.1 Self-directed learning domains and variables.

The self-directed learning model proposed by Knowles (1975, 1991) provides a systematic, linear process of developing learning contracts to utilizing SDL. The model is like this:

1. Diagnose learning needs
2. Formulating learning goals
3. Identifying human material resources for learning
4. Chosing and implementing appropriate learning strategies
5. Evaluating learning outcomes.

Zimmerman (1990) suggests the characteristics of a self-directed or self-regulated learner include: self-observation (monitoring one's activities); self-judgment (self-evaluation of one's performance); and self-reactions (reactions to performance outcomes).

Tremblay (1991), as cited by Hrimech (1995), derives the general competencies applied by self-directed learners. They are as follows:

1. Identifying the principles governing one's learning and retaining control over the process
2. Reflection in action
3. Making use of available resources in the environment
4. Showing flexibility and tolerance towards ambiguity.

Gibbons (2002) suggests these essential elements of self-directed learning:

- Student control over as much of the learning experience as possible
- Skill development
- Students' learning to challenge themselves to their best possible performance
- Student self-management – that is, management of themselves and their learning enterprises
- Self-motivation and self-assessment.

As we can see, most SDL models involve learners' self-monitoring, self-evaluation or self-assessment. Cassidy (2006) also points out that although characterising the self-directed or independent learner commonly involves a range of attributes, skills and propensities, the ability to self-assess appears central to many studies examining the issue of independent learning. Self-assessment is seen as helping students take responsibility for learning, encouraging self-motivation and independence in learning, encouraging success and life-long learning and to be fundamental to the development of intrinsic motivation and autonomous learning (Peckham & Sutherland, 2000; van Krayenoord & Paris, 1997; McAlpine, 2000, as cited by Cassidy, 2006).
Self-assessment is no doubt an important component of SDL, and is a crucial skill to acquire for successful independent learning.

Paris and Newman (1990) described co-construction where students construct strategies from experience but also can be guided by teachers and peers to discover and control effective learning tactics. Teachers facilitate the development of self-regulated learning with methods that foster co-construction of knowledge and motivation. Allal (2011) mentioned the concept of co-regulation of learning which can

be seen as a way to link scaffolding and student engagement. It is the result of joint influence of student self-regulation of learning and regulation of other sources in the classroom such as teachers, peers, assessment instruction and curriculum material.

The study by Abar and Loken (2010) takes a person-centred approach to the study of self-regulated learning by using latent profile analysis (LPA) on self-report of seven aspects of self-regulated learning. The 3 goals of the research were:

1. to describe profiles of self-regulated learners employing a broad range of indicators using a relatively novel analytic method
2. to validate these groups using goal orientations, which have been used in previous cluster analytic studies
3. to examine whether the high self-regulated, low self-regulated, and average self-regulated learners differ in their study behaviour.

Seven indicators were combined to construct the latent profiles.

1. Meta-cognition subscale – measures how an individual activates and sustains cognitive processes of self monitoring and evaluation during school work
2. Effort management subscale – measures persistence of academic exertion despite potential obstacles
3. Time and study environment subscale – measures the regulation of a personal environment necessary for learning to occur
4. Test anxiety subscale – measures nervousness during exams
5. Academic efficacy scale – concerns how capable of academic performance students believe themselves to be
6. Academic self-handicapping strategies – measures intentional engagement in

behaviours detrimental to academic success that could justify low academic achievement

7. Academic skepticism scale measures beliefs that academic studies are unimportant to ones future.

Aside from the seven indicators mentioned above, behavioural measures of self-directed learning were included in the study. A website was created as a study tool for students. Practical questions were provided from the website. Students' usage of the site was measured, for instance, the length of time using the website, the number of questions attempted, and the proportion of the tutorials viewed.

In latent profile analysis, the number of classes is determined through comparison of posterior fit statistics. Also, the characteristics of each class are also determined following the analysis. In this study, 205 11^{th} and 12^{th} grade students from a college preparation program, which aimed to enhance the likelihood of college attendance and retention, participated in the study. Students enrolled in the program were given 10 classroom sessions, in which they were provided with mathematics and English reviews, guidance in the college application process, and assistance in developing college study skills.

A series of LPAs were performed to identify the different self-regulated groups. The indicator variables were standardized for ease of interpretation. The choice of profile solution was guided by relative statistical fit and interpretability of the profile structure. Then profile membership was predicted by using goal orientations indicators. The three profile solution provided the best fit. The smallest profile (15%) was labeled the high self-regulated learner (SRL) group, reporting high meta-cognition, effort

management, time and environment skills, and academic efficacy, along with low test anxiety, low self-handicapping, and low academic skepticism. Overall these students report appropriate regulatory behaviours and cognitions while avoiding behaviours and cognitions likely to detract from achievement. The second profile (37%), labeled the low self-regulated learner group, was characterized by low meta-cognition, effort management, time and environment skills, and academic efficacy, coupled with relatively high test anxiety, self-handicapping, and academic skepticism. These students tended toward academically self-destructive thoughts and behaviours. The final and largest profile (48%) was the average self-regulated learner group. This group was close to the population average across all aspects of self-regulated learning. Students with high academic self regulation were reported to have the highest levels of mastery orientation while students with low self regulation were reported to have the highest levels of avoidant orientation. Besides, students classified in the highly self-regulated group tended to study more material and spent more time than those less self-regulated students. The difference may be due to the students in the latter group being least able to regulate meta-cognitive focus and behavioural effort. The study did not explore the relationship between self-regulation and academic performance.

The study by Darr and Fisher (2004) took the form of a teaching experiment and was conducted with a Year 7 class. The researchers, in partnership with the classroom teacher, planned and taught twelve mathematics lessons over a four-week period. The math topic chosen was proportional reasoning. The lessons provided rich opportunities for students to begin practising self-regulatory behaviours. Activities were designed at the whole class, group, pair and individual level and time was also provided for students to write journal entries reflecting on their learning. A self-directed learner should be able to reflect on performance, to judge progress, and make decisions

regarding new goals and altered behaviours. Journaling in mathematics can provide a structured opportunity for students to reflect on their learning. It allows students to write about the experiences, ideas and feelings involved in their mathematics learning. At its heart, journaling recognises that writing is a means of "knowing what we think". In the study, 5 students were interviewed at the beginning and end of the study. Short pre- and post-tests were also conducted for the class. Most of the questions were written to test elements of proportional reasoning. Some of the problem types used in the test were not covered in the lessons. Data was also collected from several other sources including artifacts from planning, field notes and student journals and workbooks. The results show that many students demonstrated that they could engage in proportional reasoning in an active way. In one student sample, it was shown that the student could think in a flexible manner and was developing increasing sophistication as a proportional reasoner. The journal had provided an opportunity to reflect on his thinking and provided a “window” through which the teacher could observe his increasing range of strategies.

2.2 Assessment for learning

Formative assessment is sometimes referred to as assessment for learning. It draws on information gathered in the assessment process to identify learning needs and adjust teaching (Looney, 2011). The purpose is to help the teachers teach and the learners to learn effectively. It puts pupils and their learning needs at the centre of teaching and learning so that the pupils become actively involved in their own learning (Boyle, 2007). It is intended to serve the student’s interests, to ask what they know, what they

are likely to learn next, and what activities should foster this learning (Rogers, 1992). Elements of assessment for learning include classroom interactions, questioning, structured classroom activities, feedback, self-assessment and peer-assessment. Allal and Ducrey (2000) argued that formative assessment should be integrated into teaching, with the aims of investigating individual differences in response to specific instruction, evaluating the effect of different teaching and assessment processes, and fostering active engagement by students in their assessment. Perrenoud (1998) also suggested that assessment is formative when integral to the processes by which teachers enable students' learning, rather than simply being an 'add on' to a 'traditional' lesson. Audibert (1980, as cited by Boyle & Charles, 2010) defining formative assessment, wrote, "takes place day by day and allows the teacher and the student to adapt their respective actions to the teaching/learning situation in question. It is thus, for them, a privileged occasion for conscious reflection on their experience". The Assessment Reform Group (2002, as cited by Boyle *et al*, 2010) suggested that assessment for learning is part of effective planning, focuses on how pupils learn, is central to classroom practice, is a key professional skill, is sensitive and constructive, fosters motivation, promotes understanding of goals and criteria, helps learners know how to improve, develops the capacity for self- and peer assessment and recognises all educational achievement.

There is significant research in existence to show that formative assessment is effective in raising achievements (e.g. Wiliam, Lee, Harrison & Black, 2004). The achievement gains associated with assessment for learning were among the largest ever reported for educational interventions (Black & Wiliam, 1998, as cited by Looney, 2011). However, Bennett (2010) argued that Black & Wiliam's research review covered studies that were far too disparate to be summarized meaningfully through

meta-analysis, and was suspicious of their claim regarding the effect size of formative assessment.

The study by Wiliam *et al* (2004) reported on the achievement of students with teachers using formative assessment strategies in classrooms. Data for 19 teachers (science and mathematics teachers) and 23 classes of students from 6 schools was collected for this study. The teachers were given support in exploring and planning assessment for learning strategies in their classrooms in a six-month period. Scores from national tests and school assessments from experimental and comparison groups were used to compute effect sizes. The mean effect size favouring the intervention was 0.32. The study also estimated the cost of support given to teachers. It was around 8% of the salary costs for one teacher for one year. Although it is much more than most schools used per teacher for professional development, it is relatively small proportion of the annual cost of each teacher, especially if the cost is one off rather than recurrent. However, as we are reminded by Gorard (2006), we need to be sure that the effect sizes are substantial enough to be worth it, and are clear and obvious from a fairly simple inspection of the data.

While many teachers agree that formative assessment is important to high quality teaching, they may also complain that there are too many logistical barriers to making assessment for learning a regular part of their teaching practice, such as large class size, extensive curriculum requirements, and the difficulty of meeting diverse and challenging student needs (OECD 2005, as cited by Looney, 2011). Other problems teachers may need to face when practicing assessment for learning in classrooms is to maximize student and school scores in high-stakes state-mandated testing and at the same time pay enough attention to the kinds of higher-order thinking involved in

formative assessment. There is good evidence that external assessments encourage teachers to “teach to the test” (Looney, 2011). Boyle *et al* (2010) also mentioned the issue, that is, external assessments encourage a pedagogy driven by ‘coverage’ and ‘pace’ which take precedence over depth and security in learning; coverage and elicitation of facts dominate the creation and co-construction of interconnected learning. However, Wiliam *et al* (2004) argued that there were studies which showed that the use of higher-order goals is compatible with success, even when attainment is measured in such narrow terms as scores on external tests.

2.3 Self-assessment

Self-assessment is basic to our capacity for self-knowledge, and an essential prerequisite for effectively directing our learning (Rogers, 1969, as cited by Long, 1997). Self-assessment skill involves a high level of self-awareness and the ability to monitor one's own learning and performance (Cassidy, 2006). It can provide learners with feedback from themselves from multiple perspectives which could help them improve their own learning by using the linguistic, cognitive and meta-cognitive insights they receive. As pointed out by Gibbons (2002), self-assessment is a component of meta-learning; learning how to learn includes learning how to assess how well one is learning. An important goal of self-assessment is that students learn to evaluate their own progress: they assess both the quality of their work and the process that they designed to bring it about. Improvement flows from students’ critical assessment of their own activities. Self-assessment can motivate students to seek the best achievement possible. It is important for the learner to be able to assess and improve the quality of the work produced through the application of the skills of self- monitoring and self- regulation (Perrenoud, 1998). Boyle (2007) reminds us that

enabling self-assessment to take place in the class does not mean that the teacher is losing control of the learning. The teacher can focus on designing interventions to support student learning.

A study was carried out by Brookhart, Andolina, Zuza and Furman (2004) on student self assessment on the Minute Math Project. There were two purposes for this action research study: first, to see whether student self assessment could add desirable outcomes (e.g. help students learn how to learn and help develop their mathematical literacy) other than just simple knowledge of math facts, and second, to examine the use of action research as a professional development tool for educators. Student self-assessment was advocated for two reasons: first, motivational, it is suggested that student self-assessment will contribute to feelings of control over one's own learning, of choice and of agency, and of self-worth; and second, cognitive, the learning task requires students to compare their performance with the desired performance and to take steps to close that gap. Forty-one third grade participants were given a 5-minute timed multiplication facts test once a week for 10 weeks. They were asked to predict and graph their test scores every week. Further, they were also asked to reflect on their progress, the success of their study and what problem-solving strategies they used, on a weekly basis. After the results were released, students were asked to graph their actual score next to their predicted score and then to predict their next week's score. Reflection sheets were given for students to write whether they had met their goal, what study techniques they had used and how well they worked, and what strategy they planned to use for next week's test. Data collected were used to address questions regarding motivational and cognitive reasons behind student involvement in assessment. For motivation: Brookhart *et al* (2004) investigated any possible relationship between goal orientation and achievement. For cognition: they

investigated the relationship between strategy use and achievement. The results show that student involvement in their own assessment can add reflection and meta-cognition to rote memory lessons like learning the multiplication tables. Throughout the study, student predictions on their next test result were accurate and became more accurate with time. Aside from that, the study showed that reflection can help students articulate the value of their own studying. However, to improve the reliability of student's reflection, it was suggested that student self-assessment needs to be taught, coached and supported. One teacher reported that she thought the third graders learned the multiplication tables better than in previous years with this intervention.

The study by Bruce (2001) evaluated the impact of student self-assessment on students' engagement in their learning and explored the feasibility of the use of student self-assessment by classroom teachers. There were 350 students involved and courses such as journalism, physics, psychology and Spanish were included. The effects of self-assessment activities were measured by using student interviews, course surveys, and a pre- and post-intervention sampling of attitudes related to learning (via the INCLASS Inventory of Classroom Style and Skills by Miles & Grummon, 1999). Self-reported teacher reflections were examined to find their opinion of student self-assessment and its impact on students. The results showed that, in general, students found self-assessment helpful. They appreciated the opportunity to provide input into their learning situation by co-designing the criteria for evaluation. In addition, they demonstrated more ownership of their learning and grew in their self-awareness as learners. Also, a significant increase in the INCLASS post-test subscale for Awareness of Quality was found.

A study by Matthews (1998) investigated the nature of sixth-grade students' self-assessment of their literacy performance. Forty-eight sixth-grade students from 2 classes, one class as treatment group and one as control group, participated in the study. Students in the treatment group engaged in 4 written self-evaluations of their reading. Ten students from each group, representing high and low performers, were selected for focus group interviews before and after intervention. At the beginning and end of the study, all students were asked to compose a summary in response to a narrative reading selection. These summaries were used as a performance measure to represent integration of multiple reading strategies, and meta-cognitive and self-regulatory actions. Data analysis yielded the following findings:

1. a clear difference in self-perceptions and self-assessment of high and low performers

2. low performers who routinely self-assessed their reading performance and behaviours demonstrated a change to more positive perceptions of themselves as readers

3. the treatment group demonstrated an increased awareness in reading process and reported more strategic behaviours

4. students' abilities to set goals revealed little change at the end of study

5. self-assessment had a moderate and positive influence on reading performance

6. the self-perceptions of the treatment group were more consistent with their actual reading performance whereas the self-perceptions of the control group were unrelated to changes in performance.

The study by Caswell and Nisbet (2005) explored ways to enhance mathematical understanding through self-assessment and self-regulation of learning. Students'

meta-awareness of their mathematical thinking was emphasized by engaging them in communication about their mathematical reasoning and in reflection on their levels of knowing and confidence to work mathematically. Twenty seven students aged 9 to 12 years participated in this ten-week study. Students were engaged in self-reflection of their learning after they experienced a range of mathematical tasks and varied interactions. They were also engaged in regulating their own learning by choosing their level of confidence and competence to engage with a particular level of knowing. Data collected included audio-recordings, transcripts, student written reflections in journals, models of 'Levels of Knowing' created by the class and also a survey. The study focused on student understanding rather than achievement. The results showed that students were very aware of their learning. They began identifying the level on which they believed they were working, and then actively choosing to extend themselves to a higher level. It was also shown that students were aware of factors that impacted on their learning and of the continuum of development evident in the classroom.

The study by Schunk and Ertmer (1999), as cited by Kitsantas *et al* (2004), examined how goals and self-evaluation affected undergraduate student achievement, self-efficacy, and perceived competence and self-regulation on computer projects. Results showed that frequent self-evaluation produced positive results regardless of the type of goal adopted, whereas infrequent self-evaluation was not beneficial for the outcome goal condition.

In fact, any self-directed learning programme must engage students in the ongoing assessment of their work (Gibbons, 2002). Students should be able to assess the importance of what they have accomplished, their attitudes as a learner, their approaches to tasks, their problem solving abilities and their criteria for success, and most importantly, see ways for improvement and change. Also, research studies have

shown that reflective learning, where students' self-criticism is present, improves academic results and contributes to developing important personal skills (Bourner, 2003; Irving *et al*., 2003; Dimaki *et al*., 2005, as cited by Cambra-Fierro & Cambra-Berdún, 2007). Students' academic achievement can improve if they think and reflect not only about the content of the subjects, but also about their attitude, effort and dedication to them. They also point out that teachers' actions in this respect are also fundamental for orienting the students. Thus, teachers' guidance throughout the students' academic career (Cassidy, 2006), together with the influence of the family and the social environment, can decisively influence the whole process.

Munns and Woodward (2006) suggest that there should be two significant aspects of pedagogical changes to conventional classroom practices:

- Classroom learning experiences should be designed to be highly cognitive, highly affective and highly operative
- Classroom processes should be designed to encourage enhanced reflective processes across the learning community.

Classroom observations and theoretical investigations (Black *et al*., 2002, on self-assessment; Cazden, 2001, on classroom discourse; Dweck, 1999, and Hattie, 2002, on teacher feedback; as cited by Munns & Woodward, 2006) saw the development of an interactive framework that constituted the key elements of classroom processes designed to encourage enhanced reflective processes. These were: creation of a student community of reflection, teacher inclusive conversations, teacher feedback and student self-assessment.

Student self-assessment had to play a central role in the classroom. Reflection had to be extended to deep-thinking conceptual planes where the cognitive, the affective and the

operative become one. The focus should be on students' reflections about their learning towards the high levels of thinking, feeling and working. Moreover, student self-assessment had to provide opportunities for students to:

- Reflect on what they were learning and how it connected to their lives (knowledge)
- Be actively involved in evaluating their own performance and working on how to improve that performance (ability)
- See that the classroom pedagogic space was to be shared between themselves, their classmates and their teacher within a community of learners (control)
- Feel that they were valued as individuals and learners (place)
- Have a say in the way learning experiences were designed and evaluated (voice). (Munns & Woodward, 2006)

Garrison (1989), as cited by Confessore (1995), describes a model of education that focuses on the balance of control between learner and facilitator. He adds that any discussion of self-directed learning must address both external and internal events because educational transactions should be concerned with the process of critical reflection and internal change of consciousness. Confessore (1995) also refers to Tremblay and Theil's (1991) research findings which suggest individuals engaged in self-directed learning projects will test their competence in a new area by analyzing results and will rely on an inner feeling to assess success. Hence, when considering how self-directed learners engage in leaning, some sort of critical reflection should affect the learning outcomes. In fact, Confessore's study (1995) finds that when student journals, serving critical reflection purposes, were used throughout a learning process, it may help to broaden and even redefine the project, as well as the

individual's capacity and willingness to evaluate the learning as it occurs, thereby assisting to determine the structure of the self-directed learning process.

Bruce's (2001) review concluded that findings from research studies are overwhelmingly in favour of the use of student self-assessment for both student and teacher related benefits. Academic and meta-cognitive skills appear to be enhanced through self-evaluation and self-correction. Furthermore, meaningfulness, motivation, self-knowledge, student-teacher communication and teachers' understanding of students improved.

2.4 Reflection

Reflection means considering at a conscious level one's thoughts, feelings and actions (Alro & Skovsmose, 2002). Costa and Kallick (2004) suggest that the purpose of reflection is to get learners into the habit of thinking about their experience, and one of the goals of self-directed learning should be to make reflection a habitual event. Reflecting on experience and learning can help students to take charge of their own learning. In mathematics learning, reflection is characterized by distancing oneself from the action of doing mathematics (Sigel, 1981, as cited by Wheatley, 1992). Students who reflect have a greater control over their thinking and can decide which paths to take, rather than simply being in action (Wheatley, 1992). In mathematics classrooms, teachers sometimes keep students so busy that they seldom have the chance to think about what they are doing. They are asked to follow a certain procedure or method to solve problems, and they may fail to be aware of others options or to have time to think about their conceptions and misconceptions.

Jones, Valdez, Nowakowski, and Rasmussen (1995, as cited by Huitt, 2005) recommended meta-cognitive strategies to promote self-directed learning. They include discussing the processes used when thinking, journaling, planning, reflecting on how the thinking process led to the outcome, and self-evaluation. Writing reflection journals, as one of the activities for helping students become more self-directed, can enable the student to develop and assess the cognitive processes used during problem-solving (Huitt, 2005).

The study by Bell (1994) was a modification of a previous experiment done by Herrington in 1992. In Herrington's study, around 70 short interventions including concept mapping, a Think Board, self questions and writing were used to improve primary school students' learning strategy awareness, mathematical achievement and confidence towards learning mathematics. Results showed that students' learning strategy awareness was significantly better in the subject group than those in the control group; however non-significant improvements were found in students' confidence and mathematical attainment.

Instead of primary school students, Bell's study focused on a group of secondary school aged students. Eighteen intervention strategies were developed to enhance reflective activities and on providing lesson experiences through which students may acquire specific knowledge about learning tasks and processes in real classroom settings.

The aims of Bell's project were:

1. To investigate secondary school students' meta-cognitive skills and concepts in typical mathematical learning environments

2. To investigate whether students' awareness could be raised by appropriate interventions
3. To study the effects of the enhancements on students' mathematical attainments.

There were 7 aspects of awareness:

1. To increase awareness of the components of mathematical activity
2. To increase awareness of mathematical content
3. To increase awareness of mathematical strategies
4. To increase awareness of types and purposes of mathematical tasks
5. To increase awareness of the purposes of different ways of working
6. To increase awareness of resources for learning and how to use them
7. To increase awareness of general learning principles

The student reflection and review activities included:

1 Students making up questions

2 Students reflecting on learning difficulties and misconceptions

3 Students reviewing and classifying

4 Students describing what learning feel like

The results showed that reflection and review activities were widely regarded as purposeful by students. Students created posters and booklets to introduce newly arriving students to mathematics, and were found useful. An interesting feature of Bell's work is that diaries were considered ineffective.

In the study by Boyle and Charles (2010), 394 schools responded to a questionnaire. One of the questions asked was: "How do you actively involve children in their own

learning?" The highest supported response (29%) stated that children were involved in their own learning through 'self-reflection/self-evaluation'. Lesson observations were also conducted to see when, how or if this self-reflection took place or the results of the self-reflection transferred into active involvement in learning. Boyle *et al* (2010) also discussed the issue of whether the current observed paradigm of controlling teacher/passive recipient moving at pace through a prescribed programme was going to develop a generation of 'deep and reflective thinkers' and lifelong learners. They pointed out that, from their classroom observations, in the current summative framework the chances of developing reflective children involved in self-motivated research activities is negligible.

Wheatley (1992) discussed the role of reflection in mathematics learning. He argued that reflection plays a critically important role in mathematics learning and that just completing tasks in insufficient, no matter how well the activities are designed. The evidence showed that establishing a learning environment in which reflecting on actions is encouraged results in higher mathematics achievement, even on standardized tests which stress procedures and conventions.

2.5 Summary of the literature review and the rationale of this study

Few of the studies show that self-directed learning and student self-assessment by reflecting about their learning directly improve performance. Nevertheless, the indications from the literature appeared to be in favour of the use of self-directed learning and student self-assessment for student-related benefits. Meta-cognitive, learning and self-assessment skills appear to be improved through students' practice of

self-reflection about their learning. Self-knowledge and motivation also seem to be enhanced through the activity.

This study will explore the efficacy of a programme designed to promote student self-assessment in mathematics education in Hong Kong on student attainment. The challenge is to explore how student self-assessment can evolve further towards a vital pedagogical activity, can be instrumental in enhancing student self-directedness, can improve learning and teaching and can change the whole context of the classroom. The researcher of this study suggested the following diagram (Figure 2.2) which shows the relationships between the components of self-directed learning and self-assessment.

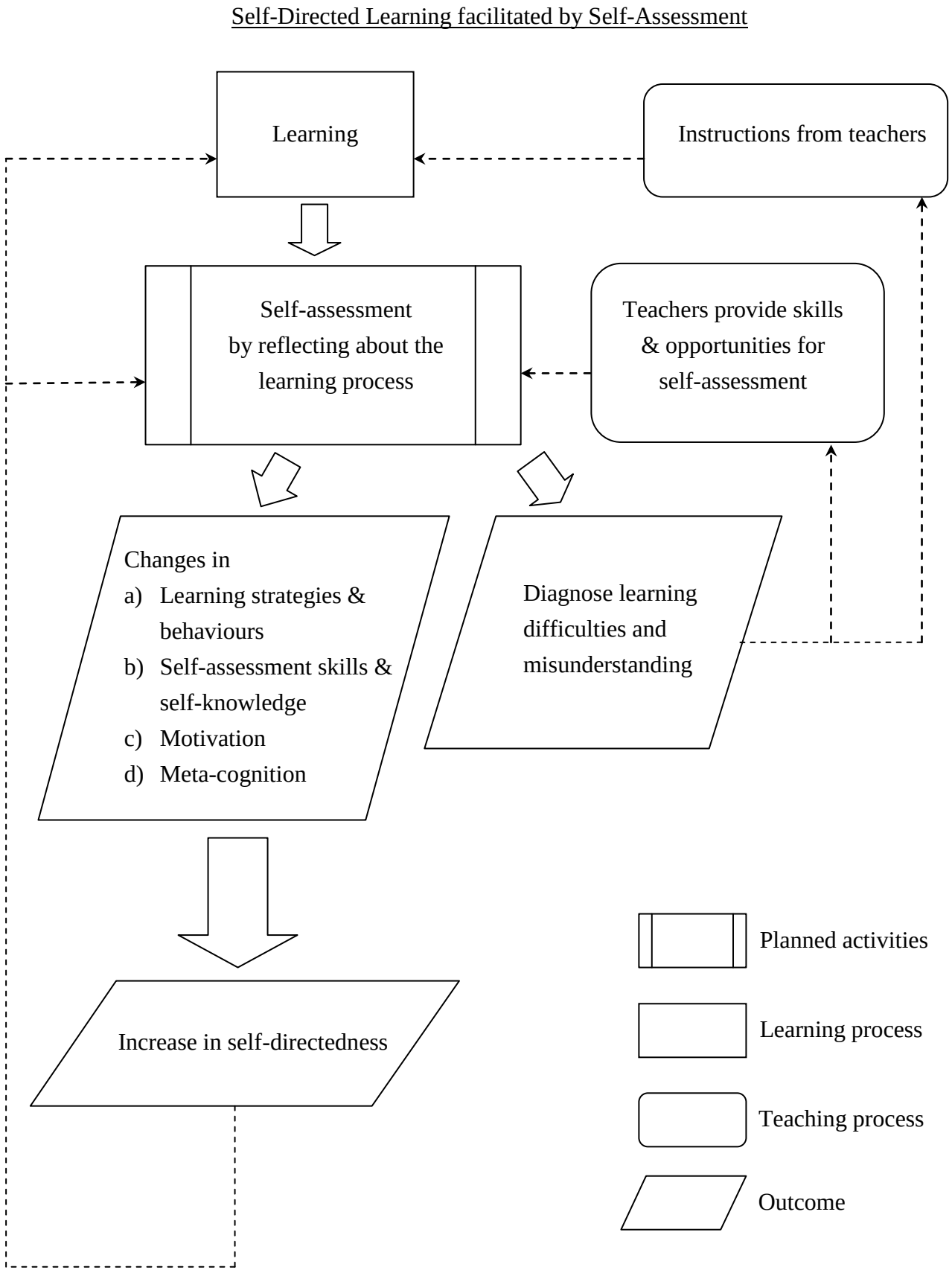


Figure 2.2 The relationships between the components of self-directed learning and self-assessment

The learning process is affected by the teacher's instructions and also by students' self-directedness in learning. After learning, teachers would provide skills and opportunities to students for self-assessment designed to support reflection about their learning processes. This allows teachers to diagnose students' learning difficulties and misunderstandings, and in return, teachers could improve their instructions as well as the self-assessment activity. Also, the self-assessment exercise could change students' (a) Learning strategies & behaviours; (b) Self-assessment skills & self-knowledge; (c) Motivation; (d) Meta-cognition. Those changes may have a positive impact on students' self-directedness in learning, and thereby enhance students' future learning and self-assessment ability.

The literature tells us that student self-assessment needs to play a more important role in classrooms. The focus should be on students' reflections about their learning towards a higher level of thinking, and one of the goals of self-directed learning should be to make reflection a habitual event. In fact, many studies examining the issue of independent learning had mentioned the importance of the ability to self-assess. In the classrooms of Hong Kong and other Asian countries, instead of continuing to use teacher-centred and exam-oriented instructions, teachers should start to change towards pedagogies which allow students to think about what they are doing and what has been learned. Teachers should facilitate self-directed learning with methods that foster co-construction of knowledge and motivation. Research on self-directed learning and self-assessment provides a good foundation on which to build; however, rather little literature relates directly to mathematics education, or to Asian students. In addition, the two areas have often been researched independently of each other and there is little evidence of linking theory and findings together in the context and manner proposed in this research.

This study will focus mainly on how structured self-assessment facilitates self-directed mathematics learning.

CHAPTER 3 Research methodology

This chapter provides an overview of the research design, materials, and the background of the project. It describes the nature of classroom interventions that the teachers used in their classes. The research questions this study would like to answer are listed. The chapter also explains the research methodology used to answer those questions.

Two research methods were used in this study. They are the pre- and post- tests design and the analysis of student self-assessment samples. This is a mixed method research design which combines quantitative and qualitative research methods to provide a broader and richer understanding of how self-assessment improves achievement and facilitates self-directed learning. Mixing multiple methods affords opportunities to use the strengths of some methods to counterbalance the weaknesses of other methods (Axinn & Pearce, 2006). This approach offers a more comprehensive description of a programme and its participants than do single methods (Bryman, 1988). The data collected from quantitative methods and qualitative methods can be used for testing hypotheses and discovering new hypotheses respectively (Sieber, 1973 as cited by Axinn *et al*, 2006). Another benefit of mixed methods is that it allows the researchers of the project to increase their involvement and familiarity. It can help researchers to gain broader insights, provide a tool for studying cause and consequence, and also develop important knowledge claims (Axinn *et al*, 2006; Bryman, 1988; Potts,1998).

In this study, the analysis of the pre- and post-test scores could tell if there is a change in achievement, however, it might not be too helpful in explaining how the change came about. Just by looking at the quantitative data, it is difficult to understand how

the use of student self-assessment to facilitate self-directed learning was practiced in mathematics classrooms, which is one of the aims of this study. The results of the analysis of student samples could compliment the results of pre- and post-tests. It could provide evidence that student self-assessment can facilitate self-directed learning, and hence, could, in principle, explain changes in achievement. On the other hand, by just looking at the qualitative data (the student samples), we could only know that students had actually practiced self-assessment and would need to find evidence to support the idea that it facilitated self-directed learning in classrooms. Through analysing the student self-assessment samples and looking for evidence of SDL from the samples, the interconnections and dynamics between learning, instruction, self-assessment, reflection, meta-cognition and other SDL components could be better understood. However, it still could not answer the research question about the extent to which this pedagogy can really improve mathematics achievement. The pre- and post-tests results might provide strong evidence to show if there was a difference in gain score between students in treatment and non-treatment groups. Therefore, the use of mixed research method in this study allowed the researcher to understand more fully, generate broader insights, and also make claims that self-assessment can or cannot facilitate SDL as well as improve achievement.

This research draws from the three-year Assessment Project funded by the Education Bureau. The project aimed to promote assessment for learning and self-directed learning. The schools which participated could choose one level (Primary 2 to Secondary 3) and one subject (Chinese, English or Mathematics). The researcher of this study was involved in the project in the second and third year for secondary mathematics. In Year 2 (2006/2007) and Year 3 (2007/2008), the researcher was in charge of 11 and 8 secondary schools respectively. The teachers involved took part in

seminars, workshops, day camps and conferences related to assessment for learning and self-directed learning organized by the Centre for Assessment Research and Development of the Hong Kong Institute of Education. Also, the researcher of this study paid regular school visits to the partner schools to provide guidelines and support to the teachers involved, and discuss practical teaching strategies to implement assessment for learning and self-directed learning in their classes. Various suggestions were given to the teachers and they were free to use any or none of strategies. This study focused on the use of student self-assessment tools to reflect about the learning process to facilitate self-directed learning. During the discussions, the teachers and the researcher would design a classroom intervention using the self-assessment tools which the researcher had introduced to them. Decisions about any modifications needed, the frequency, the duration, the type of tools used were all made in school, subject to the requirement that the overall objectives remain the same, i.e. using student self-assessment tools to facilitate self-directed learning in order to enhance learning.

3.1 The nature of classroom intervention

3.1.1 The use of self-assessment in classrooms to facilitate self-directed learning and assessment for learning

Some of the teachers who joined the project had adopted practical self-assessment strategies to enhance students' learning. The aim is to help students to be self-regulated and reflective thinkers who use their own learning preferences and meta-cognitive processes to optimize learning. The strategies include various forms of

student reflective journals, think boards and mind maps. In most cases, students would be asked to write about some or all of the following:

- What did I do? / What happened?
- What did I learn?
- How can I use it?
- How do I feel about it?
- What did I do well?
- What insight did I gain?
- What was the most difficult part?
- What am I confused about?
- What am I going to work on next?

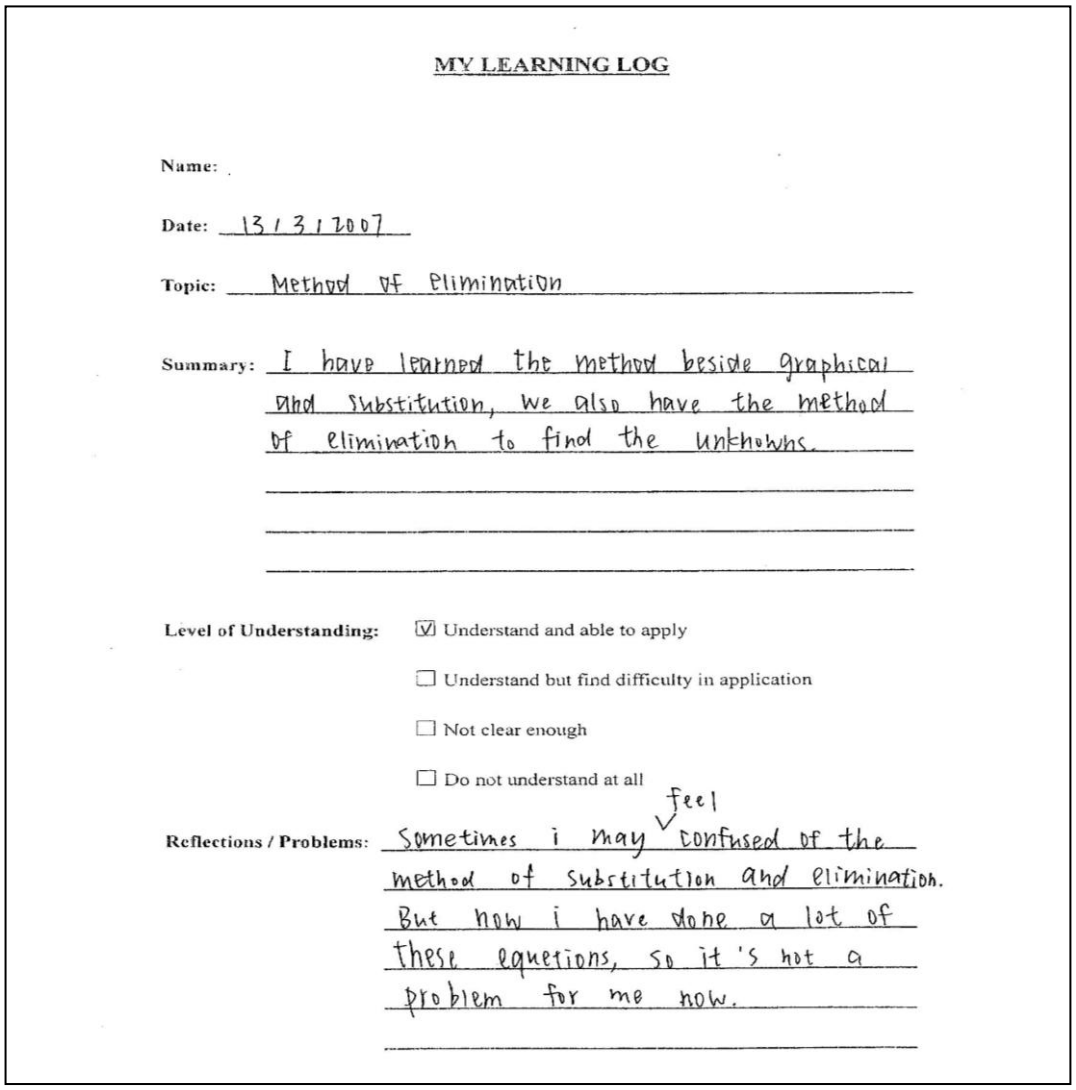
Teachers who participated in the project would have the opportunities to take part in many professional development activities such as seminars, workshops and day camps, where they could learn the theories of assessment for learning and self-directed learning in general. Also, they would be visited by the researcher in site-based professional development sessions where co-lesson planning could take place. The researcher introduced student reflective journals, think boards and mind maps to them and then co-designed classroom instructions with them using those self-assessment tools to facilitate self-directed learning. Through the researcher, the teachers were able to share some good practices of using self-assessment in classrooms with other schools. The experience sharing, together with teachers' own professional judgment, helped teachers to develop designs that suited their students best. Teachers involved in the study had the freedom to choose the kind of self-assessment tools used to suit their students' needs. They could even modify the tools themselves. Also, the teachers

could choose the topics, and the duration and the frequency of the use of student self-assessment. But in general, teachers were asked to ensure that the tools used should facilitate student self-assessments and reflections on what they had learned. As we can see from the samples (Appendix III), the designs and formats of student reflective journals varied. The journals were tailor made by the teachers for their classes. Even in the case of the think board (e.g. Sample 63 of Appendix III), where relatively few changes of the design could be made, a teacher had added some elements she thought suitable for her class. She added "creative index", "reasonableness index", "mathematical index" and "fun index" on the bottom of the think board. The students were asked to give themselves scores for the indexes, and teachers could also give them scores for those indexes. Probably due to the nature of the mind map, no change of mind map design was observed. Nevertheless, all the three kinds of student reflective activities provided useful feedback to the teachers. Some teachers might have read the students' work and diagnosed some of the students' common misconceptions. They could subsequently adjust their teaching strategies or provide feedback to students. For students, after the self-assessment activities, it is hoped that they would be able to understand their weaknesses and strengths, what they had mastered and where they still had difficulties. They might make some changes in their learning strategies through the reflective process.

3.1.2 Student reflective journals

In some schools, students were asked to write journals or learning logs after a lesson. They would reflect on what they had learned and seen in class and write it down in their own words. They would reflect on their strengths i.e. the parts they have

mastered and weaknesses i.e. their learning difficulties. Students wrote down their insight gained in learning a particular topic and also suggested ways by themselves to improve their learning. Teachers can then use the information formatively to keep track of students' thoughts, experiences and progress in learning. Teachers found that writing about mathematics helped students' thinking process become more concrete, although it took both teachers and students extra time and effort. There were open-ended prompts in the journals to encourage students to write about their feelings and opinions on mathematical topics. Also, the journals had provided information about their different levels of understanding of mathematics concepts and problem-solving processes. This could help teachers to adjust their pedagogies and teaching pace. Some teachers would give feedback to the students so that they could understand where they are standing and where to go next. Figure 3.1 and figure 3.2 are two forms of student reflective journal.



MY LEARNING LOG

Name:

Date: 13/3/2007

Topic: Method of Elimination

Summary: I have learned the method beside graphical and substitution, we also have the method of elimination to find the unknowns.

Level of Understanding:
- [x] Understand and able to apply
- [ ] Understand but find difficulty in application
- [ ] Not clear enough
- [ ] Do not understand at all

Reflections / Problems: Sometimes i may feel confused of the method of substitution and elimination. But now i have done a lot of these equations, so it's not a problem for me now.

Figure 3.1 Student Reflective Journal 1

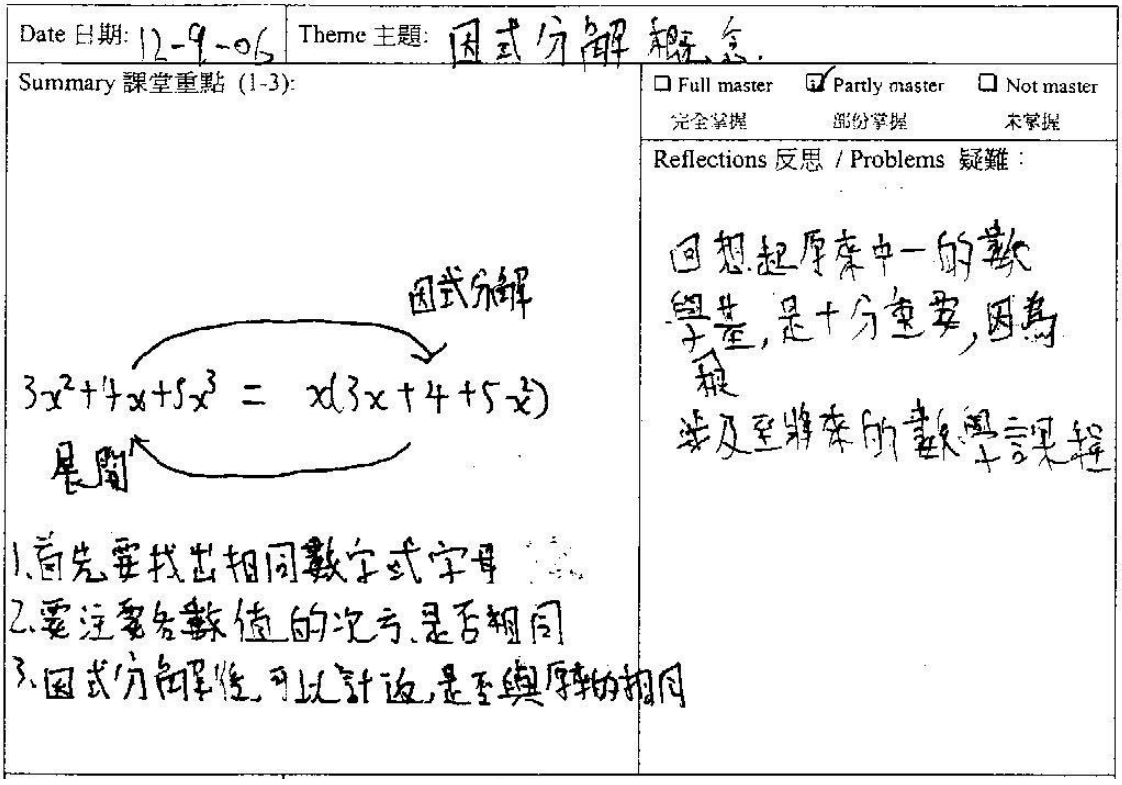


Figure 3.2 Student Reflective Journal 2

According to the literature (Finch, 2010; Srimavin & Pornapit, 2004; Flaitz, 2006), reflecting on learning experiences:

- facilitates recall of knowledge and encourages integration of concepts
- builds deeper understanding by writing about what is learned
- promotes growth in critical analysis and reasoning
- encourages autonomy and creativity
- stimulates students' reflective abilities
- promotes meta-cognition
- facilitates change
- encourages communication between students and teachers

With the use of student reflective journals, students were able to self-assess, reflect and also learn more in more self-directed ways.

3.1.3 Think boards and mind maps

Other schools used think boards and mind maps. Students were asked to use the space to draw or write about what they have learned. They could recall what they had learned and then could reconstruct and represent it in their own ways. Figure 3.3 and figure 3.4 are samples of a think board and mind map respectively.

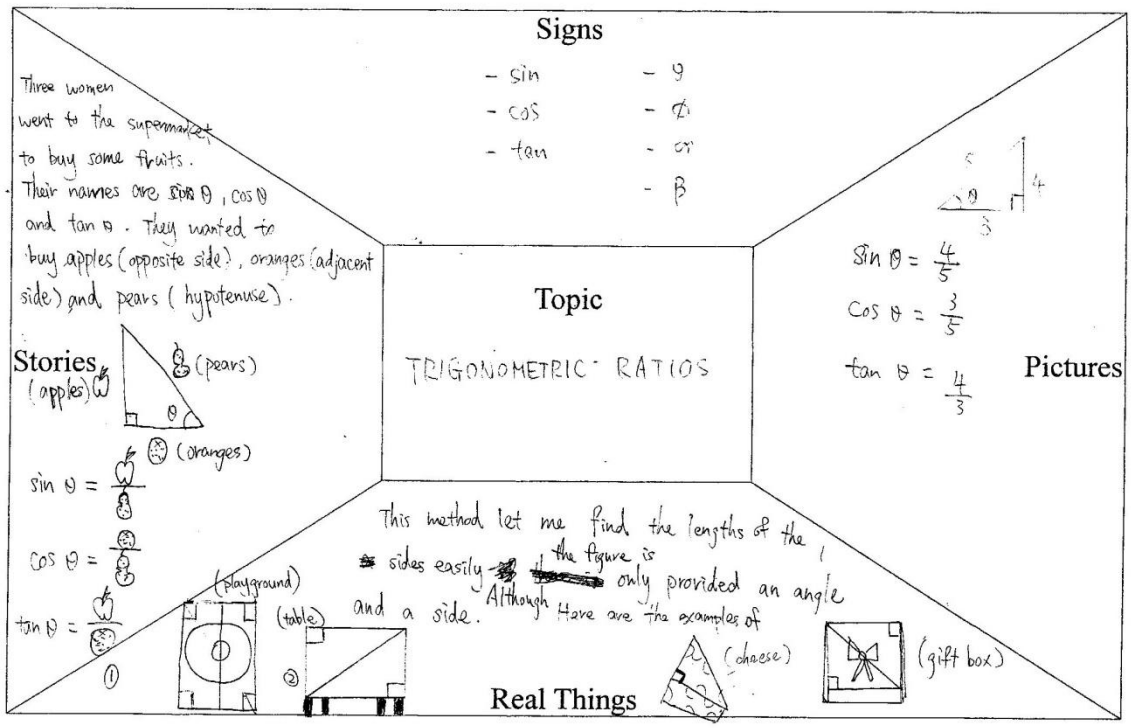


Figure 3.3 Think Board

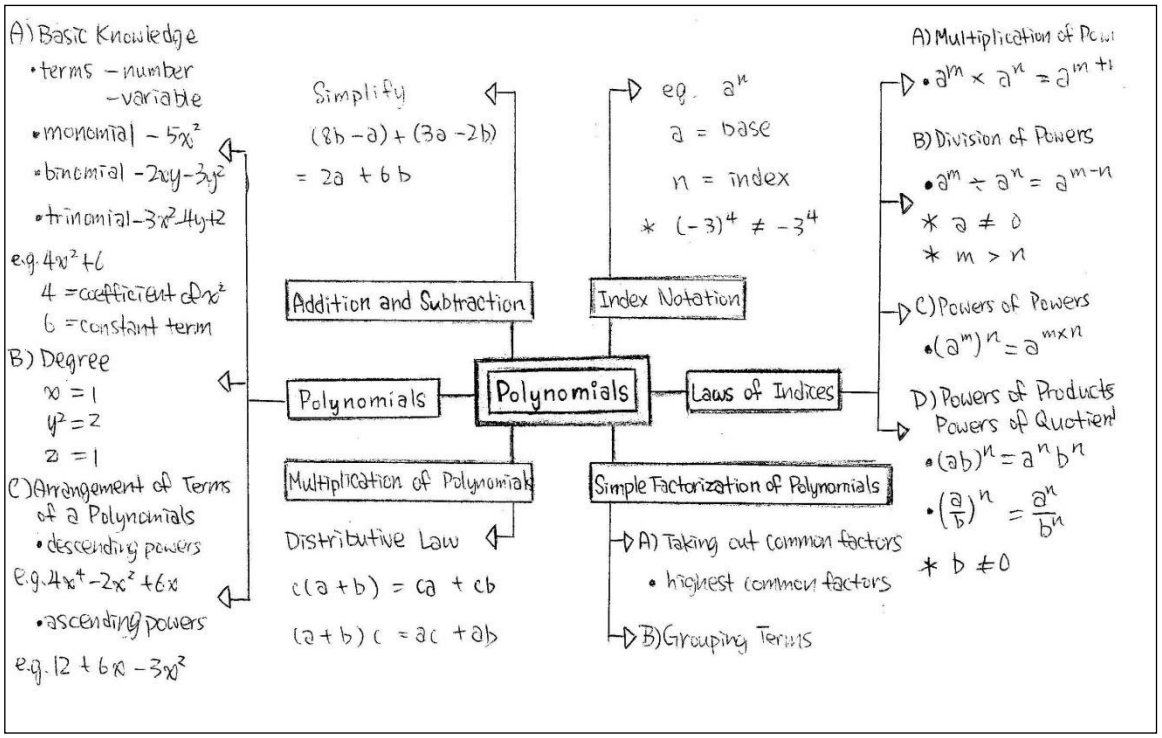


Figure 3.4 Mind Map

Based on the literature (Wong, 2006; Margulies & Valenza, 2005; Callingham, 2006), the use of mind map and think board activities in classrooms were shown to:

- help students to abstract the relevant mathematical concepts in different modes (flexibility in thinking)
- allow students to express their insights
- encourage creativity
- be useful for self assessment
- be good for formative assessment
- allow diagnosis of misconceptions

3.1.4 Issues to be addressed when using self-assessment tools

When teachers want to use self-assessment tools in classrooms, some issues need to be addressed (Callingham, 2006; Flaitz, 2006):

Workload - The self-assessment exercise will inevitably increase both the teachers' and students' workload. Therefore, based on the students' needs and the effectiveness of the activities, the teachers need to decide how often the students will need to write about their learning.

Feedback - Teachers' feedback is important to students. It should be non-judgmental and supportive, but need not be lengthy.

Self-assessment skills - Teachers need to help students to develop self-assessment skills. Most students are not used to reflecting on their learning. It takes time and teachers' guidance for students to understand what they should write.

Formative or summative assessment - The self-assessment tools can inform students' learning. However, if they are used for summative assessment, good rubrics are needed.

3.2 Research questions

The general hypothesis is that the introduction of student self-assessment activities to facilitate self-directed learning in secondary mathematics classrooms will result in students displaying a deeper understanding of mathematics concepts, adapting better self-learning strategies and improving mathematics achievement.

This study is designed to answer the following questions:

1. Do the self-assessment activities used in this study have an impact on students' mathematics achievement?

2. Do the self-assessment activities used in this study have a differential impact on the mathematics achievement of students with different levels of attainment?

3. Do the self-assessment activities used in this study have an impact on students' learning strategies in mathematics?

4. Do the self-assessment activities used in this study have an impact on students' understanding of mathematics concepts?

Students should have the opportunity to assess their own learning. They should be offered opportunities to apply criteria to their work in progress and for reflection. According to Nitko and Brookhart (2011), student self-assessment fosters both motivation and achievement. Students who can size up their work, figure out how close they are to their goal, and plan what they need to do to improve are, in fact,

learning as they do that. Carrying out their plans for improvement not only makes their work better, it also helps them feel in control, and that is motivating. This process of self-regulated or self-directed learning has been found to be a characteristic of successful, motivated learners. For many students, effective self-assessment techniques do not come naturally. Student self-evaluation needs to be taught. Students progress to eventually become skilled at analyzing and critiquing their own work (McMillan, 2004). It has been shown that students who have been taught self-assessment techniques can provide more reflective answers in self-assessment activities. Regulation of learning can be internal, as when students use self-assessment information to improve, or external, as when students use teacher feedback to improve (Nitko *et al*, 2011). The aims of this study are to investigate the pedagogical usefulness of self-assessment to facilitate SDL, and the extent to which one can equip students and teachers with the capacity to use self-assessment to facilitate SDL. Therefore, it is hoped that this study would help to gain a better understanding of how self-assessment can be adopted as a pedagogical approach to support SDL in classroom. However, besides understanding the process, we also need to know if this process can produce better academic results, which students, teachers and parents are most concerned about. This would provide teachers with the justification and incentive to adopt student self-assessment in their pedagogy. That is why research questions 1 and 2 are important. By knowing if self-assessment has an impact on achievement and on which level of students is most effective, teachers can make their own decisions on whether they should use this reflective activity in their mathematics classrooms. Moreover, the ability to consciously select the appropriate learning strategies and meta-cognition are important components of SDL. By analyzing the student self-assessment samples, we can get to know more about students' thinking process and how they choose their learning strategies. Therefore, it is worth finding the

answers of research questions 3 and 4. We can know whether self-assessment activities used in this study have an impact on students' learning strategies as well as the understanding of mathematics concepts. By answering the four research questions, hopefully, we can develop a better understanding of the interrelationships between self-assessment, self-directed learning, pedagogy, achievement, learning strategies and meta-cognition. As a result, we can have a clearer idea on how to design the pedagogy and how to equip teachers and students with the capacity to use this pedagogy.

3.3 Research methods

A pre-test and a post-test were administered to investigate the effects of using guided self-assessment on student mathematics achievement. It was a controlled experiment using two groups. Also, an analysis of student samples was done to explore if the self-assessment exercise had facilitated self-directed learning.

3.3.1 Pre- and post-tests design

Pre-tests and post-tests were conducted at the beginning of the school year and the end of the school year respectively to measure the change in student mathematics achievement.

A total of 533 Secondary Three (S3) students in 16 classes from 6 schools did the pre- and post-tests. Out of the 533 students, 315 students from 9 classes did self-assessment with teachers' guidance. The nature of the interventions is described in Section 3.1. The rest of the 218 students from 7 classes who did not do self-assessment comprised

the control group. Six teachers had volunteered to try the intervention in their classrooms and 5 teachers did not use any kind of student self-assessment in their teaching. Table 3.1 shows the number of students, schools, classes and teachers in each group.

	Treatment group (with self-assessment)	Control group (without self-assessment)	Total
No. of students	315	218	533
No. of schools	3	3	6
No. of classes	9	7	16
No. of teachers	6	5	11

Table 3.1 The number of students, schools, classes and teachers in each group.

The pre-test and post-test were designed according to the content listed in the "Syllabuses for Secondary Schools, Mathematics (S1 – S5), 1999" published by the Hong Kong Education Bureau and the teaching schedules of the schools participating in the project. Questions were set on three dimensions - Number and Algebra; Measures, Shape and Space; and Data Handling. Each test contained 33 items. There were 19 items which were identical on the pre- and post-tests. The common items were designed to help to keep track of students' growth. The tests are shown in Appendix I and Appendix II. Fourteen new items were constructed to explore differences between the experimental and control group on new material.

In the pre-test, 12 items were set on Number and Algebra, 19 items were set on Measures, Shape and Space and 2 items were set on Data Handling.

In the post-test, 14 items were set on Number and Algebra, 16 items were set on Measures, Shape and Space, and 3 items were set on Data Handling.

Out of the 19 common items, 9 items belonged to the Number and Algebra Dimension, 9 items belonged to Measures, Shape and Space and 1 item belonged to the Data Handling Dimension. Table 3.2 shows the number of items set on each dimension in the pre- and post-tests.

Dimension	Pre-test	Post-test	No. of common items
Number & Algebra	12 items	14 items	9
Measures, Shape & Space	19 items	16 items	9
Data Handling	2 items	3 items	1
Total	33 items	33 items	19

Table 3.2 Number of items set on different dimensions.

Analyses were done to see if self-assessment can improve students' performance in mathematics. The gain in raw scores between the pre- and post-tests was used to compare the treatment group and the control group. The computer software SPSS was used to perform analysis of variance (ANOVA). Also, an analysis was done, based on Rasch scores. Rasch scores for each item were derived via the WINSTEPS software. This analysis was performed to see if the analysis using raw scores and Rasch scores would produce similar conclusions.

The following hypotheses were tested:

Null hypothesis 1a

There is no significant difference at alpha level 0.05 in students' gain scores between the treatment group (with self-assessment) and the control group (without self-assessment).

Null hypothesis 1b

There is no significant difference at alpha level 0.05 in students' gain on Rasch scores between the treatment group (with self-assessment) and the control group (without self-assessment).

Null hypothesis 2a

There is no significant difference at alpha level 0.05 in gain scores between the low ability students with self-assessment and the low ability students without self-assessment.

Null hypothesis 2b

There is no significant difference at alpha level 0.05 in gain scores between the middle ability students with self-assessment and the middle ability students without self-assessment.

Null hypothesis 2c

There is no significant difference at alpha level 0.05 in gain scores between the high ability students with self-assessment and the high ability students without self-assessment.

Effect sizes were used as a common expression of the magnitude of study outcomes. The formula for calculating effect size is as follows:

$$\text{Effect size} = (\text{Mean}_{\text{treatment}} - \text{Mean}_{\text{control}}) / \text{pooled sample standard deviation}$$

According to Hattie (2009), an effect size of d=1.0 (i.e. one standard deviation increase in outcome), is typically associated with advancing achievement by two to three years, improving the rate of learning by 50%, or a correlation between some variable and achievement of approximately r = 0.50.

An analysis on the common and non-common items was also done to see if there is a difference in performance between the treatment and control groups on the two types of items.

3.3.2 Analysis of samples of student self-assessment

The student samples were the products of student self-assessment activities guided by the teachers. There were different kinds of documents, namely student reflective journals, think boards and mind maps. The documents were analysed in order to gather evidence to see if the self-assessment activities had facilitated self-directed learning (SDL). Teachers used their professional judgement to decide which tool was most appropriate for their students. Factors such as the topic, time constraints, workload, students' interest and ability, and teachers' preferences would also be considered. The samples were provided by the teachers involved in the project. Sixty student reflective journals, twenty-nine think boards and twelve mind maps were collected and analysed. The 101 samples are presented in Appendix III.

The treatment group has 315 students. The 101 samples were submitted to the researcher by the 6 teachers teaching 9 classes in the treatment group. But how the samples were chosen is unclear. Therefore, there is a concern that the teachers would select some good samples and the work done by weaker students might not be represented. As a result of the non-random sampling, there may be difficulty generalizing the results to a larger population.

The elements related to SDL to be identified from the samples include the following:

SDL elements	Label
Learning strategies & behaviours	
- Consciously select and implement learning strategies	Learn1
- Strategic help seeking, know when to seek help	Learn2
- Can identify what is important	Learn3
- Know what needs to be understood or memorized	Learn4
Self-assessment skills & self-knowledge	
- Know better about current performance levels	Self1
- Can self-evaluate the level of understanding	Self2
- Can self-assess the learning outcomes	Self3
- Can reflect on what is learned	Self4
Meta-cognition	
- Awareness that he/she does or does not understand	Meta1
- Can evaluate how good a particular learning strategy is	Meta2
- Think about learning	Meta3
- Able to re-organize and re-construct	Meta4
Motivation	
- More engaged in learning	Moti1
- Want to learn more	Moti2

The consideration of the above SDL elements to be identified from the samples were based on the literature on self-directed learning, assessment for learning, self-assessment and reflection, and also the diagram (see P.44) created by the researcher which shows the dynamics and relationships between the components of self-directed learning and self-assessment. It was found that learning strategies and behaviours, self-assessment skills and self-knowledge, meta-cognition, and motivation are some of the major elements in many SDL models (Mok *et al*, 2001; Gibbons, 2002;

Tremblay, 1991 as cited by Hrimech, 1995; Costa, 2008). The consideration for the sub-categories of each major SDL element was as follows:

Learning strategies and behaviours

The self-directed learning model proposed by Knowles (1975, 1991) provides a systematic, linear process of developing learning contracts to utilizing SDL. Knowles suggested that consciously selecting and implementing learning strategies is one of the important processes of SDL. In addition, self-directed learners should have the capability of help seeking (Mok *et al*, 2001). They would ask questions such as "Should I seek help and if so from where should I get help?" (Mok, 2009). Also, learners should learn to provide feedback to themselves from multiple perspectives which could help them improve their own learning by using the linguistic, cognitive and meta-cognitive insights they receive (Cassidy, 2006). Therefore, with reference to the above, consciously selecting and implementing learning strategies (Learn1), strategic help seeking, knowing when to seek help (Learn2), identifying what is important (Learn3) and knowing what needs to be understood and memorized (Learn4) were considered as the sub-categories of learning strategies and behaviours.

Self-assessment skills and self-knowledge

Self-assessment is basic to our capacity for self-knowledge, and an essential prerequisite for effectively directing our learning (Rogers, 1969, as cited by Long, 1997). As pointed out by Gibbons (2002), self-assessment is a component of meta-learning; learning how to learn includes learning how to assess how well one is learning. Students should learn to evaluate their own progress and the quality of their work. Research studies have shown that reflective learning improves academic results and contributes to developing important personal skills (Bourner, 2003; Irving *et al*.,

2003; Dimaki *et al*., 2005, as cited by Cambra-Fierro & Cambra-Berdún, 2007). Students' academic achievement can improve if they think and reflect not only about the content of the subject, but also about their attitude, effort and dedication to them. Caswell and Nisbet (2005) explored ways to enhance mathematical understanding through self-assessment and self-regulation of learning. Students' meta-awareness of their mathematical thinking was emphasized by engaging them in reflection on their levels of knowing and confidence to work mathematically. It was found that students were very aware of their learning. They began identifying the level on which they believed they were working, and then actively choosing to extend themselves to a higher level. In view of the above, knowing better about current performance levels (Self1), can self-evaluate the level of understanding (Self2), can self-assess the learning outcomes (Self3) and can reflect on what is learned (Self4) were considered as the sub-categories of self-assessment skills and self-knowledge.

Meta-cognition

Meta-cognition is the awareness of our own thinking (Costa, 2008). Flavell defined meta-cognition conceptually as "thinking about thinking" (Miller, Kessel, & Flavell, 1970 as cited by Mok, 2009). Some researchers suggested that self-regulation of cognition is a component of meta-cognition, and it should include assessing and evaluating effectiveness, and revising strategies being used (Nietfeld, Cao, & Osborne, 2005; Mok, 2009). To write about one's thought or the translation of thought into an external symbolic representation is to apply meta-cognition (Hacker, Keener & Kircher, 2009). In order to organize and re-construct a concept learned through writing journals, think boards or mind maps, one must have a deep understand of the concept and should have developed meta-cognition. With reference to the above, awareness that he/she does or does not understand (Meta1), can evaluate how good a particular

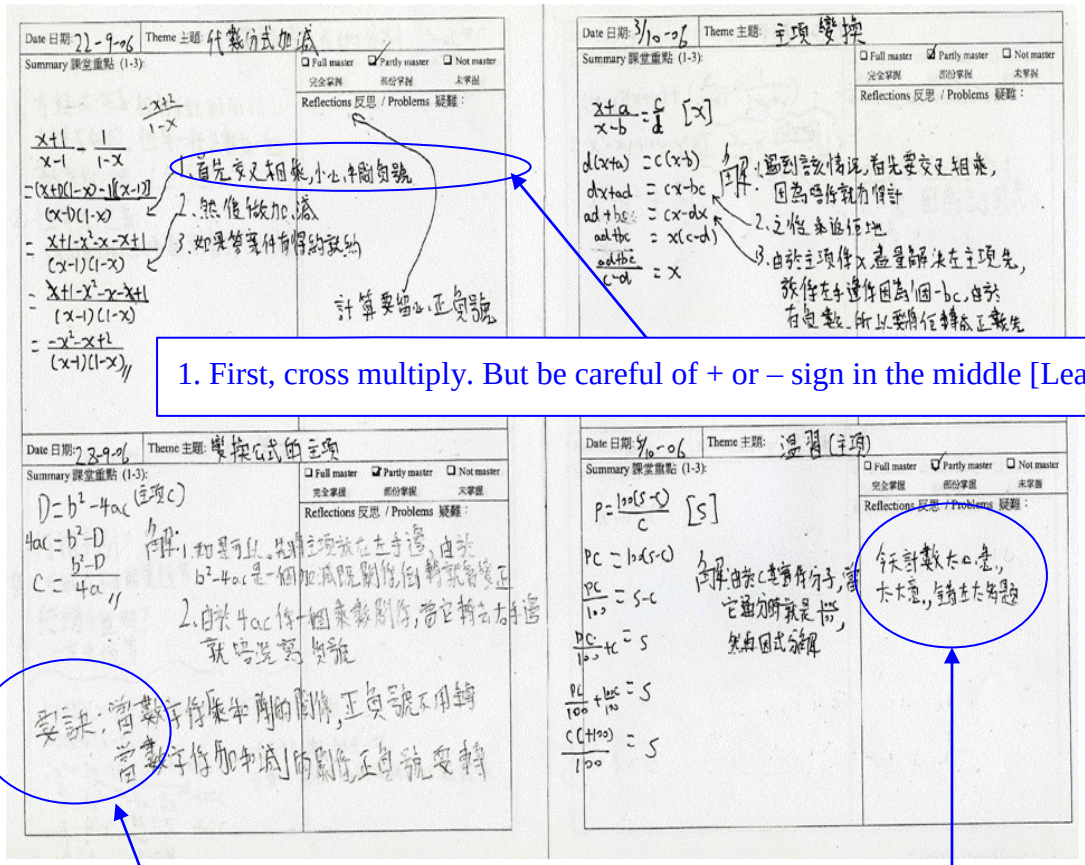
learning strategy is (Meta2), think about learning (Meta3) and ability to re-organize and re-construct (Meta4) were considered as the sub-categories of meta-cognition.

Motivation

Students who are motivated can stay engaged for a long period of time, whereas an unmotivated child will give up very easily when not instantly successful (Fox, 2005; Brophy, 1997). Therefore, more engaged in learning (Moti1) was considered as one of the sub-categories of motivation. People, especially children, are naturally curious; they want to explore and discover. If their explorations bring pleasure or success, they will want to learn more (Brophy, 1997; Mok *et al*, 2001). Hence, want to learn more (Moti2) was included as a subcategory of motivation as well.

3.3.2.1 Student reflective journal

The followings are some of the samples of student reflective journals:



1. First, cross multiply. But be careful of + or – sign in the middle [Learn3]

Figure 3.5 Sample of student reflective journal 1.

It means key points. It says when you multiply or divide, no need to change sign. But when you add or subtract, need to change sign. [Learn4]

I was doing my math too quickly today. Not careful enough. [Self1]
I've got too many questions wrong. [Self3]

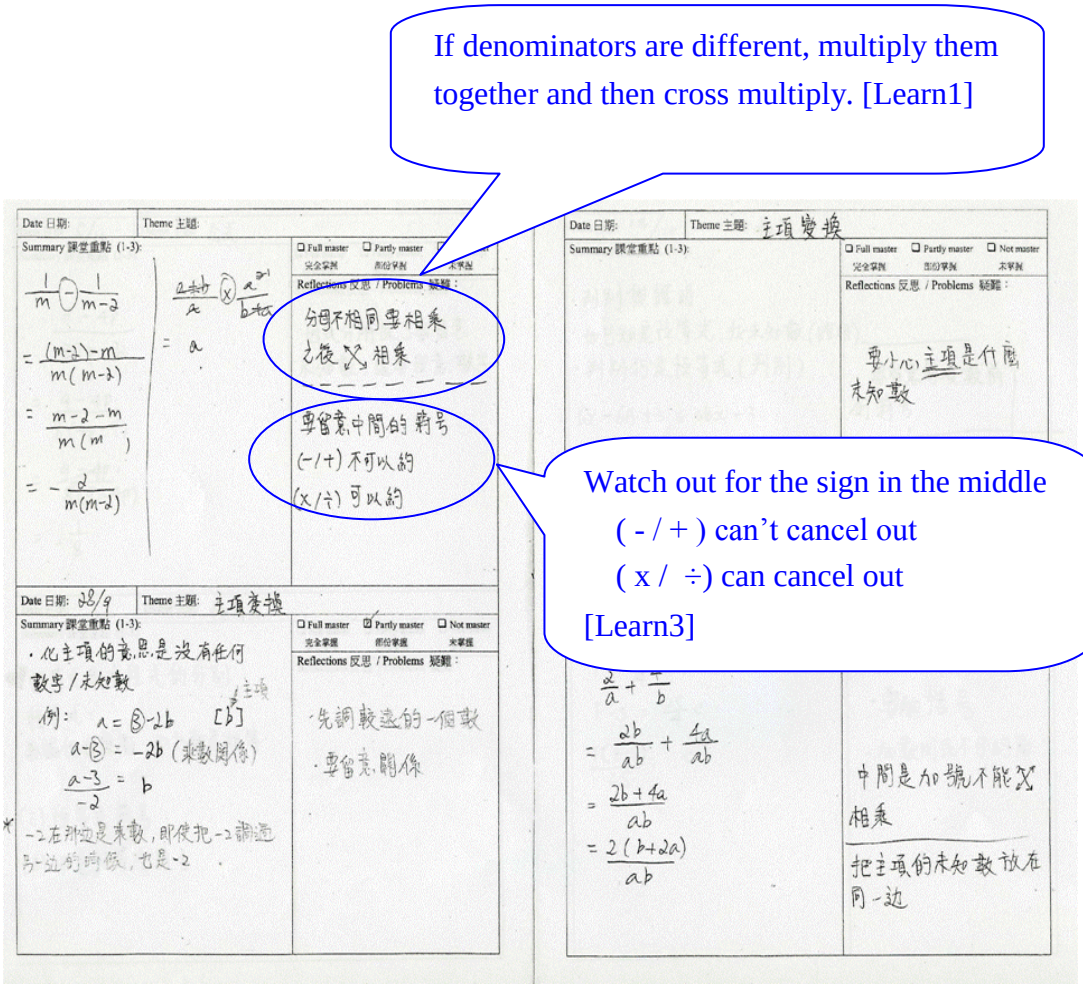


Figure 3.6 Sample of student reflective journal 2.

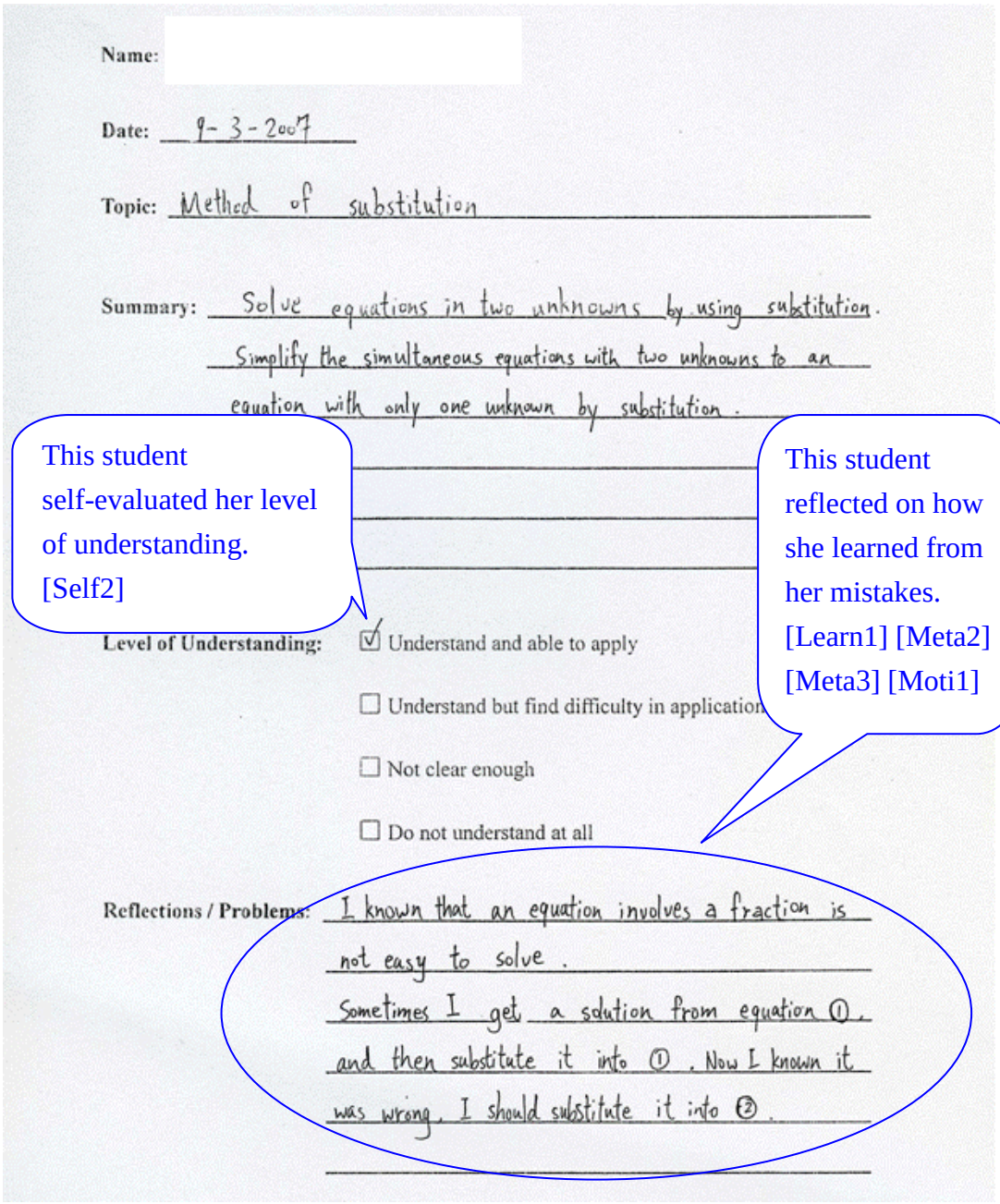


Figure 3.7 Sample of student reflective journal 3.

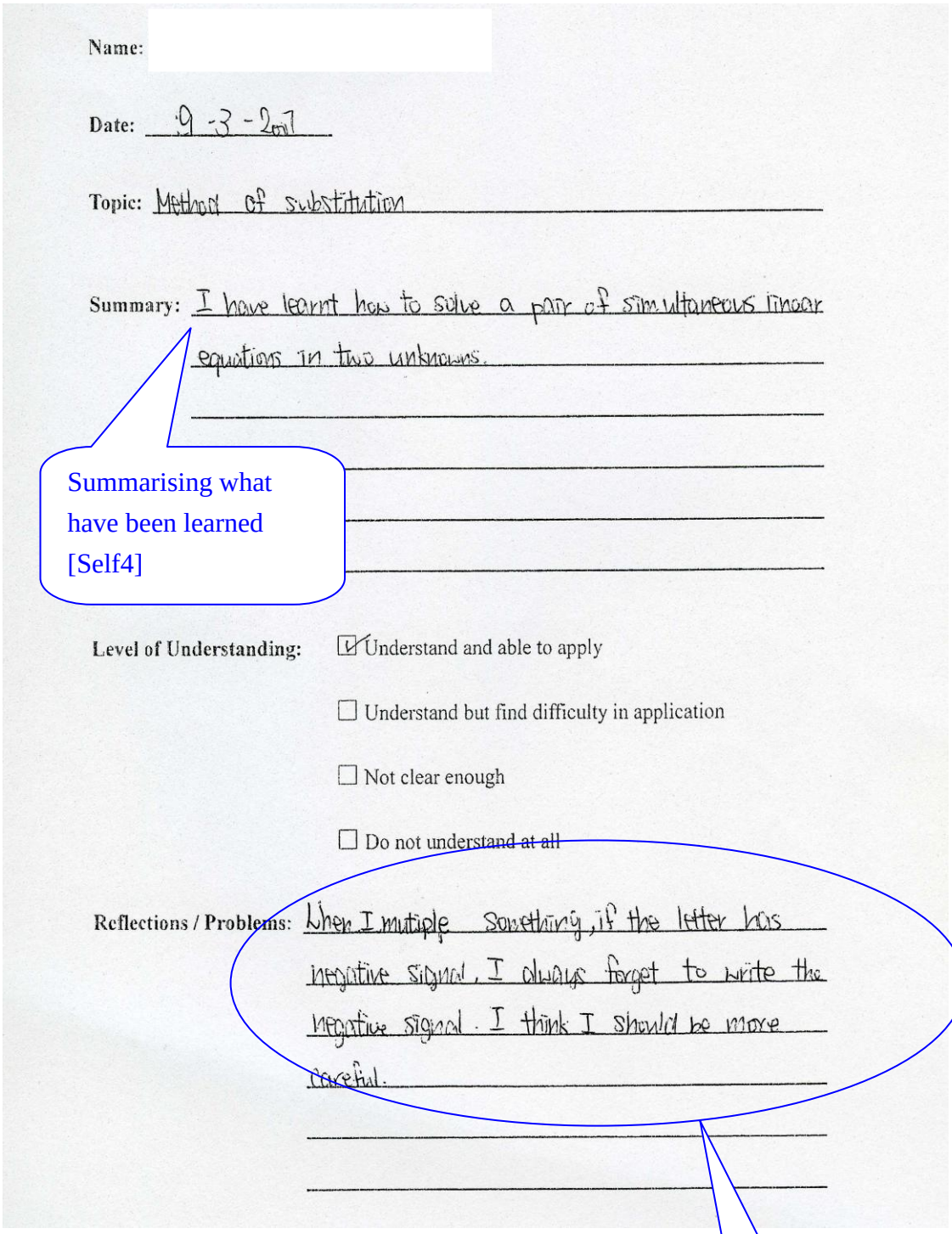


Figure 3.8 Sample of student reflective journal 4.

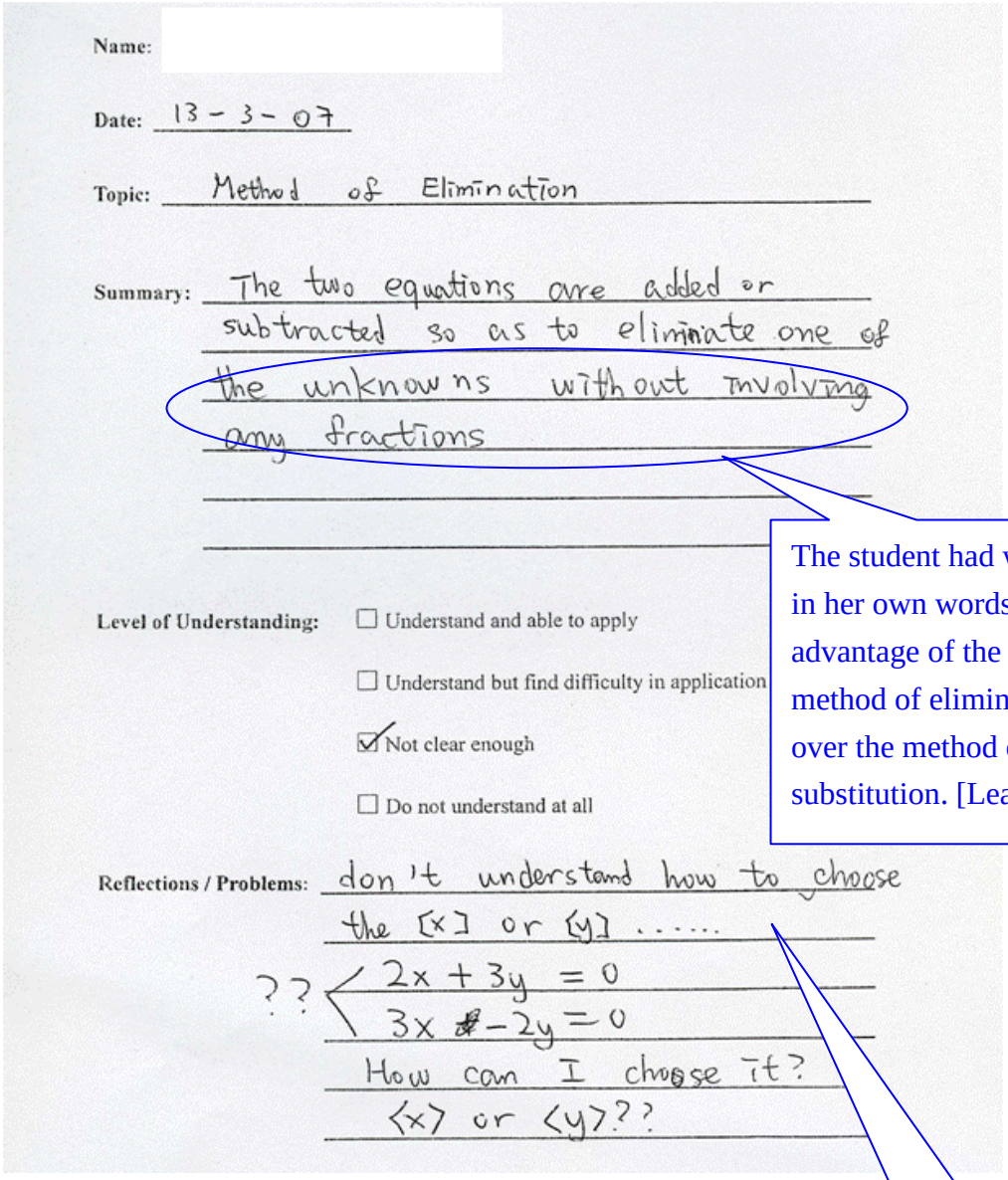


Figure 3.9 Sample of student reflective journal 5.

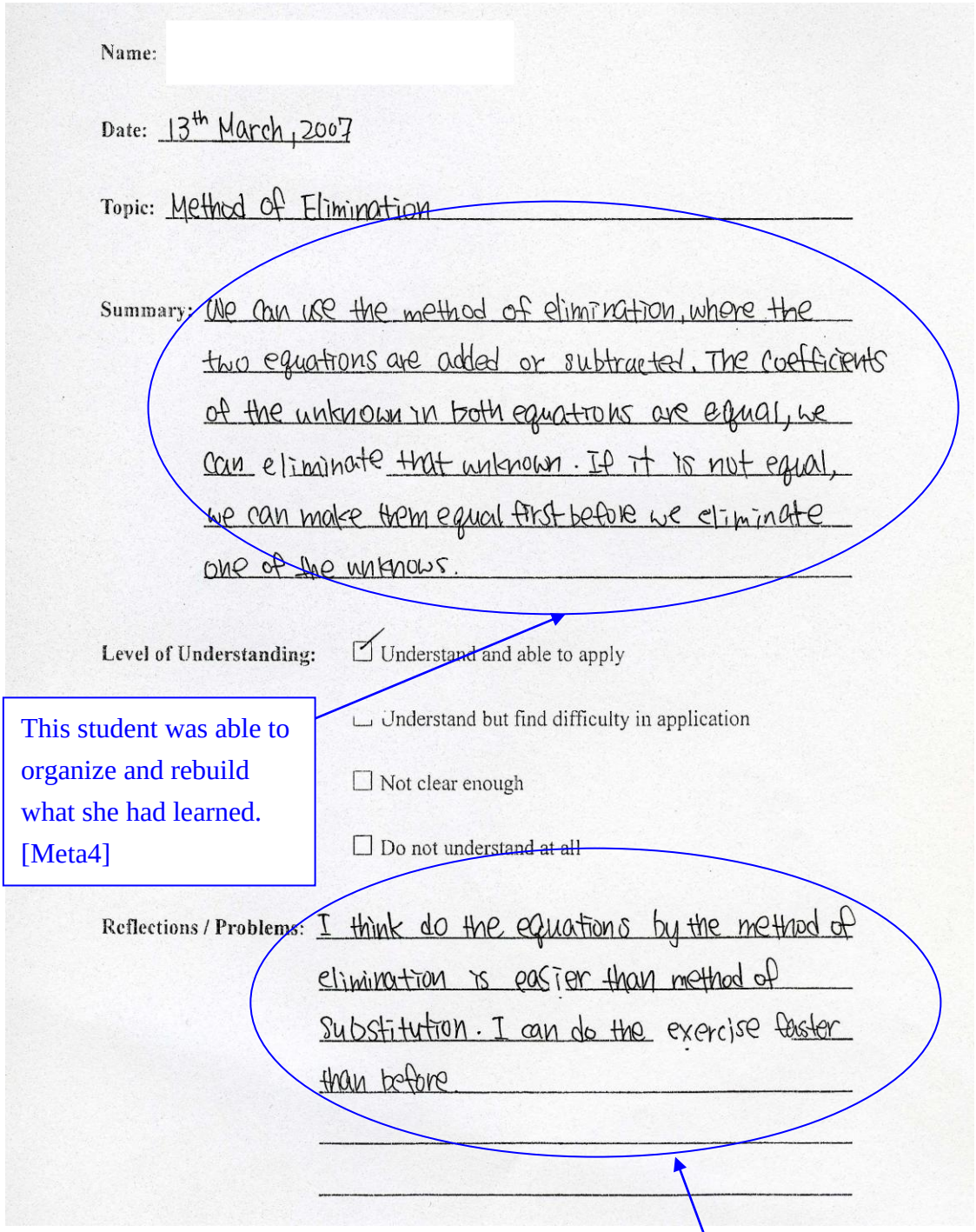


Figure 3.10 Sample of student reflective journal 6.

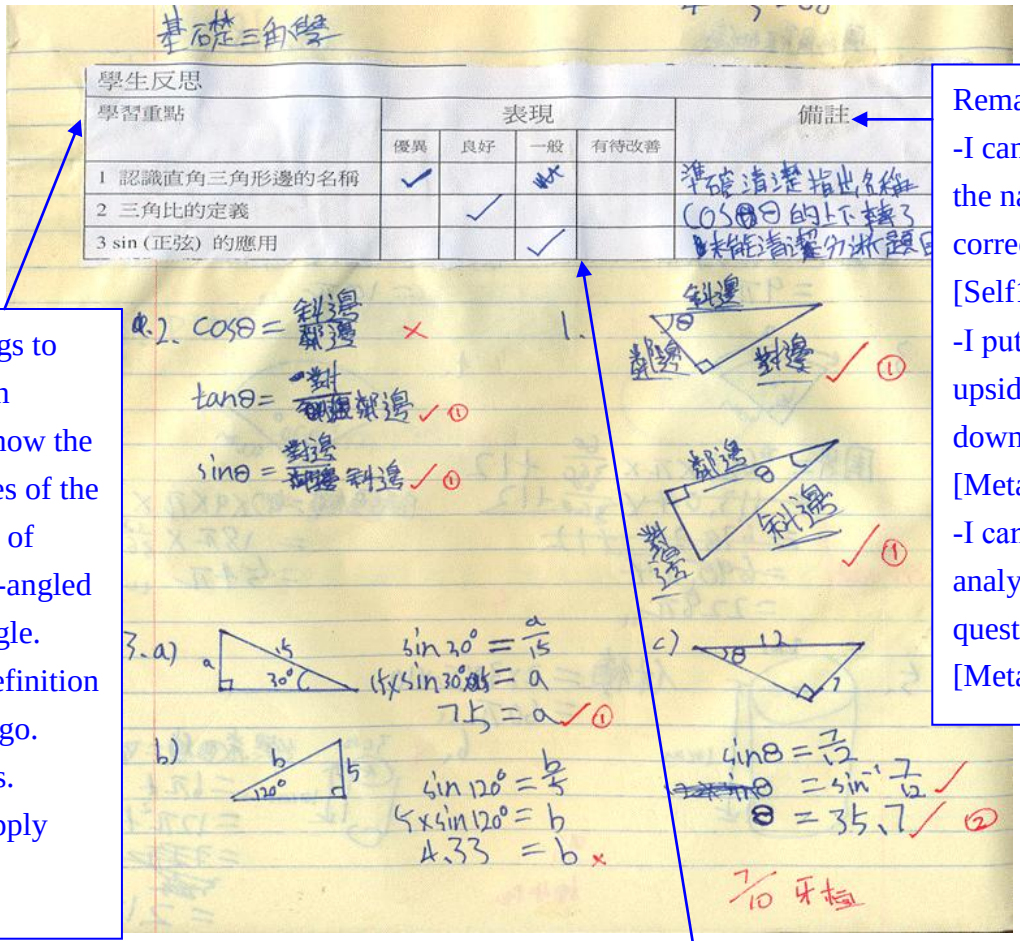


Figure 3.11 Sample of student reflective journal 7.

3.3.2.2 Think board

The followings are some of the samples of think board:

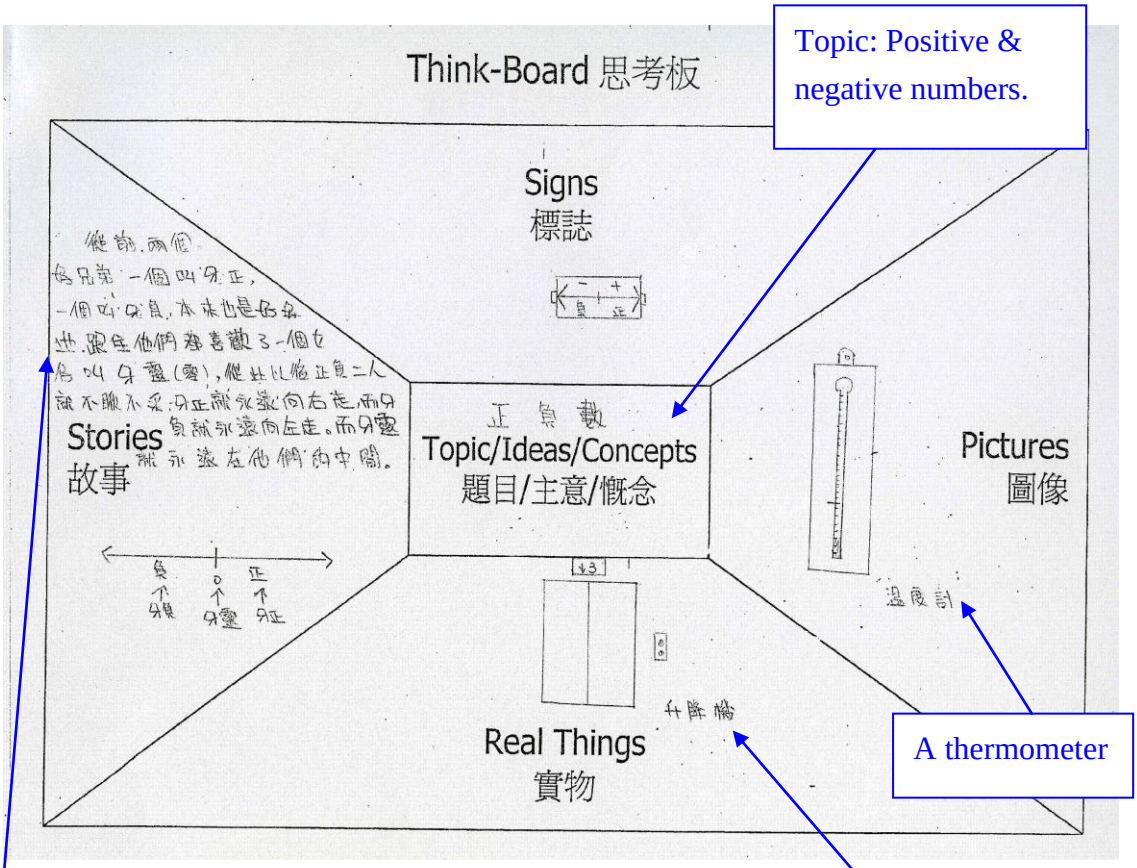


Figure 3.12 Sample of think board 1.

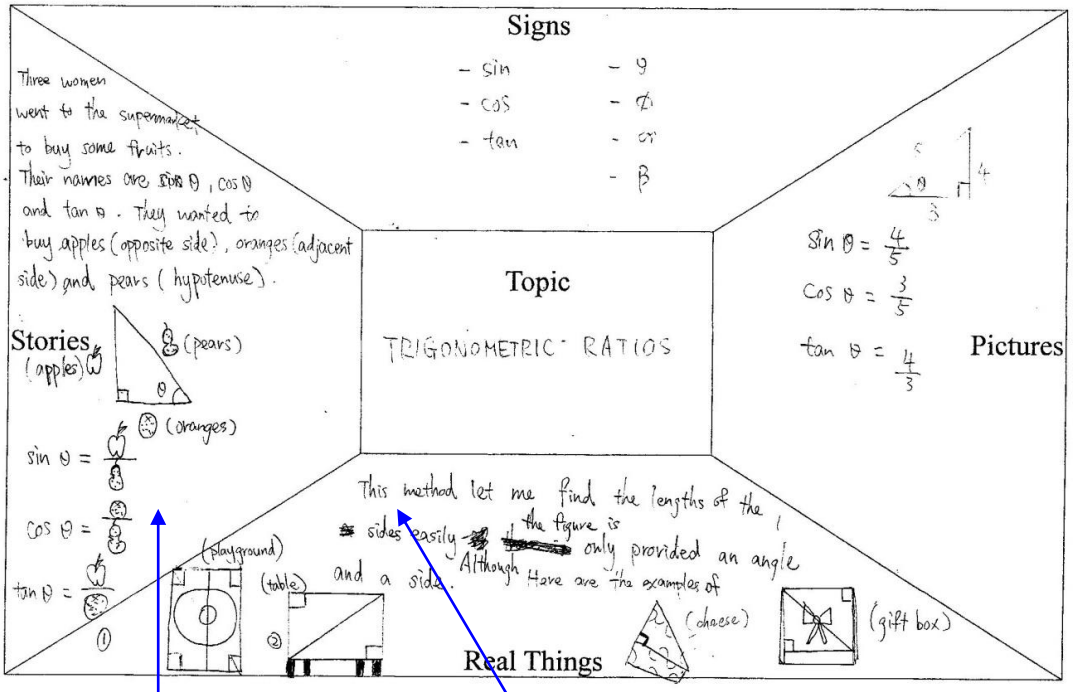


Figure 3.13 *Sample of think board 2.*

Able to re-construct and recognize the important materials [Learn3][Meta4]

The student is evaluating how good this method is and thinking in what conditions it is useful [Meta2][Meta3]

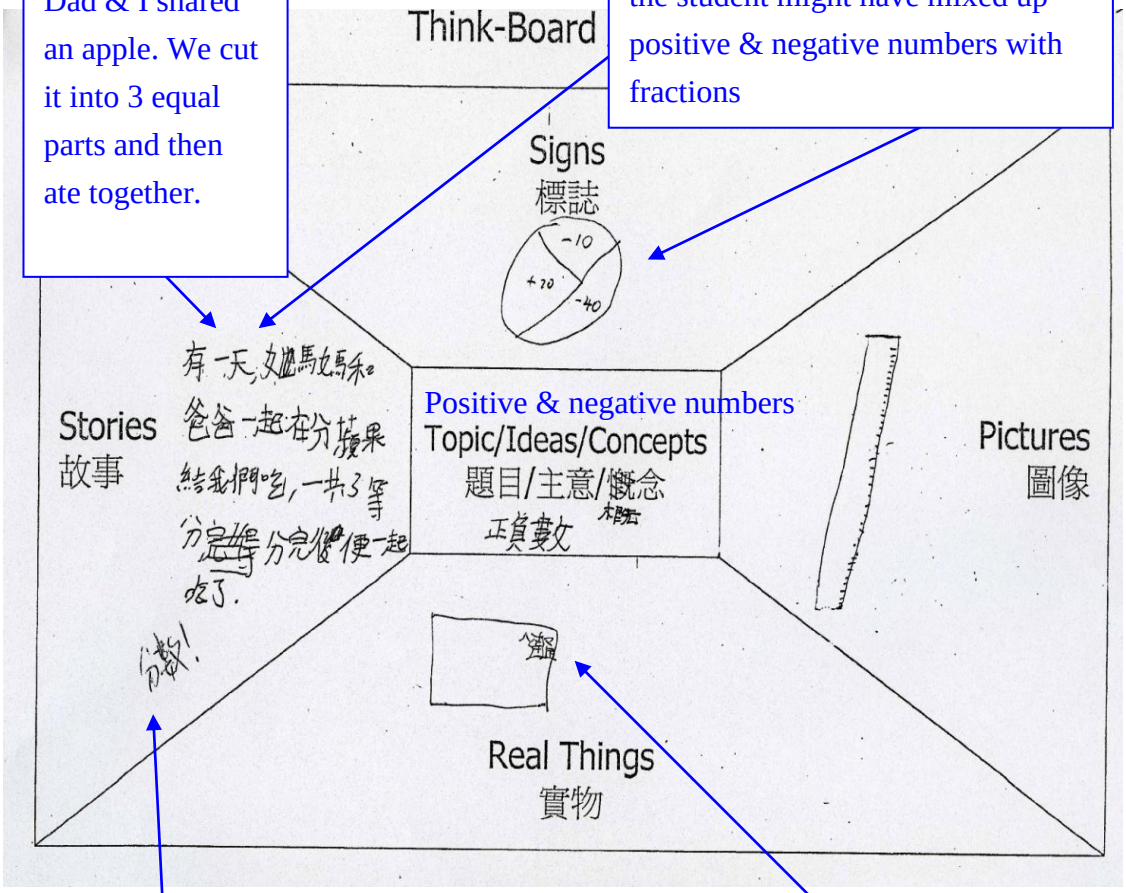


Figure 3.14 *Sample of think board 3.*

The teacher wrote down "Fraction!" to indicate student's misconception

An Octopus card (a very common form of electronic money used in Hong Kong, which users can add value into the card. The balance will be deducted when purchasing or receiving services such as taking a bus or train)

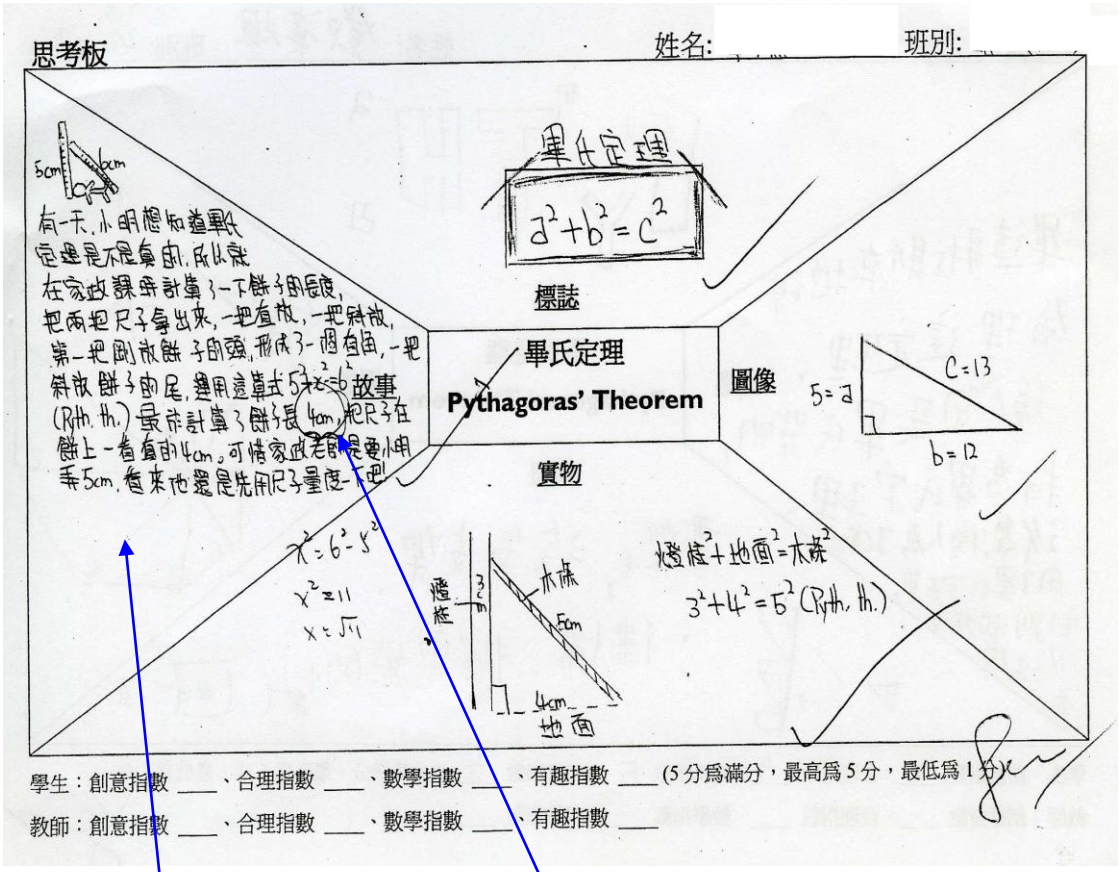


Figure 3.15 Sample of think board 4.

The story is about a student in home economics class used a biscuit and 2 rulers to verify if Pythagoras theorem is true.

The teacher spotted an error. But it may not be just a calculation mistake, the student might have a big misconception i.e. the student may think that if 3,4,5 can form a right-angled triangle, so can 4,5,6. However, that is not true, 4,5,6 can't form a right-angled triangle. The teacher may investigate further to see if this is a general misconception among the students in class, and then make the appropriate adjustment in delivering future lessons.

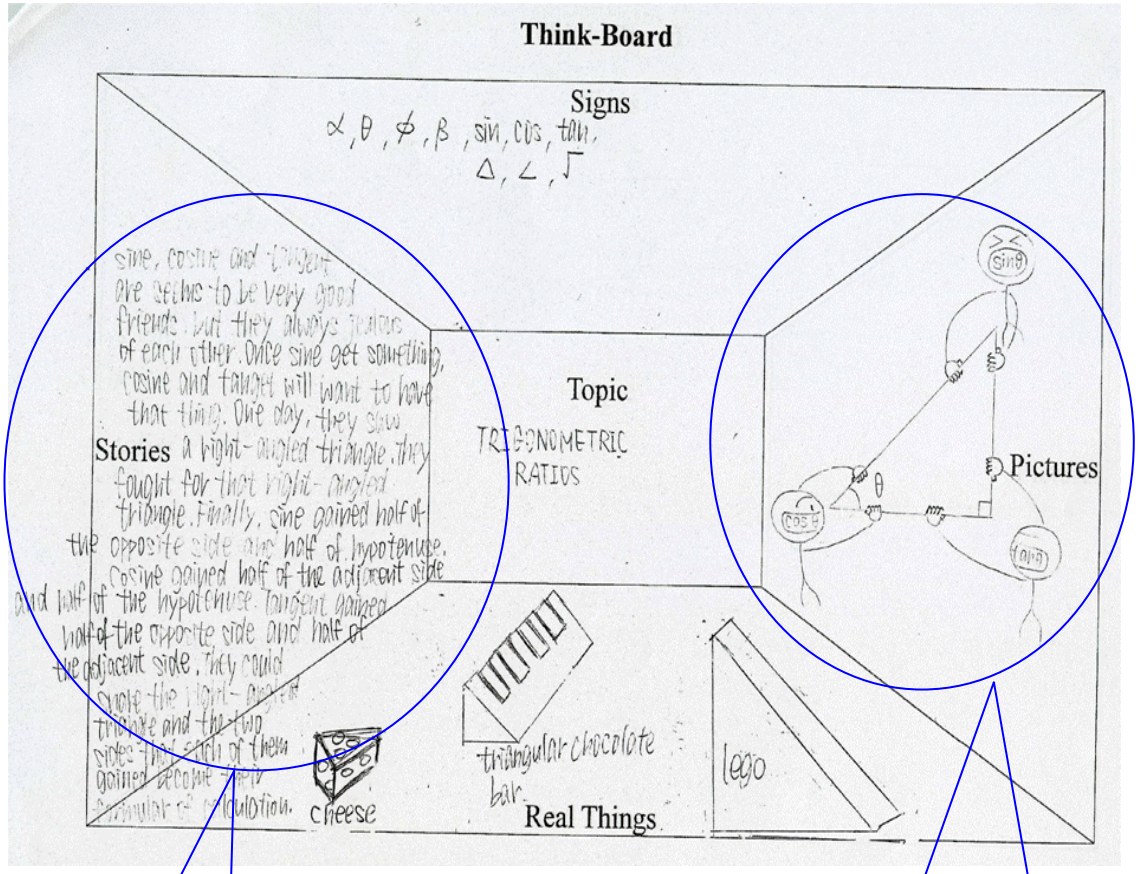


Figure 3.16 Sample of think board 5.

A love story: 3 good friends (sine, cosine, tangent) in love with right-angled triangle. They fought. Sine ended up getting half of opposite side & hypotenuse; cosine getting half of adjacent side and hypotenuse; and tangent getting half of opposite side and adjacent side. [Meta4]

The students drew a picture of the love story between sine, cosine, tangent and right-angled triangle. It seems that the student was able to re-organize and re-construct what he had learned and then represent it in a different way. [Meta4]

3.3.2.3 Mind map

The followings are some of the samples of mind map:

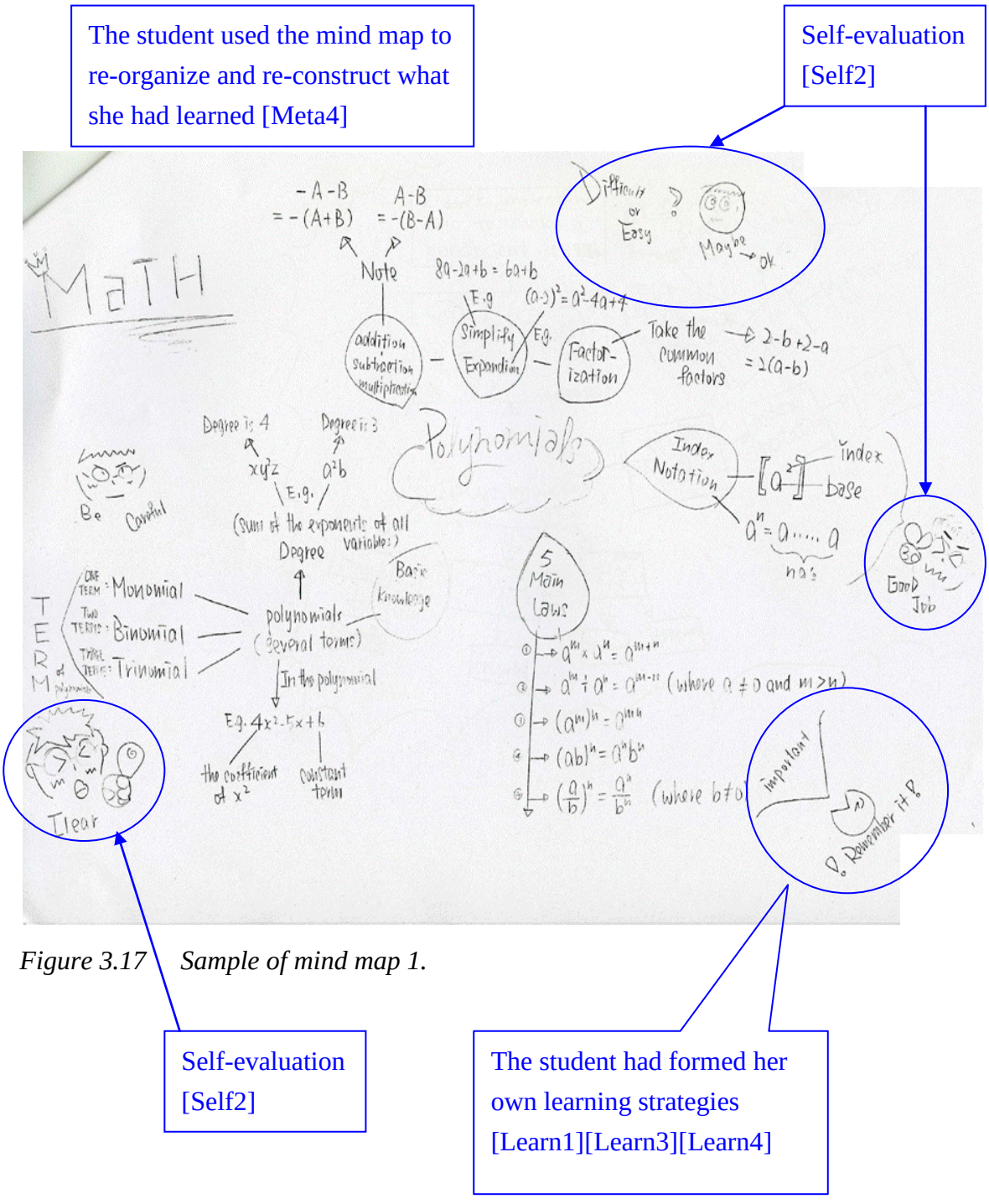


Figure 3.17 Sample of mind map 1.

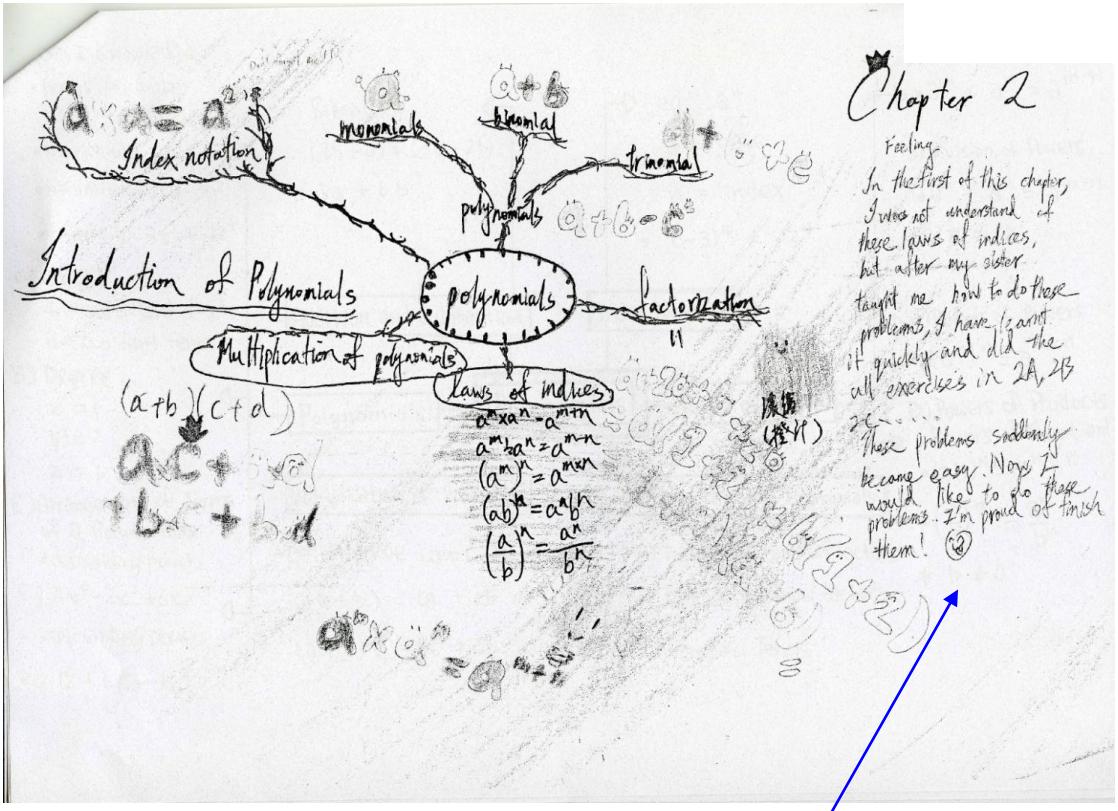


Figure 3.18 Sample of mind map 2.

This mind map was beautifully drawn with a lot of self created cartoons characters in colour pencils. The scanner was unable to capture all the details. The student talked about her feelings and problems. At the end, her self-efficacy increased (with a smiling face too). [Self4] [Learn2] [Moti1]

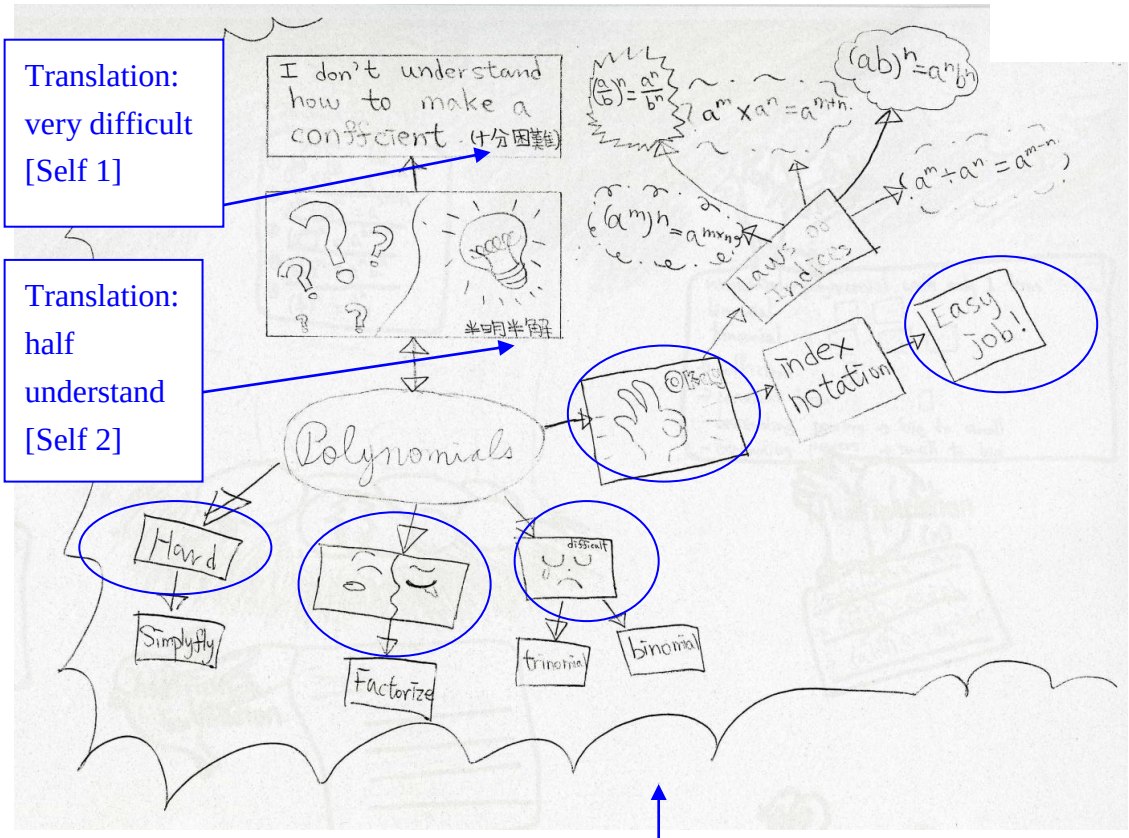


Figure 3.19 Sample of mind map 3.

This student self-assessed the level of her understanding of different topics using crying faces, drawings and her own words. [Self 1] [Self2] [Meta4]

The analysis of the 101 student samples was carried out by the researcher alone. Each sample was read line by line thoroughly to identify any occurrence of SDL elements. Each occurrence was recorded. The results of coding all 101 samples are shown in the Appendix V.

3.3.2.4 Test for reliability of the coding scheme

There were a total of 101 samples. Every fifth sample was taken out to be coded twice to test for reliability of the coding method. A total of 21 samples were used for the test. The results of the 2 ratings are shown in the Appendix IV. The results show that there are 287 agreements and 9 disagreements. Therefore, it can be concluded that the coding scheme is accurate and reliable.

CHAPTER 4 Results

4.1 Results of the analysis of student achievement

Null hypothesis 1a:

There is no significant difference at alpha level 0.05 in students' gain scores between the treatment group (with self-assessment) and the control group (without self-assessment).

Table 4.1 shows the results of analysis of variance on gain raw scores of students with self-assessment and without self-assessment.

ANOVA

Raw_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1271.141	1	1271.141	9.902	.002
Within Groups	68168.092	531	128.377		
Total	69439.233	532			

Table 4.1 ANOVA on gain raw scores of students with self-assessment and without self-assessment.

Table 4.2 shows the mean gain raw scores of treatment group (with self-assessment) and control group (without self-assessment).

Report

Raw_gain

treatment	Mean	N	Std. Deviation
0	1.14	218	11.94
1	4.28	315	10.89
Total	3.00	533	11.42

Table 4.2 Mean gain raw scores of treatment group (with self-assessment) and control group (without self-assessment).

Both the pre-test and post-test have 33 items containing 33 marks. The raw scores are converted to a scale of 100 points for the purpose of easier understanding, calculation and comparison.

Based on the results presented in table 4.1, the null hypothesis that there is no significant difference in students' gain scores between the treatment group and the control group is rejected ($t=0.05$, $n=533$, $p<0.002$).

From table 4.2, the mean gain score for all students was 3.00. The mean gain score for self-assessed students was 4.28, while the mean for control group was 1.14.

The results indicated that the students with in the self-assessment group out-performed the students in the control group.

Effect sizes were used as a common expression of the magnitude of study outcomes. The effect size was calculated in the following way:

$$\text{Effect size} = (\text{Mean}_{\text{treatment}} - \text{Mean}_{\text{control}}) / \text{ pooled sample standard deviation}$$

For pre-and post-tests design, the numerator is

(Post-Test Mean $_{treatment}$ – Pre-Test Mean $_{treatment}$) – (Post-Test Mean $_{control}$ – Pre-Test Mean $_{control}$). This is equivalent to the difference between the mean gain of treatment group and the mean gain of control group.

Therefore, in this case, the effect size = (4.28-1.14)/11.42 = 0.27

This means the treatment group had an increase of 0.27 standard deviation on mathematics achievement compared with the control group.

Hattie (2009) asserts that when judging educational outcomes, an effect size of d = 0.2 is small, d = 0.4 is medium and d = 0.6 is large. If one year's gain in school is used as a comparison and an effect size of d = 1.0 corresponds to a two to three years' gain, then a small effect size (d=0.2) corresponds to 0.4 to 0.6 year's gain, a medium effect size (d=0.4) corresponds to 0.8 to 1.2 years' gain and a large effect size (d=0.6) corresponds to 1.2 to 1.8 years' gain. Therefore, student self-assessment with an overall effect size of d = 0.27 is of magnitude small to medium which corresponds to a 0.5 to 0.8 year's gain, or about six to ten months' gain.

Hattie (2009) points out that, when deciding on whether a certain intervention is worth implementing, the cost of the intervention should also be taken into account instead of just considering the effect size on its own. It may be that the cost is so small that it is worth using even the effect size is small, whereas it may be too costly to implement another intervention even if it is likely to have a larger effect.

The analysis of pre-test and post-test results of treatment and control groups at class level

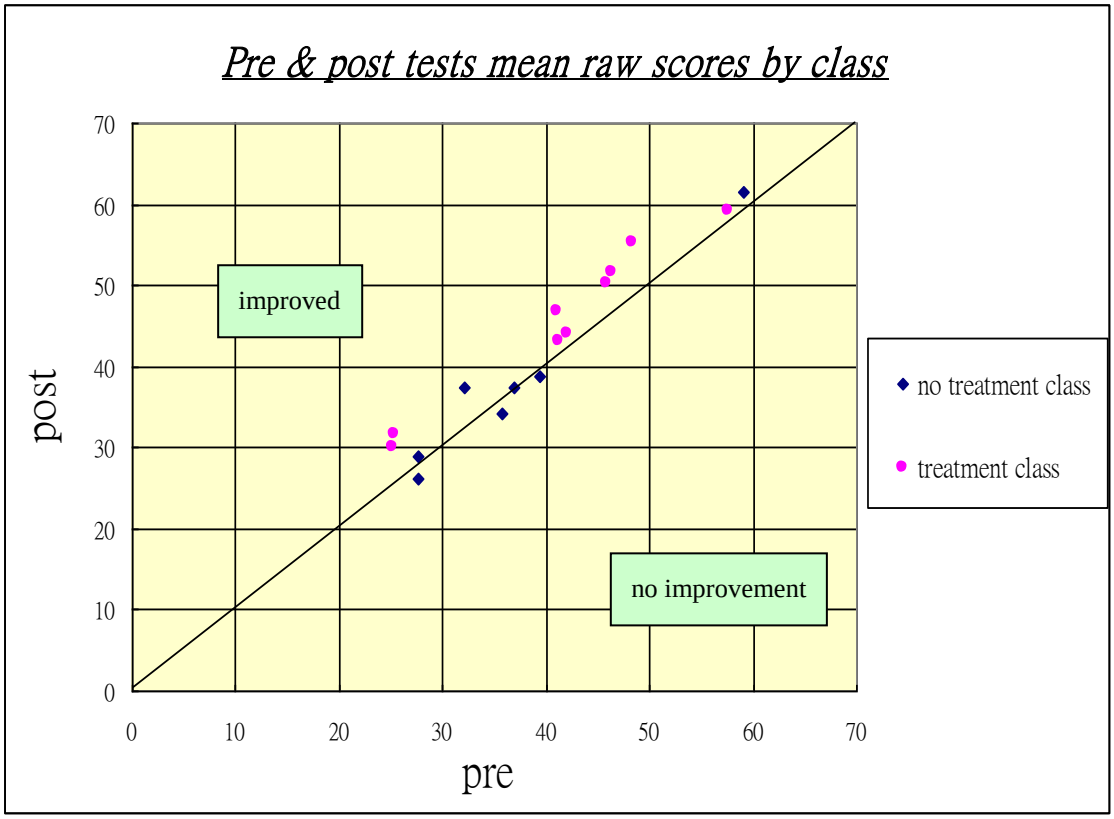


Figure 4.1 Pre- and post-tests mean scores by class.

Figure 4.1 represents the mean pre- and post-tests scores of the classes with self-assessment and those without. All of the 9 classes with self-assessment made improvement. For the 7 classes without self-assessment, 4 of them improved and 3 of them did not. Another observation is that there is no obvious relationship between score gains and pre-test scores. It seems that at class level, students of different attainment could make similar amount of gain.

The comparison of mean pre-test and post-test raw scores of treatment and non-treatment groups

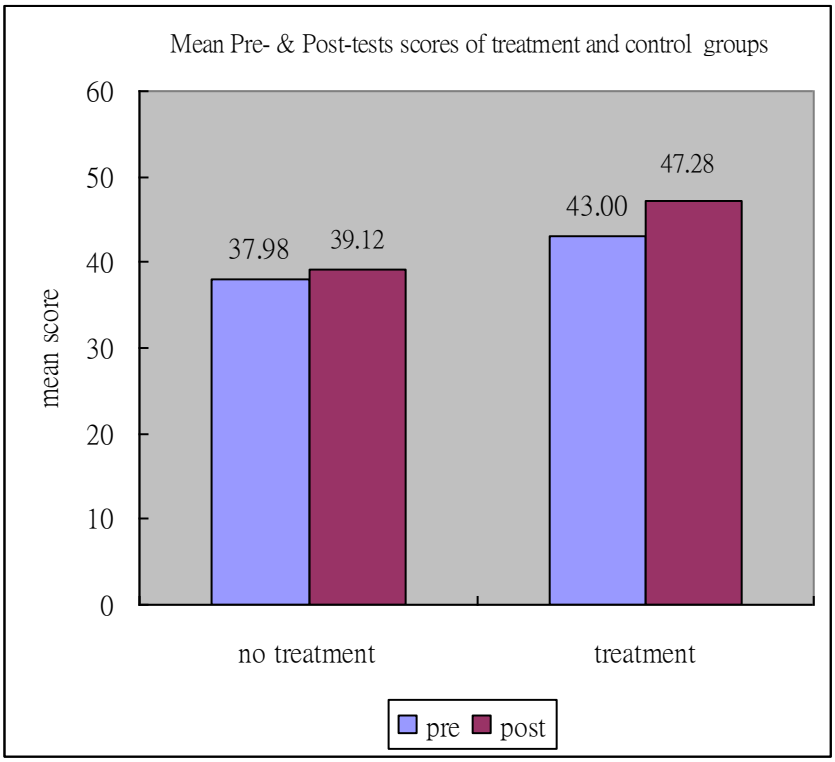


Figure 4.2 Mean pre- and post-tests raw scores of treatment and control groups.

Figure 4.2 represents the pre- and post-tests mean scores of treatment group (315 students) and control group (218 students). It shows that both groups have made some gain. However, the treatment group has gained more than the control group.

A t-test was done to see if the pre-test raw scores of the treatment group and control group were different.

ANOVA

pre_raw_perc

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3253.665	1	3253.665	12.105	.001
Within Groups	142725.865	531	268.787		
Total	145979.529	532			

Table 4.3 ANOVA on pre-test raw scores of students with self-assessment and without self-assessment.

Table 4.3 is the result of the t-test which shows that the pre-test scores of the two groups were different. The control group mean was 37.98 and the treatment group mean score was 43.00 (see figure 4.2). A reasonable concern is that the difference in the gain scores of the experimental and control groups could be accounted for in part by their initial differences in attainment. However, one can notice first in figure 4.1 earlier that there are no obvious associations of gain scores and initial attainment at the level of class performance. Classes of various attainments had made similar amount of progress. The relative gains by students who differ in their initial performance can be explored directly.

Correlations

		pre_raw	Raw_gain
pre_raw	Pearson Correlation	1	-.255**
	Sig. (2-tailed)		.000
	N	315	315

Table 4.4 The correlation between initial attainment and raw score gains of the treatment group.

Correlations

		pre_raw	Raw_gain
pre_raw	Pearson Correlation	1	-.291**
	Sig. (2-tailed)		.000
	N	218	218

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.5 The correlation between initial attainment and raw score gains of the control group.

Tables 4.4 and 4.5 show that the correlation between gain raw scores and initial performance for the experimental and control groups are -0.255 and -0.291 respectively. It seems that the correlation between student ability and student gain is not strong in either group. In addition, since both figures are negative, higher attaining students did not make more gain compared with lower attaining students. So, initial

differences in attainment could not be responsible for differences between the experimental and control group.

Figures 4.3 and 4.4 are the scatter plots of pre- and post-tests scores for the treatment and control groups. It seems that there is no obvious relationship between score gains and pre-test scores.

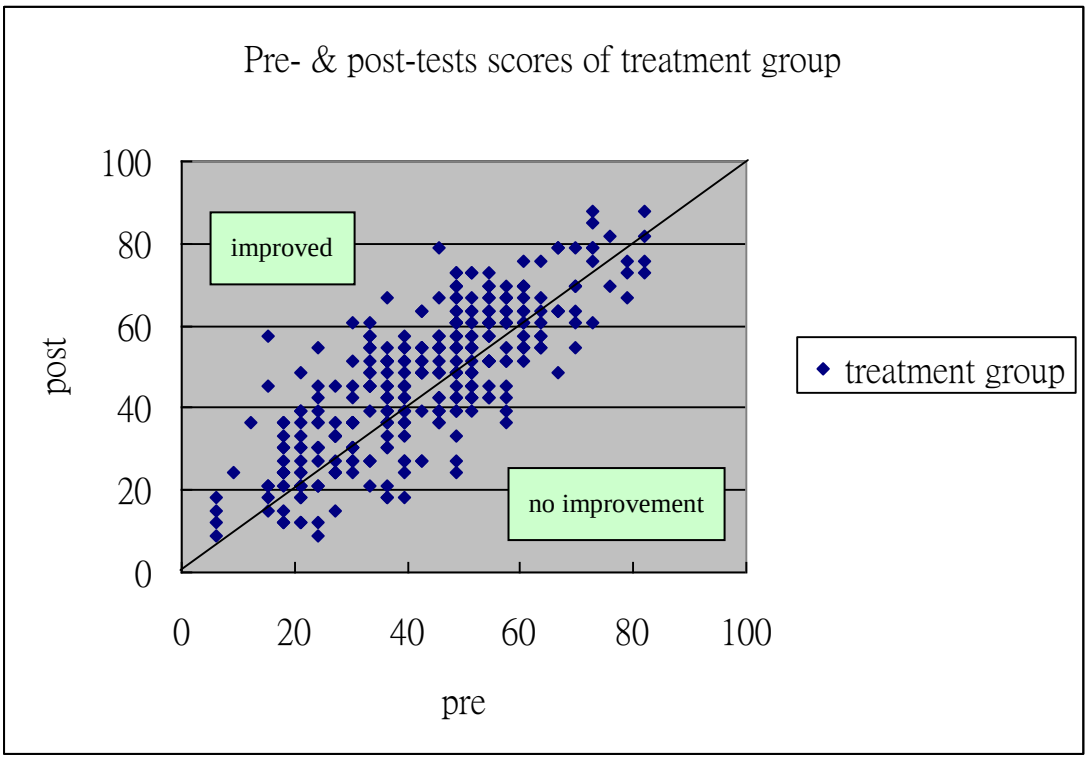


Figure 4.3 The scatter plot of pre- and post-tests scores of treatment group.

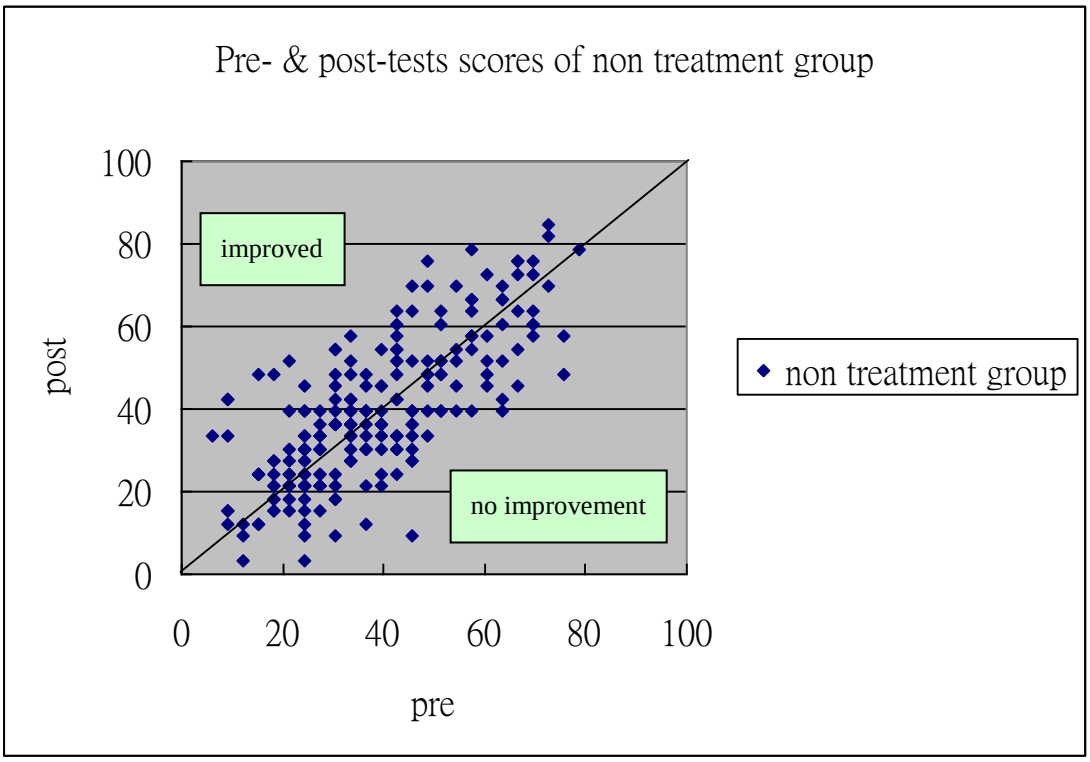


Figure 4.4 The scatter plot of pre- and post-tests scores of non treatment group.

The follow graphs are the residuals plots. The residuals were calculated by subtracting the predicted post-test raw scores from the actual post-test raw scores. It seems that the residuals are uniformly distributed, and therefore initial attainment does not appear to have an effect on raw gain score.

Figure 4.5 The residual plot for all students.

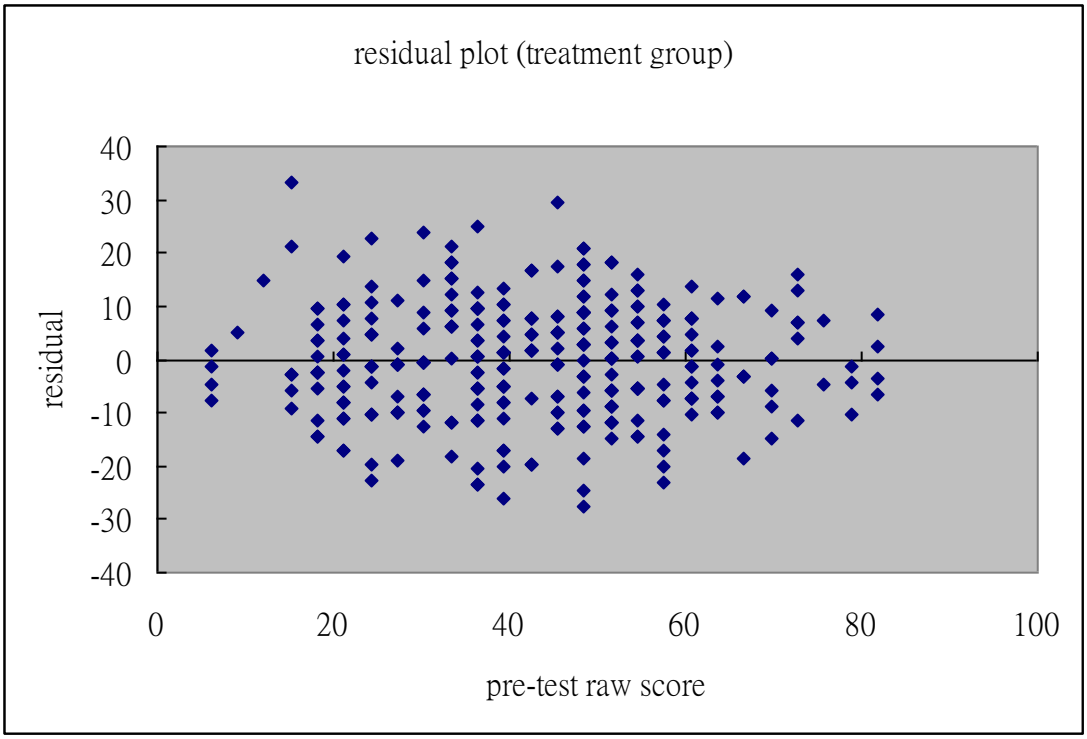


Figure 4.6 The residual plot for the treatment group.

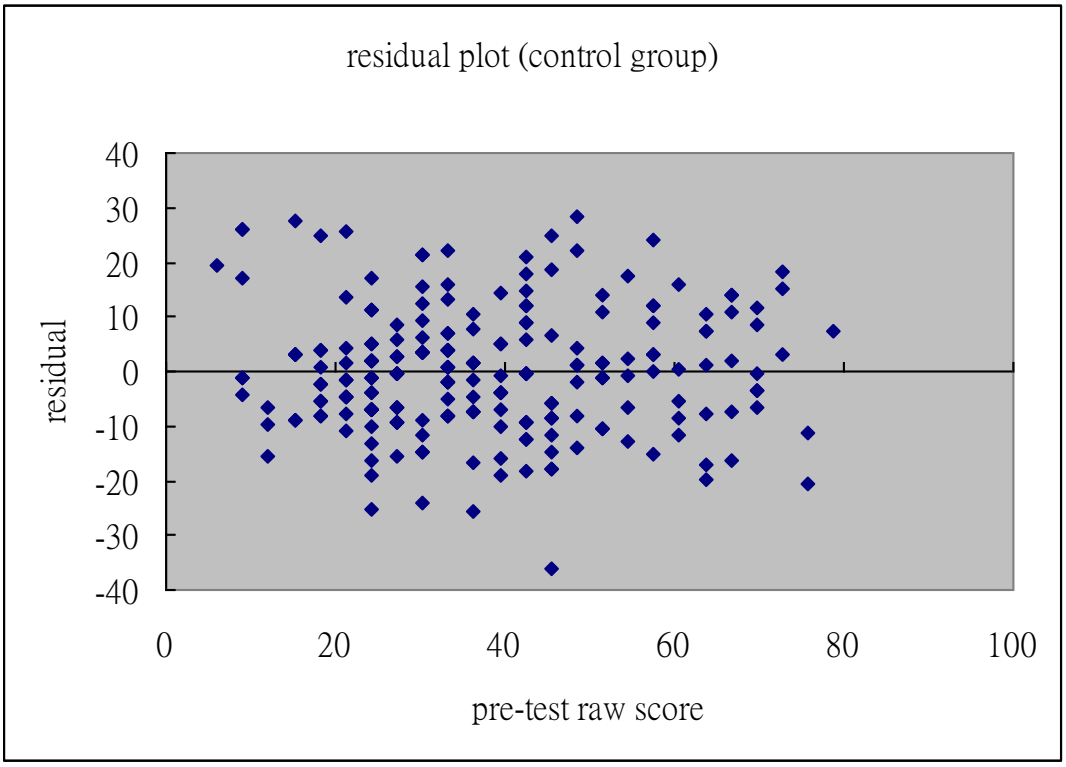


Figure 4.7 The residual plot for the control group.

Data obtained using the pre- and post-tests were subjected to Rasch analysis. An analysis of variance was done on the gain in Rasch scores of the two groups to see if there was a significant difference between the groups. These results will be used to triangulate the results of the analysis of raw scores.

Null hypothesis 1b:

There is no significant difference at alpha level 0.05 in students' gain on Rasch scores between the treatment group (with self-assessment) and the control group (without self-assessment).

Table 4.6 shows the results of analysis of variance on gain Rasch scores of students with self-assessment and without self-assessment.

ANOVA

gain_rasch

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1062.849	1	1062.849	12.025	.001
Within Groups	46934.721	531	88.389		
Total	47997.570	532			

Table 4.6 ANOVA on Rasch score gains of students with self-assessment and without self-assessment.

Table 4.7 shows the mean gain on Rasch scores of treatment group (with self-assessment) and control group (without self-assessment).

Report

gain_rasch

treatment	Mean	N	Std. Deviation
0	.96	218	9.94
1	3.83	315	9.01
Total	2.66	533	9.50

Table 4.7 Mean gains in Rasch scores of treatment group and control group.

The above shows that the results of using Rasch scores for analysis and the results of using raw scores for analysis were similar to those using raw scores. The null

hypothesis that there is no significant difference in students' gain Rasch scores between the treatment group and the control group is rejected (t=0.05, n=533, p<0.001).

From table 4.7, the mean gain Rasch score for all students was 2.66. The mean gain Rasch score for self-assessed students was 3.83, while the mean for control group was 0.96.

The effect size = (3.83-0.96)/9.50 = 0.30

These results also indicated that the students within the self-assessment group out-performed the students in the control group. It seemed that the results of analysis using Rasch scores did not make much difference to the overall results using raw scores.

In order to know if students with different ability levels would receive more or less benefit from self-assessment, the students were divided into three groups – high ability, middle ability and low ability, for further analysis. Pre-test scores were used to categorize the 3 ability groups:

Ability / Group	Low	Middle	High	Total
With self-assessment	82	125	108	315
Without self-assessment	89	78	51	218
Total	171 (Bottom 32%)	203 (Middle 38%)	159 (Top 30%)	533

Table 4.8 The number of students in different ability groups.

Null hypothesis 2a:

There is no significant difference at alpha level 0.05 in gain scores between the low ability students with self-assessment and the low ability students without self-assessment.

ANOVA

Raw_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	278.668	1	278.668	2.256	.135
Within Groups	20872.342	169	123.505		
Total	21151.010	170			

Table 4.9 ANOVA on gain scores of low ability students with self-assessment and without self-assessment.

Based on the results presented in table 4.9, the null hypothesis that there is no significant difference in students' gain scores between the low ability students with self-assessment and the low ability students without self-assessment is accepted (t=0.05, n=171, p=0.135).

Null hypothesis 2b:

There is no significant difference at alpha level 0.05 in gain scores between the middle ability students with self-assessment and the middle ability students without self-assessment.

ANOVA

Raw_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1527.178	1	1527.178	10.835	.001
Within Groups	28329.653	201	140.944		
Total	29856.831	202			

Table 4.10 ANOVA on gain scores of middle ability students with self-assessment and without self-assessment.

Based on the results presented in table 4.10, the null hypothesis that there is no significant difference in students' gain scores between the middle ability students with self-assessment and the middle ability students without self-assessment is rejected ($t=0.05$, $n=203$, $p<0.001$).

Null hypothesis 2c:

There is no significant difference at alpha level 0.05 in gain scores between the high ability students with self-assessment and the high ability students without self-assessment.

ANOVA

Raw_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	415.369	1	415.369	4.351	.039
Within Groups	14988.527	157	95.468		
Total	15403.896	158			

Table 4.11 ANOVA on gain scores of high ability students with self-assessment and without self-assessment.

Based on the results presented in table 4.11, the null hypothesis that there is no significant difference in students' gain scores between the high ability students with self-assessment and the high ability students without self-assessment is rejected ($t=0.05$, $n=159$, $p<0.039$).

Ability	Group	N	Std. Deviation	Mean gain	p-value	Effect size
Low	control	89	11.59	4.39		
	treatment	82	10.57	6.95	0.135	0.23
	Total	171	11.15	5.62		
Middle	control	78	12.08	-.04		
	treatment	125	11.74	5.60	0.001	0.46
	Total	203	12.16	3.43		
High	control	51	11.03	-2.73		
	treatment	108	9.12	.73	0.039	0.35
	Total	159	9.87	-.38		
Total	control	218	11.94	1.14		
	treatment	315	10.89	4.28	0.002	0.27
	Total	533	11.42	3.00		

Table 4.12 Mean gain scores, p-values and effect sizes of different groups.

The above results show that middle and high ability students who did self-assessment had made significant gain compare with the middle and high ability students without self-assessment. However, there is no significant difference in gain scores between the low ability students with self-assessment and those without. Nevertheless, the direction of difference is the same as in the other two groups. Among the three ability groups, the middle ability group had the largest effect size (0.46). One can conjecture that middle ability students received the most benefit from self-assessment. To check whether the difference in effect sizes has occurred by chance. A test was done to see if there was an interaction effect of treatment and ability on gain scores.

Tests of Between-Subjects Effects

Dependent Variable:Raw_gain

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5248.711[a]	5	1049.742	8.618	.000
Intercept	3035.161	1	3035.161	24.918	.000
treatment	1858.384	1	1858.384	15.257	.000
ability_raw	3405.656	2	1702.828	13.980	.000
treatment * ability_raw	228.057	2	114.029	.936	.393
Error	64190.522	527	121.804		
Total	74224.059	533			
Corrected Total	69439.233	532			

a. R Squared = .076 (Adjusted R Squared = .067)

Table 4.13 Test results of interaction effect of treatment and ability on gain scores.

Table 4.13 shows the results of interaction effect of treatment and ability on gain scores. It shows that there is no significant interaction effect of treatment and ability on gain scores. Therefore, the difference in effect sizes among the three groups may have occurred by chance. It is reasonable to conclude that the effects of self-assessment apply across the ability range.

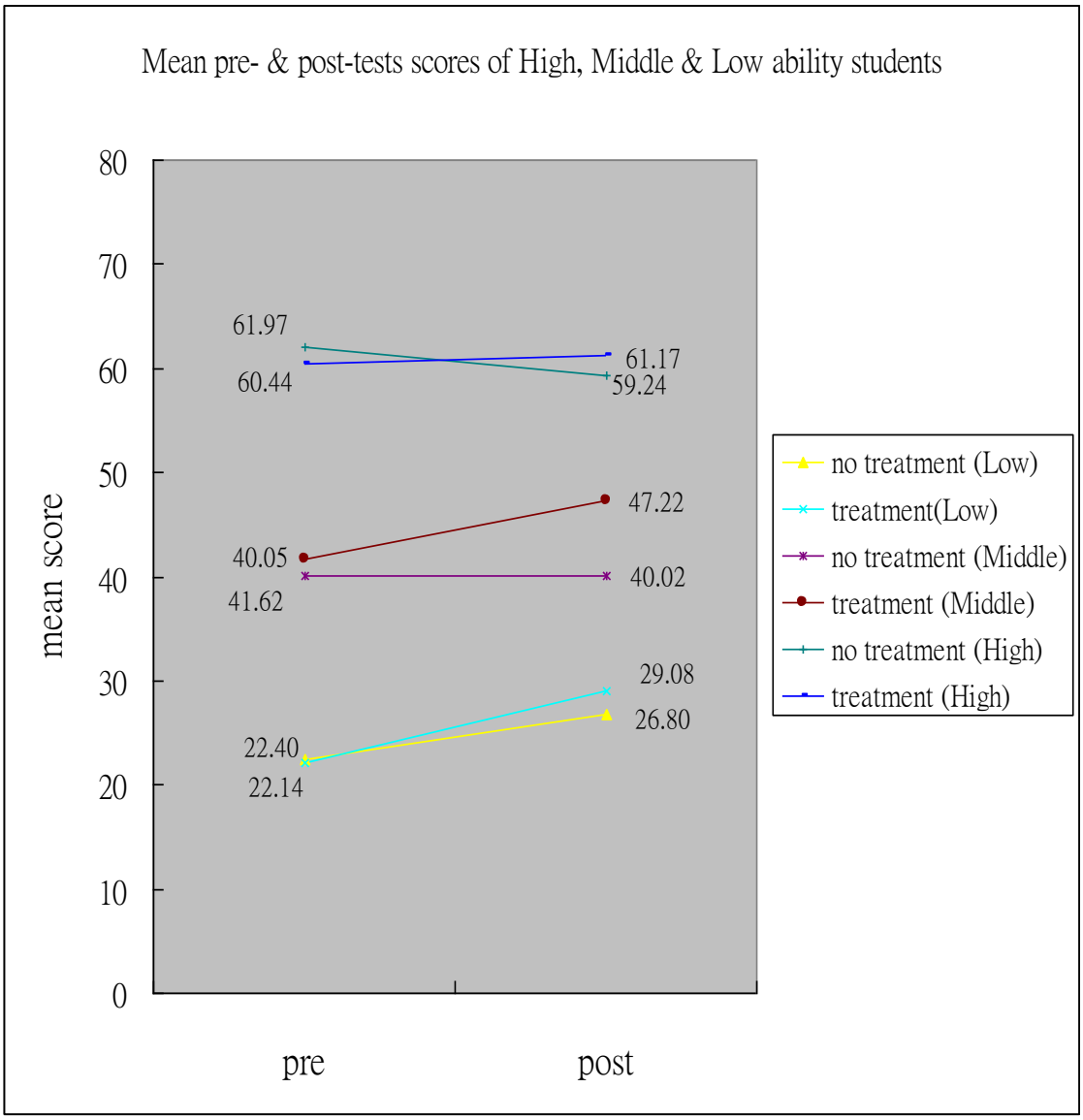


Figure 4.8 Mean pre- and post-tests scores of low, middle and high ability students.

Figure 4.8 represents the mean pre- and post-tests scores of high, middle and low ability groups. It indicated that students with self-assessment from all the three ability groups had gained more, compared with those without self-assessment within the ability group.

For high ability students, it seems that there was little gain. The high ability control group had a negative gain and the high ability treatment group had only a small gain. Nevertheless, the difference in their gains was still significant.

Analysis on items

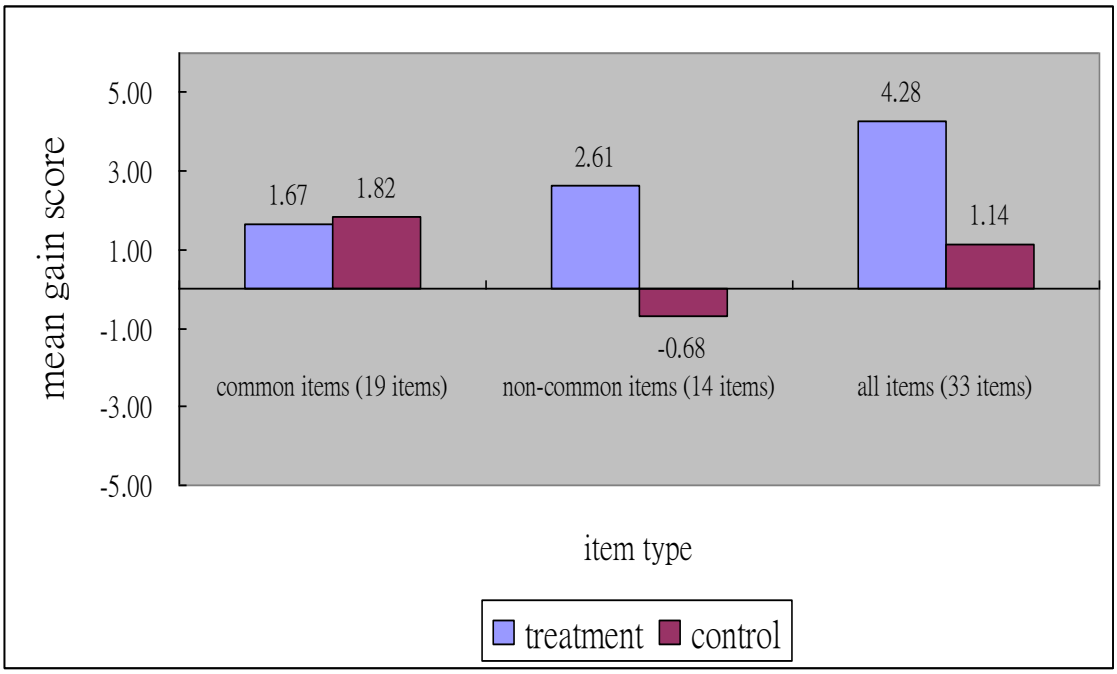


Figure 4.9 Mean gain scores by item type.

As shown in figure 4.9, the mean gain score (scale of 100 points) of all items of the treatment group was 4.28 and the mean gain score of the control group was 1.14. For the common items, the mean gain of treatment group was 1.67 and the mean gain of control group was 1.82. For the non-common items, the mean gain of treatment group was 2.61 and the mean gain of control group was -0.68. It seems that most of the gain of the treatment group came from non-common items. So, although students with self-assessment did not gain as much as those without for items they have seen before, they did much better for new items.

	treatment				control			
	pre		post		pre		post	
	mean	SD	mean	SD	mean	SD	mean	SD
all items (33)	14.19	5.37	15.60	5.65	12.53	5.47	12.91	5.74
common items(19)	8.17	3.55	8.72	3.60	7.03	3.34	7.63	3.80
non-common items (14)	6.02	2.37	6.88	2.61	5.50	2.55	5.28	2.31

Table 4.14 Average number of items correct and standard deviation of different groups by item type.

The above table shows the average number of items correct of different groups categorized by item type.

Report

treatment		Overall	Common item	Non-common item
0	Mean	1.14	1.82	-.68
	N	218	218	218
	Std. Deviation	11.94	8.75	6.38
1	Mean	4.28	1.67	2.61
	N	315	315	315
	Std. Deviation	10.89	8.09	7.05
Total	Mean	3.00	1.73	1.26
	N	533	533	533
	Std. Deviation	11.42	8.36	6.97

Table 4.15 The mean gain and standard deviation of different groups by item type.

With reference to table 4.15, the effect size by item type can be calculated:

The effect size of self-assessment on common items

= (1.67-1.82)/8.36

= -0.02

The effect size of self-assessment on non-common items

= (2.61-(-0.68))/6.97

= 0.47

The above results show that there was no effect on common items but there was a medium to large effect on non-common items.

Analysis of Rasch scores

A Rasch analysis was performed on all the items in the pre- and post-tests. The simple Rasch model is a mathematical model that represents the probability of a response in terms of a logistic function of the difference between the ability of the person taking the test and the difficulty level of an item (Mok, 2010). The model can be used to examine and validate psychometric properties of a measurement instrument. In this study, the Rasch scores were used to test if there was a difference in gains between the treatment and control groups, and see if the results were similar to the analysis using raw scores. Also, item measures were used to see if different groups found the items in the pre- and post-tests more or less difficult. The Rasch Model was also used to examine, validate and analyze items relating to students' ability in mathematics. The misfit statistics could show the quality of test items. Items with high misfit statistics would be looked into and, after discussing with the teachers (an example of the discussion is shown on P. 106), some of them might be discarded and would not be put in the post-test.

The following figure is the item-item map of pre- and post-tests items from Rasch analysis. Items on the lower part of the scale are easier items (low item measure), whereas items on the upper part of the scale are harder items (high item measure). The pre- and post-tests item labels were the labels used in the actual tests (see Appendices I and II).

Item – Item Map (Pre-test and Post-test)

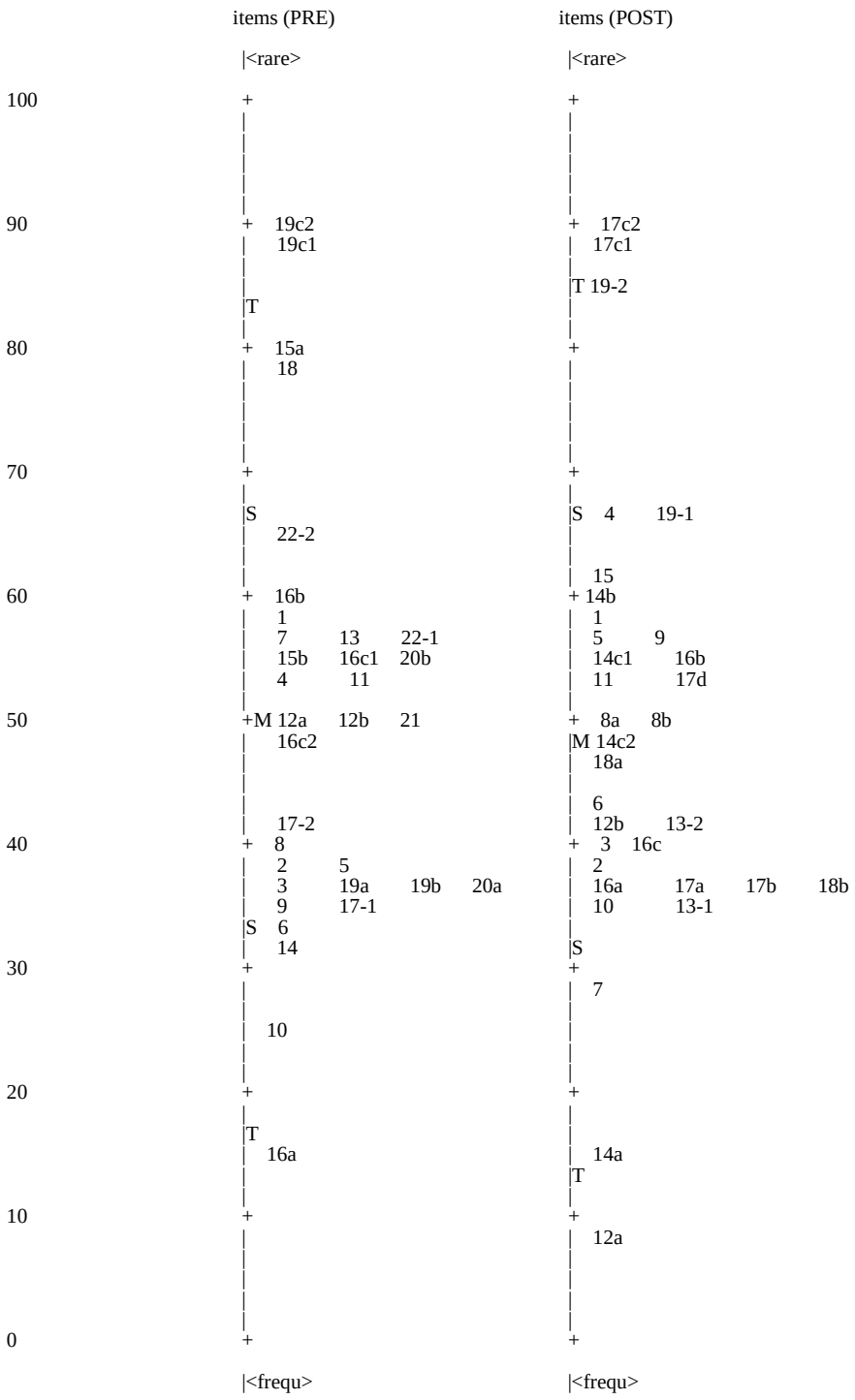


Figure 4.10 Item-item map of pre-and post-test items.

The following table (Table 4.16) shows the item measures and fit statistics of pre-test and post-test items. Items with small item measures are easier items, whereas items with large item measures are harder items. There were 33 items in pre-test and also 33 items in post test. The 19 common items, which appeared in both the pre- and post-tests, were labelled C1 to C19. Those items have the same item measures in both tests. The non-common or unique items Pre1 to Pre14 appeared in pre-test only, whereas Post1 to Post14 appeared in post-test only. The pre- and post-tests item labels were the labels used in the actual tests. The standardized fit indexes (Z) are for assessing item fit. As a rule of thumb, items with Z values greater than 2 are items with unexpected or irregular response pattern across items, and items with Z values smaller than -2 are items with possible redundancy in responses (Schumacker, 2004). Another useful fit statistic is the point-measure correlation coefficient. A negative value indicates an inverse relationship between the dichotomous response and the total raw score. A rule of thumb is to delete items with point-measure correlation coefficients less than or equal to zero.

A Rasch analysis was first performed on the pre-test items. Items with misfit statistics were identified. Those items were looked into by the researcher and the teachers. If they found that there was a problem of the quality of the items, those items were not put in the post-test. For example, items Pre2, Pre8 and Pre12 are misfit items and were not put in the post-test. Some items such as C1, C12, C13 and C19 did not fit well but were kept after discussions with teachers when it was agreed that those items were mathematically valuable items, and should be used again in the post-test. However, other factors such as the syllabus, the teaching schedules of different schools and item measures also affected the choice of which items could appear in the post-test.

	Pre-test					Post-test				
Common item label	item label	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.	item label	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.
C1	1	58.58	7.8	9.3	-0.08	1	58.58	6.5	8	-0.05
C2	2	39.14	0.7	0.7	0.39	2	39.14	5.8	4	0.42
C3	7	56.22	1.2	1.5	0.35	5	56.22	6	6.1	0.33
C4	8	39.44	-2.2	-1.9	0.49	3	39.44	-2.3	-2.1	0.47
C5	12a	49.31	-0.5	-0.8	0.45	8a	49.31	1.7	1.8	0.35
C6	12b	49.37	0.6	1	0.4	8b	49.37	1	0.9	0.39
C7	13	57.35	-1.7	-1.5	0.47	9	57.35	-0.1	-0.2	0.5
C8	16a	15.79	-0.7	-0.7	0.32	14a	15.79	-2.1	-1.9	0.29
C9	16b	60.06	0.9	0.8	0.33	14b	60.06	2.5	2	0.43
C10	16c1	55.12	-0.8	-1.5	0.46	14c1	55.12	-2.4	-2.3	0.57
C11	16c2	48.48	-0.5	-0.9	0.45	14c2	48.48	-3	-3.1	0.58
C12	17-1	34.96	-3.8	-3.2	0.55	13-1	34.96	-6.4	-5	0.53
C13	17-2	41.83	-3.6	-3.4	0.54	13-2	41.83	-4.8	-4.4	0.57
C14	19a	36.55	2.5	1.3	0.31	17a	36.55	0.3	0.5	0.37
C15	19b	36.94	1	0.6	0.37	17b	36.94	-1.8	-2.1	0.47
C16	19c1	88.67	-0.3	-2	0.31	17c1	88.67	1.9	0.2	0.28
C17	19c2	89.78	-0.1	-1.4	0.25	17c2	89.78	-0.6	-1.3	0.2
C18	20a	36.49	-1	-0.1	0.44	16a	36.49	-0.8	0.1	0.4
C19	20b	54.25	-2.5	-2.6	0.53	16b	54.25	0.1	0.1	0.45
	Pre-test					Post-test				
Unique item label	item label	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.	item label	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.
Pre1	3	37.19	-1.1	-1	0.45					
Pre2	4	53.95	2.5	2.7	0.31					
Pre3	5	38.95	1	0.5	0.39					
Pre4	6	34.36	0.2	-0.4	0.39					
Pre5	9	36.2	1.7	3.8	0.32					
Pre6	10	25.57	0.2	0.2	0.31					

Pre7	11	54.87	0.1	-0.7	0.42					
Pre8	14	33.47	2.2	1.2	0.28					
Pre9	15a	79.72	-0.6	-1.7	0.37					
Pre10	15b	56.19	-0.8	-1.4	0.46					
Pre11	18	78.77	-0.1	-1.6	0.32					
Pre12	21	49.9	-4.6	-4.2	0.59					
Pre13	22-1	57.5	-1.1	-0.9	0.45					
Pre14	22-2	65.05	-1.1	-1.4	0.44					
Post1						4	66.94	-0.1	2.6	0.31
Post2						6	43.68	-1.6	-1.5	0.48
Post3						7	27.97	-0.5	1.6	0.36
Post4						10	35.79	2.4	4.7	0.27
Post5						11	53.63	-0.5	-0.6	0.45
Post6						12a	8.89	0	-0.1	0.2
Post7						12b	41.13	-0.4	0.3	0.43
Post8						15	61.43	0.6	0.9	0.35
Post9						16c	39.62	0	0.4	0.41
Post10						17d	53.18	4.9	6.2	0.2
Post11						18a	47.12	-3.7	-3.7	0.56
Post12						18b	36.08	1.8	0.7	0.33
Post13						19-1	66.55	-1.4	-1.6	0.46
Post14						19-2	85.48	-0.6	-1.6	0.36

Table 4.16 Item measures and fit statistics of pre-test and post-test items.

The Rasch analysis of pre-test items shows that item C1 did not fit well. It has large Z values, and its point-measure correlation coefficient is negative. Item C1 is shown below:

Which of the following(s) is/are factor(s) of $3(a-b)^2 + (a-b)$?

(I) a-b

(II) 3a-3b+1

(III) 3

A. I only

B. I and II only (correct answer)

C. I and III only

D. I,II and III

Many students with high ability could not get this item right. Before deleting the misfit item, a discussion was conducted on this item with the teachers of one of the participating schools. It was found that most students who got it wrong in the pre-test chose A as the answer (see table 4.17). According to the Rasch analysis shown below, the best students chose A. The next best chose C, and then B, and then D.

Answer	Score value	percentage	Average student measure
A	0	42%	47.86
B (correct answer)	1	24%	44.73
C	0	30%	46.30
D	0	4%	43.30

Table 4.17 Distribution of choices of item C1.

The teachers first investigated whether there is something wrong with the question such as misleading or unclear wordings, grammar etc. They concluded that the item is fine in that sense. In the discussion, one teacher suggested that perhaps the question is too hard so everyone just guessed the answer (this item has a high difficulty level for students of that school). However, after a deeper discussion, the teachers came up with a conclusion:

Most students who did this question wrong chose A as the answer. So it is not likely that they were guessing. Why so many students (even the more able students) chose A? One teacher suggested that perhaps most students knew how to factorize a polynomial, but the problem was when the students took the common factor (a-b) out, they thought that (a-b) is the only factor. The students did not consider that (3a-3b+1) is also a factor. They misunderstand that only the factor being taken out is a factor and those left behind are not. This showed that the students may know how to do factorization (a lot of drilling was done) but not fully understand the concept of ‘factor’. The teachers

then did some follow up actions and adjust their teaching strategies to help students understand the meaning of factor better. This showed a valuable use of the Rasch model.

The following table shows the fit statistics and measures of pre-test items for the treatment and control groups. It seems that the fit statistics of the two groups are quite similar, except item C14, which has a slight difference.

pre-test								
LABEL	treatment				control			
	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.
C1	61.62	5.1	7.9	-0.11	55.44	5.8	4.8	-0.08
C2	34.05	-0.6	-0.9	0.45	45.07	1.8	1.8	0.33
C3	54.64	0.7	0.9	0.37	59.1	1.8	2.3	0.21
C4	37	-1.8	-1.6	0.5	41.4	0.1	0.1	0.42
C5	51.46	-0.7	-0.8	0.45	45.87	-0.3	-0.5	0.45
C6	52.17	0	1	0.4	45.43	0.3	0.5	0.41
C7	57.48	-1.1	-1.4	0.46	55.05	-1.8	-1.4	0.52
C8	17.18	-0.7	-0.9	0.36	13.91	-0.2	-0.2	0.27
C9	60.89	0.8	1.1	0.31	58.67	-0.1	-0.4	0.4
C10	52.01	-0.4	-0.8	0.44	60.87	-0.2	-0.6	0.41
C11	48.44	0.3	-0.1	0.41	50.64	-1.1	-1.1	0.5
C12	35.32	-3.5	-2.9	0.59	32.99	-1.9	-1.7	0.51
C13	42.57	-3.3	-3.2	0.57	40.22	-0.7	-0.8	0.47
C14	42.29	0.5	-0.2	0.41	29.35	1.9	2	0.18
C15	36.13	1.5	1.3	0.32	37.12	0.2	-0.4	0.41
C16	86.76	-0.3	-1.7	0.35	94.45	0.2	-0.5	0.21
C17	88.2	0	-1.1	0.27	94.45	0.2	-0.5	0.21
C18	35.58	0	1	0.37	36.1	-0.3	-0.2	0.41
C19	52.57	-2.4	-2.2	0.53	56.97	-1.3	-1.6	0.54
Pre1	35.87	-0.5	-0.8	0.44	38.31	-0.7	-0.3	0.44
Pre2	54.88	2.9	2.3	0.26	53.62	0.4	1.5	0.36
Pre3	42.14	1.2	1	0.38	34.61	-1.2	-1.4	0.47

Pre4	34.19	-0.2	-0.7	0.42	37.75	0.2	-0.1	0.4
Pre5	32.44	1.4	4.5	0.26	38.1	0.8	0.5	0.37
Pre6	25.96	0.7	0.7	0.26	25.75	-0.3	0.5	0.34
Pre7	53.64	0.5	-0.4	0.4	57.92	0	-0.3	0.4
Pre8	35.1	2.4	1.3	0.24	30.18	0.5	0	0.34
Pre9	77.29	-0.6	-1.3	0.4	84.11	0	-0.9	0.32
Pre10	60.05	-0.3	-1	0.43	51.48	-1.7	-1.5	0.54
Pre11	76.79	-0.1	-1.2	0.33	75.42	-0.1	-1.2	0.34
Pre12	50.34	-3.2	-3	0.56	49.13	-3.7	-3.3	0.65
Pre13	61.47	-1.7	-1.9	0.51	50.47	0.1	-0.3	0.43
Pre14	63.5	-0.3	-0.2	0.38	70.06	-0.7	-1.2	0.42

Table 4.18 Fit statistics and measures of pre-test items for the treatment and control groups.

The following table shows the fit statistics and measures of post-test items for the treatment and control groups. It seems that the fit statistics of the two groups are quite similar, except for item C1, which the treatment group fits slightly better than the control group.

post-test								
	treatment				control			
LABEL	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.	item measure	infit ZSTD	outfit ZSTD	PTMEA CORR.
C1	65.19	3.7	5.2	0.05	57.67	6.3	7.3	-0.17
C2	44.74	0	-0.3	0.45	53.73	1.7	1.2	0.33
C3	54.9	2.1	2.9	0.34	46	1.2	0.4	0.39
C4	38.15	-0.5	-0.3	0.45	38.66	-1	-1.6	0.48
C5	62.02	1.3	1	0.32	44.85	-1.7	-1.4	0.52
C6	62.92	0.9	0.4	0.35	45.81	-2.5	-2.2	0.57
C7	56.62	-1.6	-1	0.49	53.91	-1.6	-1.5	0.53
C8	17.57	-0.4	-0.6	0.32	4.74	-0.1	-1	0.28

C9	57.48	-1.1	-1.3	0.47	55.95	0.8	0.9	0.37
C10	52.94	-2.6	-2.6	0.55	55.02	-2.3	-2.1	0.6
C11	58.03	-3	-2.7	0.57	55.42	-2.3	-2.1	0.6
C12	32.64	-2.5	-2.1	0.54	30.35	-1.9	-2.1	0.51
C13	40.57	-2.4	-2.2	0.54	43.04	-3.1	-3	0.58
C14	33.47	1.5	2.1	0.26	40.52	-0.4	-0.8	0.45
C15	37.37	-0.8	-1.1	0.46	37.3	-1	-1.4	0.47
C16	82.06	-0.3	-0.7	0.3	92.11	0.2	-0.6	0.23
C17	93.53	0.1	-0.4	0.19	92.11	0.2	-0.6	0.23
C18	38.12	-0.6	0.1	0.43	34.41	0.2	0.7	0.35
C19	53.05	-0.6	0.2	0.44	53.46	0	-0.5	0.45
Post1	71.18	-0.4	1.8	0.33	63.33	0.3	1.9	0.32
Post2	40.97	-0.9	-1	0.48	49.45	-0.2	-0.4	0.45
Post3	27	-0.6	1.8	0.39	30.62	0.3	0.9	0.31
Post4	40.57	2.9	4.5	0.25	30.74	0	0.6	0.35
Post5	50.04	0.4	0.6	0.41	65.07	-0.7	-0.6	0.46
Post6	4.73	0.1	-0.1	0.16	13.07	0.1	0.4	0.21
Post7	40.33	-0.5	0.2	0.44	44.24	0.9	1.4	0.38
Post8	58.14	1	1.1	0.36	84.31	0.2	1.2	0.16
Post9	40.6	0.4	0.8	0.38	40.45	0	0	0.42
Post10	55.92	4.3	5.3	0.18	51.3	2.6	3.4	0.25
Post11	48.65	-2.8	-2.9	0.56	47.18	-2.2	-1.9	0.57
Post12	37.22	1.4	0.5	0.34	36.41	1.5	0.9	0.3
Post13	67.25	-1.7	-1.8	0.5	69.37	0.1	-0.1	0.36
Post14	86.03	-0.8	-1.6	0.42	89.4	0.2	-0.1	0.2

Table 4.19 Fit statistics and measures of post-test items for the treatment and control groups.

For the common items (C1 to C19), the treatment group found 7 out of 19 items easier compared to the control group. For unique items (Post1 to Post14), the treatment group found 8 out of 14 items easier compared to the control group. It seems that the control group performed better than the treatment in responding to common items. But the treatment group did better than the control group in responding to unique items.

The results of analysis using Rasch scores were as follows:

- The treatment group out-performed the control group (null hypothesis 1b rejected). The results of analysis using Rasch scores did not make much difference to the overall results using raw scores.
- By looking at the misfit items, some of the students' misconceptions were identified and teaching strategies were adjusted accordingly. Also, some of the misfit items were discarded.
- The treatment group out-performed the control group in answering new items. But the control group did better than the treatment group in responding to common items.

4.2 Results of the analysis of student samples

When the mathematics teachers had finished a lesson, or had taught students a mathematics concept or topic, the students were asked to do some self-assessment. At the beginning, the teachers would tell them the purpose of the self-assessment exercise and give them guidance on how to do so. The analysis of student samples showed that, in many cases, the self-assessment activity had provided opportunities to reflect on their learning and learning strategies. Some students showed a deep understanding of mathematics concepts; some showed their abilities to self-evaluate and find ways to change and improve; some showed a higher engagement in their learning; some showed the ability to reorganize what they had learned and present it in their own ways. It seemed that the self-assessment had made some impact on their Learning strategies & behaviours, Self-assessment skills & self-knowledge, Meta-cognition and

Motivation, which are important elements of self-directed learning. The following table is a summary of the result of the analysis.

SDL elements	Label	No. of occurrences
Learning strategies & behaviours		
Consciously select and implement learning strategies	Learn1	48
Strategic help seeking, know when to seek help	Learn2	12
Can identify what is important	Learn3	65
Know what needs to be understood or memorized	Learn4	68
		193
Self-assessment skills & self-knowledge		
Know better about current performance levels	Self1	31
Can self- evaluate the level of understanding	Self2	46
Can self-assess the learning outcomes	Self3	11
Can reflect on what is learned	Self4	74
		162
Meta-cognition		
Awareness that he/she does or does not understand	Meta1	42
Can evaluate how good a particular learning strategy is	Meta2	11
Think about learning	Meta3	29
Able to re-organize and re-construct	Meta4	49
		131
Motivation		
More engaged in learning	Moti1	43
Want to learn more	Moti2	10
		53

Table 4.20 The summary of the results of the analysis of student samples.

It can be seen that the number of occurrences of learning strategies & behaviours is the highest compared to the other three SDL components. Self-assessment skills & self-knowledge is the second highest, then followed by Meta-cognition. Motivation has the lowest number of occurrences.

In general, the total number of occurrences of learning strategies & behaviours is relatively high (193). However, when we look closer at each individual element, we can see that the SDL element - Strategic help seeking, know when to seek help (Learn2), has a relatively low occurrence (12). It could imply that the students did not know when and how to seek help from their teachers and peers. The rest of the other 3 elements had high occurrences. It seems that students were able to select and implement learning strategies (48), identify what is important (65), and know what needs to be understood or memorized (68). It is likely that teachers were constantly and consciously stressing the importance of particular concepts and co-constructing good problem solving strategies with their students.

The total number of occurrences of self-assessment skills & self-knowledge was quite high too (162). Many students knew their performance level (31), could self-evaluate their level of understanding (46) and were able to reflect on what was learned (74). Perhaps, the on-going reflective activity had given students opportunities to reflect on their learning and the students had eventually mastered the skill. However, most of them were unable to self-assess their learning outcomes (11 occurrences only).

Meta-cognition had a total of 131 occurrences. Many of the student samples showed that students had a deep understanding of mathematics concepts. A relatively large

number of occurrences (49 occurrences) of the SDL element – the ability to re-organize and re-construct (Meta4), were identified from the student samples. As we can see from some of the samples, students were able to write stories in their own words or make drawings about certain mathematics concepts. It is unlikely that students lacking the understanding of a mathematics concept would able to display the concept correctly in their own ways. Also, many students had the awareness that they do or do not understand a particular mathematics concept (42). It seems that the reflective approach had facilitated the development of meta-cognition, and therefore it had a positive impact on students' understanding of mathematics concepts. However, the ability to evaluate how good a particular learning strategy is relatively low (the number of occurrences of Meta2 is only 11).

The samples also showed that some students became more engaged in their learning (43 occurrences). The self-assessment exercise seems to have motivated the students to become more engaged in learning. The approach provided students an alternative way to express their ideas and even their feelings about mathematics concepts. As seen from the student samples, some students wrote long and interesting stories, and some drew beautiful mind maps and think boards to express their thinking.

From the student samples and the results of the analysis, we can see that the use of self-assessment tools to reflect about the learning process in classrooms had facilitated self-directed learning. The improvement in students' self-directedness in learning would have a positive impact on students' future learning and also their self-assessment ability.

On the other hand, the above results could also inform pedagogy as well. They provide useful information to teachers to design more appropriate instructions for their students in the future. With regards to student self-assessment, there were areas where students were weaker and might need more facilitation. Teachers could put more emphasis on improving those skills in their classrooms. For instance, both the ability to self-assess their learning outcomes and the ability to evaluate how good a particular learning strategy is are relatively low. It is helpful for pupils to be able to self-assess their learning outcomes. If they are unaware of the level of specific competencies that are expected of them, students will have no way to become aware of any gaps between their current competency levels and those required to complete a course (TLTC, 2004). Also, to involve students in assessing the quality of their work can give them a clearer sense of the learning outcomes toward which they are working and can motivate them to learn. In order to help students to self-assess their learning outcomes, teachers should let students know what they are supposed to learn. Students must have a clear sense of the learning outcomes teachers want them to learn. One way is to develop a rubric with students that outline the attributes of a quality performance. Another way is to share examples of prior student performances with students and work with them to identify the qualities of quality performances (SERGE, 2008). From the student self-assessment samples, we can see that another area which needs improvement is the ability to evaluate how good a particular learning strategy is. Self-regulation of cognition is a component of meta-cognition, and it should include assessing and evaluating effectiveness, and revising strategies being used (Nietfeld, Cao, & Osborne, 2005; Mok, 2009). In Hong Kong many students are not used to focusing on how they learn, instead, the focus is on what they learn. To overcome that, strategies instruction should be given to pupils. The result from the analysis of student self-assessment samples suggested that learning how good a particular strategy or groups of strategies

actually is requires direction and guidance from the teachers. The aim of this strategy instruction is to help students to gain the ability to evaluate strategies and use them appropriately in different contexts (EILS, 2010), and hence, to become more self-directed in learning.

CHAPTER 5 Discussion of results and conclusions

This final chapter presents the discussion of results and the conclusions of the study. It begins by listing the important findings, revisiting the theories and frameworks about self-directed learning and self-assessment, and discussing the results of the study, linking in the literatures. Then, the implications for the education policy, school development and teacher professional development are discussed.

5.1 Discussion of findings

The present study examined the ways to use student self-assessment in classrooms to promote self-directed learning and improve achievement in the mathematics of Secondary Three students in Hong Kong. Specifically, the research investigated the relationship between the use of self-assessment tools to reflect about the learning process and self-directed learning. The self-assessment tools used were student reflective journals, think boards and mind maps. Students from both the treatment and control groups completed a pre-test and post-test, and the tests results were used to measure the change in mathematics achievement before and after the intervention.

5.1.1 The findings

The study produced a number of important results.

Increase in achievement

The study findings indicated that when guided self-assessment was used, an increase in achievement was observed. The overall effect size of this student self-assessment

strategy is d = 0.27. This means that the treatment group had an increase of 0.27 standard deviation on mathematics achievement compared with the control group. An overall effect size of d = 0.27 is of magnitude small to medium which corresponds to a 0.5 to 0.8 year's gain, or about six to ten months' gain.

The difference between the gain scores of treatment group and control group is statistically significant (t=0.05, p=0.002, n=533). The result indicates that the difference is most unlikely to have arisen by chance.

More gains on new items

The treatment group gained on both the items that were common to the pre- and post-tests, and on the non-common items. The control group found the common items easier but the control group found the non-common items more difficult than did the experimental group. The largest part of the control group's gain was from common items. Therefore, it is reasonable to conclude that the students with self-assessment were better able to tackle new challenges more effectively than students without self-assessment. The reflective approach seems to prepare students better for engaging with new materials.

Facilitate Self-Directed Learning

This study also explored the relationship between student self-assessment and self-directed learning. In particular, how students reflect about their own learning can affect students' self-directedness in learning. It seems that the self-assessment activity is most helpful in facilitating students to develop learning strategies and behaviours. Many students were able to write down what is important, and what needs to be understood or memorized. Also, self-assessment seems to help students to develop

self-assessment skills and self-knowledge. Many students were able to reflect on what is learned and self- evaluate their level of understanding. Although the total number of occurrences of Meta-cognition and Motivation are not as high as Learning strategies & behaviours and Self-assessment skills & self-knowledge, it was found that many students were able to re-organize and re-construct what they have learned and were aware whether they understand the concept or not.

Raw gain scores and initial performance are not correlated

Initial attainment does not appear to be associated with raw gain score in any simple way. The correlation between gains in raw scores and initial performance for the experimental and control groups are -0.255 and -0.291 respectively. The results are statistically significant even though the effect size is small. The correlation between students' initial attainment and student gain is not strong in either group. Since both figures are negative, higher attaining students did not make more gain compared with lower attaining students. One might speculate that the reflective activities would be of most benefit to the lowest attaining pupils. It is possible that higher attaining pupils are doing better because they already engage in reflective activities.

Gains at class level

At class level, each of the 9 classes with self-assessment made improvement. For the 7 classes without self-assessment, 4 of them improved and 3 of them did not. Also, there is no obvious relationship between score gains and average class pre-test scores. It seems that at class level, students of different attainment could make similar amount of gain.

Gains by different ability groups

Based on the pre-test scores, students were divided into three groups – high ability, middle ability and low ability, for analysis. Students with self-assessment from all the three ability groups had gained more compared with those without self-assessment within the ability group. Among the three ability groups, the middle ability group had the largest effect size of 0.46. The low ability and high ability groups have effect sizes of 0.23 and 0.35 respectively. The gains appeared to be somewhat uneven across the attainment range. However, the difference in effect sizes may have occurred by chance as there is no significant interaction effect of treatment and ability on gain scores.

5.1.2 Discussion

The results of this study show that many components, attributes or skills of self-directed learning can be found in the student self-assessment work. It does support Cassidy's (2006) point that the ability to self-assess appears central to many studies examining the issue of independent learning. Also, Gibbons (2002) suggests that any self-directed learning programme must engage students in the ongoing assessment of their work. Students should be able to assess the importance of what they have accomplished, their attitudes as a learner, their approaches to tasks, their problem solving abilities and their criteria for success, and most importantly, see ways for improvement and change. In this study, self-assessment activity in mathematics had provided a structured opportunity for students to reflect about their learning process. Journaling in mathematics allows students to write about the experiences, ideas and feelings involved in their mathematics learning (Darr & Fisher, 2004). As shown in

many of the student samples in this study, the self-assessment tools used - student reflective journal, think board and mind map, had provided a chance to reflect on students' thinking and provided a channel which the teacher could observe the range of strategies students used and the misconceptions students might have.

The qualitative results have provided strong evidence to support the assertion that self-assessment can facilitate self-directed learning. The student samples show that many students were able to evaluate their level of understanding. For example, they can tell whether they fully master, partly understand, or do not understand a concept. Others can identify what is important and know what needs to be understood or memorized. Some of them would draw pictures or write remarks to remind themselves that a certain concept is important. The results also show that many students can consciously select and implement learning strategies. They can write down reminders or the most appropriate strategies to help them solve mathematics problems. The SDL element – can reflect on what is learned – had the highest occurrence among other elements. This is a good evidence to support that the use of self-assessment tools had helped students to reflect on their learning, and hence, had an impact on meta-cognition and self-directedness in mathematics learning. The self-assessment activities also helped to identify areas where students were relatively weak, such as the ability to self-assess their learning outcomes and the ability to evaluate how good a particular learning strategy is. These results provide clearer directions for practice to teachers to help their students to become independent learners. Therefore, teachers should make sure their pupils clearly understand what they are expected to achieve. Also, instructions for evaluating strategies should be given to students.

The results also show that students' mathematics achievement improved when students were engaged in self-assessment activities which allows them to reflection about their learning. This supports Wheatley's (1992) study which shows that reflection in mathematics learning results in higher mathematics achievement, even on standardized tests which stress procedures and conventions. Also, the reflective activity plays a critically important role in mathematics learning and that just completing tasks in insufficient, no matter how well the activities are designed.

Another important result of this study is that students who practice the reflective learning approach gained more than those without on new items, but showed no difference on old items. The intervention seems to have helped students to face new challenges much better. The reason could be that the students who practiced self-assessment had the chance to reflect on their learning process and hence affected their learning strategies and self-directedness. As a result, the students were able to transfer this reflective learning approach to learning new topics and to other situations. The result supports research studies reviewed by Cambra-Fierro *et al* (2007) that reflective learning improves academic results and contributes to developing important personal skills. Students' academic achievement can improve if they think and reflect not only about the content of the subjects, but also about their attitude, effort and dedication to them.

This study provides evidence that student self-assessment can facilitate self-directed learning and also improve achievement in mathematics. The implication could be student self-assessment should play a more important role in the classroom. The focus should be on students' reflections about their learning towards the high levels of thinking. As suggested by Costa and Kallick (2004), one of the goals of self-directed

learning should be to make reflection a habitual event. Hence, schools, teachers and students in Hong Kong would need to explore ways to adopt a pedagogy which includes student self-assessment. This will require teacher professional development as well as adjustment in school policies. As pointed out by Grow (1991) and Pintrich (1995), self-direction can be taught and teachers must adapt their pedagogical approaches to match students' self-directedness in order to increase students' abilities in self-directed learning. Schools, teachers, students and even the parents may need more understanding on how self-assessment can facilitate self-learning and hence enhance learning. Hong Kong teachers and students have been very used to teacher-centred and exam-driven teaching. To implement SDL in classrooms may subject to constraints. As reminded by Candy (1991), self-directed learning could create tension as learners who are expected to be responsible for their own learning and to be self-directed, whilst at the same time being controlled by a particular teaching methodology and the need to master specific subject matter. Also, students may doubt that why they need to do the new tasks and spend the extra time. Teachers and students often have difficulty at the beginning and need time to familiarize with new approaches. The teachers involved in this study have become more aware of the usefulness of self-assessment to implement SDL and how to integrate that in their teaching practices. The experience and insights gained have helped themselves and could also help other schools and teachers to implement self-assessment and SDL in classrooms more successfully.

5.2 Limitation of study

In this study, the results showed that the treatment group (9 classes taught by 6 different teachers) had gained more than the control group (7 classes taught by 5 different teachers).The teachers who used student self-assessment in their teaching practices had reasonable levels of outside support, but with a lot of teacher autonomy. The time scale of the intervention was long and the effect size is well worth having. However, we should note that we cannot be sure that the difference was caused by better teaching because better teachers volunteered to be in the treatment group or was due to the intervention. It is possible that those teachers who were willing to try the new intervention are more engaged as teachers and more willing to make adjustment and seek improvements to their classroom teaching practice. Nevertheless, even if this is the case, it is worth knowing that this intervention enabled these teachers to change classroom practices and stimulate their students to reflect and make large gains.

Teachers who took part in this project had the autonomy to decide the kind of student self-assessment they would use in their classrooms and also how they would use it. The teachers, based on their students' needs and the teaching schedules and curriculum, designed the self-assessment activities they believed to be suitable for their pupils. Therefore, the topics chosen, the frequency, duration and form of self-assessment tools used, will have varied from school to school, and teacher to teacher. We knew that students in the treatment group did a certain amount of self-assessment work and achieved a positive gain; however, we could not tell how much student self-assessment work should be done in order to achieve such gains.

Throughout this study, the researcher had made contact with the teachers involved through regular meetings, school visits, lesson observation and seminars. Their teaching experiences varied from one year to more than 10 years. It seemed that this non-traditional teaching and learning method, which used student self-assessment to facilitate self-directed learning, was considered quite new, especially in mathematics. Most of the teachers were not familiar with the theories and concepts of self-assessment and self-directed learning. At the beginning, some teachers were uncertain about how to apply those ideas in their classrooms. It took some time and teacher capability building to let the teachers understand the concepts and engage in active discussions on instructional design. It is true that the level of understanding and the acceptance of self-directed learning of different teachers varied, and might have affected the effectiveness of the intervention.

The medium of instruction (MOI) was not considered in this study. The language used by the pupils to write down their reflections on their mathematics learning was either Chinese or English, although some students who used English might have written a couple of Chinese characters in their work. In Hong Kong, depending on the banding of the students received, the schools could employ either Chinese or English as the medium of instruction. According to the Education Bureau and research, mother-tongue is generally the most effective learning tool for students. Most schools in Hong Kong can only be allowed to adopt Chinese as their MOI; only the students with high attainment, as said by the EDB, could use a second language (English) in learning. In this study, some students used English to write their reflections. We do not know how students' expression of their ideas on what they have learned was affected by using a second language. Also, we do not know if the performance of the students

who did the English versions of pre- and post-tests would have been different if they had been allowed to do the Chinese version instead.

Both students and teachers participated in the intervention were not randomly chosen. It was largely up to the teachers' professional judgement to decide whether their students could be benefited from involving in the study and trying the new teaching method. As a result, there may be difficulty generalizing the results to a larger population.

5.3 Recommendations for future research

The purpose of this study was to explore the effectiveness of guided student self-assessment in enhancing students' self-directedness as well as achievement in mathematics learning. The results of the study suggest that student self-assessment can be both effective in increasing student performance and self-directedness. Therefore, additional experimentation in other settings with approaches similar to this study seems to be beneficial. The recommendations for future study are as follows:

1. Replicate this research with other subjects and student levels.
2. Investigate how teachers' feedback for students' reflection on their learning can improve performance and self-directedness.
3. Use the Self-Directed Learning Readiness (SDLR) Scale by Guglielmino to measure students' self-directedness before and after the intervention to see if there is a change.

4. Design the study in the way that the teachers' enthusiasm and expertise are controlled. For example, the allocation of teachers to the different treatment groups could be randomized.
5. Investigate more deeply the effectiveness of student self-assessment on different attainment groups, in order to understand which ability group would receive the most benefit from this intervention.
6. Design a more structured student self-assessment activity for teachers to use in their classrooms, so that the variables such as topics chosen, the frequency, duration and form of self-assessment tools used are controlled.

5.4 Conclusion

This study has provided a basis to explore some of the ways to implement self-directed learning by using student self-assessment tools. The teachers involved in this research had integrated self-assessment in their teaching practices. The pupils were provided with opportunities to reflect on their learning process. By reflection on learning experience, students' (a) Learning strategies & behaviours; (b) Self-assessment skills & self-knowledge; (c) Motivation; and (d) Meta-cognition were affected. This helped pupils to improve their self-directedness in learning. Also, the self-assessment activity allowed teachers to diagnose their students' misconceptions in mathematics, and as a result, teachers could provide quality feedback and adjust their classroom instructions accordingly. The results of analysis of student samples had shown that students were weak in some of the self-directed learning skills. Guidance should be provided to students to let them fully understand the learning outcomes. Also, students need instructions from teachers for evaluating learning strategies. As students became more

self-directed learners and teachers better informed, the quality of teaching and learning improved. The implication is that educators, parents, schools and the Education Bureau should allow pupils to shoulder more responsibilities for their own learning. All parties should understand the benefits and process of SDL and then commit to this new style of teaching and learning. Students should be given the opportunities to co-construct knowledge through pedagogies that facilitate independent learning. Self-assessment, an important component of assessment for learning, has been shown to be effective in fostering SDL in this study. It has also made a positive impact on achievement and students' understanding of mathematics concepts. Therefore, teacher professional development programmes, which focus on engaging students in SDL using strategies such as self-assessment to reflect about learning, must continue. This would need the support from the authorities as well as the school administrators. In addition, a deeper investigation of how student self-assessment tools should be structured and used is essential for helping pupils to learn more effectively and independently. Moreover, to explore ways to use feedback to students, and from students, to construct better instructions and improve students' self-learning skills is as important. Self-assessment enables teachers and pupils to improve on teaching and learning in ways not possible with the traditional teacher-centred and exam-driven approach. As students are promoted to higher levels, the mathematics, or in fact any subject, will demand a deeper understanding and independent thinking. Rote learning may not be most effective anymore (despite the fact that some teachers in Asia are satisfied with the success in PISA and TIMMS of their lower form students). The experimental work done in this study was encouraging in its pedagogical possibilities. An emphasis on the student self-assessment should find its way into mathematics classrooms in Hong Kong. The sharing of good practices and the benefits among schools of using the self-assessment tools to promote SDL could invite more educators

to change from their current practices to embrace the newer theories of learning and assessment.

The results of the study and the positive feedback from those teachers who have used the student self-assessment tools in their classrooms suggest that self-assessment can be an effective way to improve student self-directedness as well as academic achievement, which both teachers and students are most concerned. The use of student self-assessment does show hope and give us new tools in mathematics instruction. Exploration to find out which approaches are effective and most compelling to teachers should continue. It is important to the future of Hong Kong education because, after all, the most vital skill student should learn nowadays and many years to come is the skill of learning to learn.

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APPENDICES

Appendix I

The English version of the pre-test paper is shown below.

1. Which of the following(s) is/are factor(s) of $3(a-b)^2 + (a-b)$?

   (I) a-b

   (II) 3a-3b+1

   (III) 3

   A. I only
   B. I and II only
   C. I and III only
   D. I,II and III (1 mark)

2. $(2a - a^0) =$

   A. a
   B. 2a
   C. 2a + 1
   D. 2a – 1 (1 mark)

3. Which of the following is/are identity/identities?

   I. $x^3 = x$

   II. $(x – 1)^2 = x^2 – 2x + 1$

   III. $5x – 5 = 5(x + 1)$

   A. I only
   B. II only
   C. III only
   D. I and III only (1 mark)

4. Which of the following statement(s) is/are true?

   I All equilateral triangles are similar.

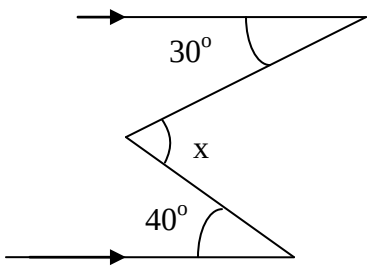
   II All isosceles triangles are similar.

   III All squares are similar.

   IV All parallelograms are similar.

   A. I and III only
   B. II and IV only
   C. I,II and III only
   D. All of them (1 mark)

5.

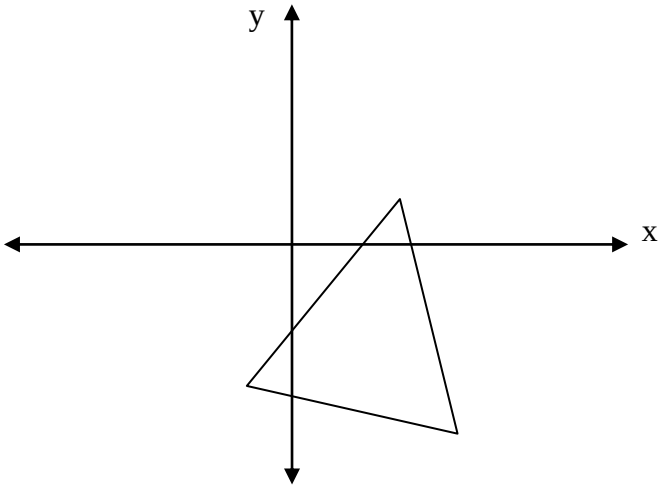


Find the value of x.

A. 20^o B. 40^o

C. 60^o D. 70^o (1 mark)

6.



The coordinates of the centre of the above triangle could be

A. (-20,-10) B. (-6,4)

C. (0,0) D. (3,-5)

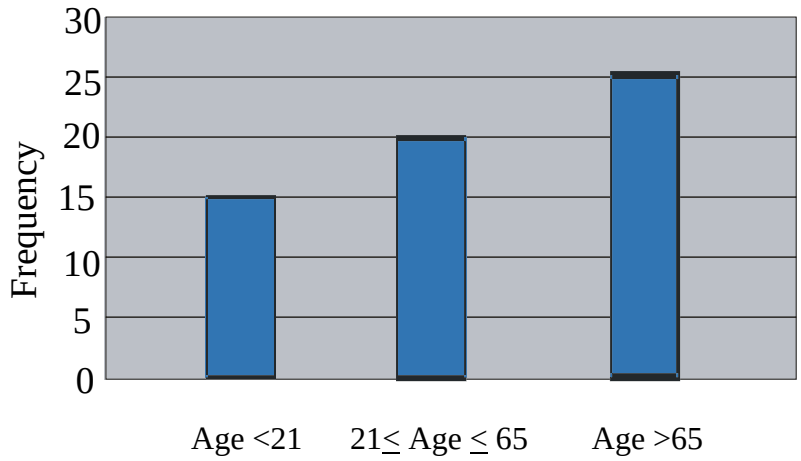
(1 mark)

7. If $\cos 2x = \sin 35^o$ then x =

A. 17.5^o B. $\frac{\sin 35^o}{\cos 2^o}$

C. 27.5^o D. 55^o (1 mark)

8. The following figure shows the age distribution of people in a building.



Find the percentage of people who are below the age 21.

A. 15% B. 25%

C. 20% D. 60% (1 mark)

9. The temperatures from Monday to Friday are 20^{o}C, 22^{o}C, 18^{o}C, 22^{o}C and 24^{o} C.

For the temperature record, which of the following(s) is/are true?

I. The mode is 18^{o} C.

II. The mean is 19^{o} C.

III. The median is 20^{o} C.

A. I only B. II only

C. III only D. none of above (1 mark)

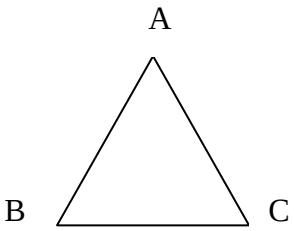
10. Write the number 2.75×10^{3} as whole number.

2.75×10^{3} = _____ (1 mark)

11. Find $2.75 \times 10^{3} \times 3$. Express your answer as scientific notation.

$2.75 \times 10^{3} \times 3$ = _____ (1 mark)

12. John wants to know whether Δ ABC is an equilateral triangle. Describe two methods to show that the triangle is an equilateral triangle.

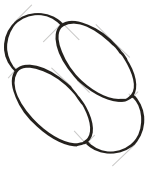


(a) Method 1 : _____ (1 mark)

(b) Method 2 : _____ (1 mark)

13. In triangle ABC, if AB>BC>AC, which of the three interier angles is the largest ?

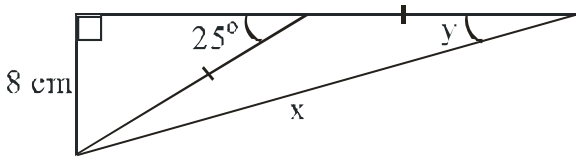
_____ (1 mark)

14. 

The number of axes of symmetry of the figure above is

_____. (1 mark)

15. Find the values of x and y , correct answers to 1 decimal places if necessary.



(Give your answers with units)

(a) x = _____ (1 mark)

(b) y = _____ (1 mark)

16. A basket carries x oranges and y apples.

The sum of oranges and apples is 40. Write an equation connecting x and y.

(a) Equation 1 : _____ (1 mark)

The ratio between the number of oranges and the number of apples is 3:2. Write another equation connecting x and y.

(b) Equation 2 : _____ (1 mark)

(c) Find the number of apples and oranges in the basket. Show your steps.

(1 mark)

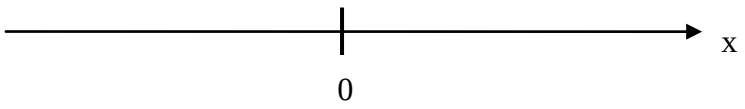
(1 mark)

17. The orginal price of a dress is $400. The price is increased by 20% before Christmas. After Christmas, the price is reduced by 20%. What is the final price? (Show your steps)

(1 mark)

(1 mark)

18. Represent the solution of $5 - x > 1.5$ on a number line.



(1 mark)

19. The followings are a square and a regular hexagon.

(a)(i) The perimeter of the square is _____, and

(ii) the perimeter of the regular hexagon is _____. (1 mark)

(b) Do they have the same area ?

Yes OR No (1 mark)

(c) Show your steps.

(1 mark)

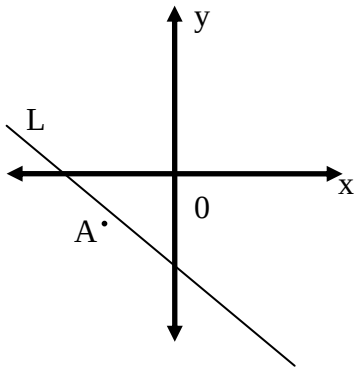
(1 mark)

20. (a) Given three points P(-1,2), Q(4,2) and R(2,-2). Draw x-axis and y-axis and plot P,Q and R.

(1 mark)

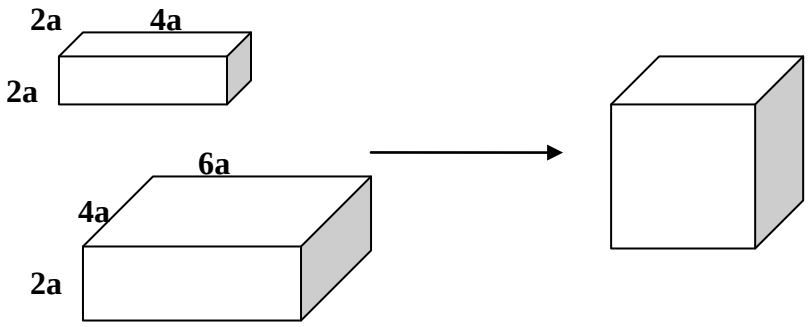
(b) The area of triangle PQR is _____ square units. (1 mark)

21. Point A is reflected about L to get point B. Mark the position of point B on the following rectangular coordinate plan.



(1 mark)

22.



Two rectangular blocks of gold, with dimensions shown above, are melted and recasted into the shape of a cube. Find the length of the cube in terms of a. Show your steps.

(1 mark)

(1 mark)

End of pre-test

Appendix II

The English version of the post-test paper is shown below.

1. Which of the following(s) is/are factor(s) of $3(a-b)^2 + (a-b)$?

(IV) a-b

(V) 3a-3b+1

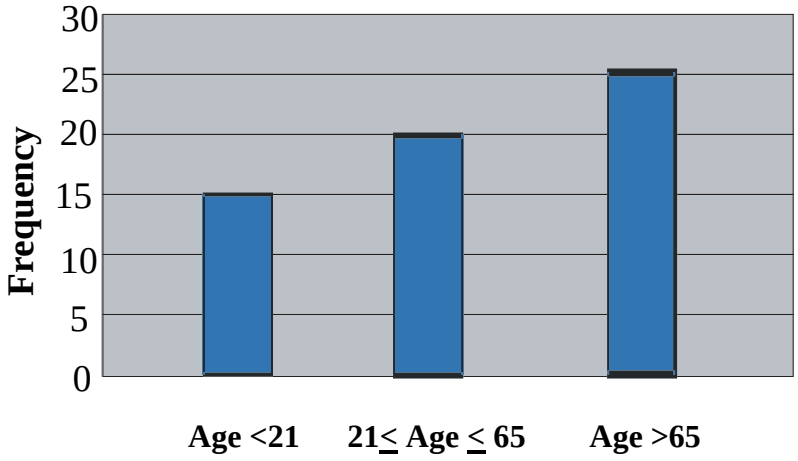
(VI) 3

A. I only
B. I and II only
C. I and III only
D. I,II and III (1 mark)

2. $(2a - a^0) =$

A. a
B. 2a (1 mark)
C. 2a + 1
D. 2a – 1

3. The following figure shows the age distribution of people in a building.



Find the percentage of people who are below the age 21.

A. 15%
B. 25%
C. 20%
D. 60% (1 mark)

4. 72 km/h : 24 m/s =

A 5:6 B. 4:3

C. 30:1 D. 3000:1 (1 mark)

5. If $\cos 2x = \sin 35^o$, then x =

A. 17.5^o B. $\frac{\sin 35^o}{\cos 2^o}$

C. 27.5^o D. 55^o (1 mark)

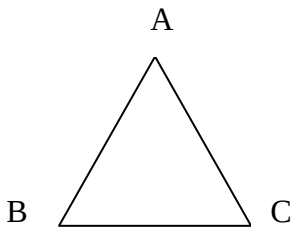
6. Correct 0.003718 to 3 significant figures.

0.003718 = _____ (1 mark)

7. Find 68.764 x 3. Correct your answer to 3 significant figures.

68.764 x 3 = _____ (1 mark)

8. John wants to know whether $\triangle$ ABC is an equilateral triangle. Describe two methods to show that the triangle is an equilateral triangle.

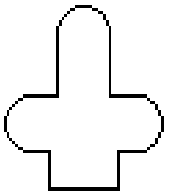


(a) Method 1 : _____ (1 mark)

(b) Method 2 : _____ (1 mark)

9. In triangle ABC, if AB>BC>AC, which of the three interier angles is the largest ?

_____ (1 mark)

10. 

The number of axes of symmetry of the figure above is

_____ (1 mark)

11. Factorize 7 (6-x) + y (x-6).

_____ (1 mark)

12. The following frequency distribution table shows the test result of a group of students.

Grade	Frequency
A	7
B	22
C	x
D	8
E	3
Total	50

(a) x = _____ (1 mark)

(b) If getting a "C" or above is a pass, then the passing percentage of this group of students is _____ . (1 mark)

13. The orginal price of a dress is $400. The price is increased by 20% before Christmas. After Christmas, the price is reduced by 20%. What is the final price? (Show your steps)

(1 mark)

(1 mark)

14. A basket carries x oranges and y apples.

The sum of oranges and apples is 40. Write an equation connecting x and y.

(a) Equation 1 :_____ (1 mark)

The ratio between the number of oranges and the number of apples is 3:2. Write another equation connecting x and y.

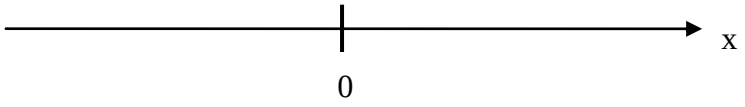
(b) Equation 2 : _____ (1 mark)

(c) Find the number of apples and oranges in the basket. Show your steps.

(1 mark)

(1 mark)

15. Represent the solution of $7 - 5x \geq -3x+1$ on a number line *(Write the answer on answer sheet).*



(1 mark)

16. (a) Given three points P(-1,2), Q(4,2) and R(2,-2). Draw x-axis and y-axis and plot P,Q and R.

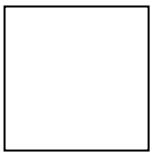
(1 mark)

(b) The area of triangle PQR is _____ square units. (1 mark)

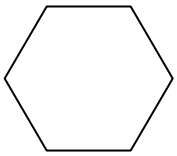
(c) If a circle centred at the orgin has radius of 3 unit, then the point P must be _____ the circle. (Hint: Select a correct one among inside/outside/at.) (1 mark)

17. The followings are a square and a regular hexagon.

15cm



10cm



(a)(i) The perimeter of the square is _____, and (1 mark)

(ii) the perimeter of the regular hexagon is _____. (1 mark)

(b) Do they have the same area ?

Yes OR No

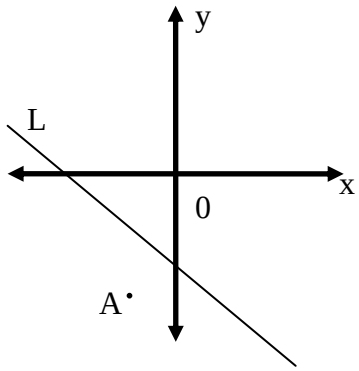
(c) Show your steps.

(1 mark)

(1 mark)

(d) Given a circle and a regular hexagon. If they have the same perimeter, then area of the circle must be _____ the area of the regular hexagon. (Hint: Select a correct one among bigger than / smaller than / as same as.) (1 mark)

18. Point A is reflected about L to get point B. Mark the position of point B on the following rectangular coordinate plan.



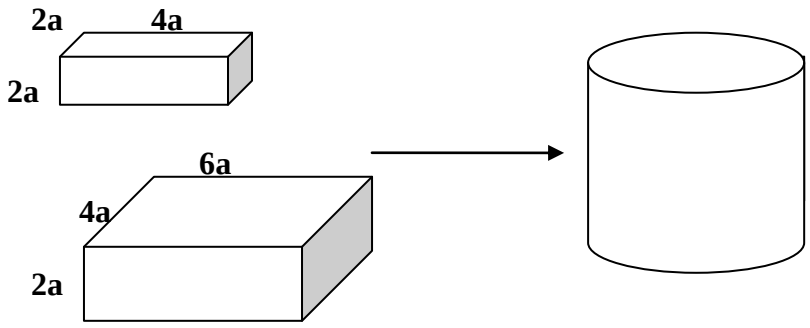
(1 mark)

(b) Is line AB perpendicular to line L?

(1 mark)

Yes OR No

19.



Two rectangular blocks of gold, with dimensions shown above, are melted and recasted into the shape of a cylinder with diameter 4π.

Find the height of the cylinder in terms of a . Leave π in your answer if necessary. Show your steps.

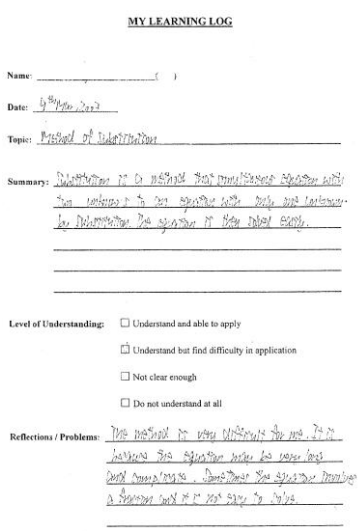
(1 mark)

(1 mark)

End of post-test

Appendix III

The 101 samples are shown below.



MY LEARNING LOG

Name: ( )

Date:

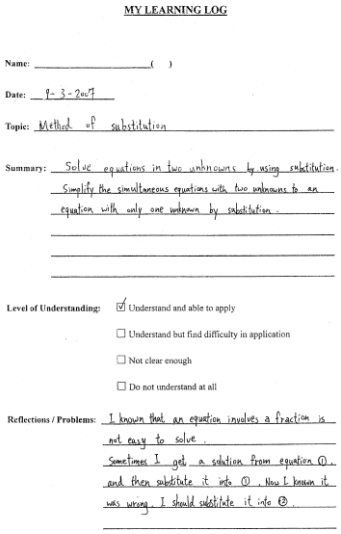
Topic:

Summary:

Level of Understanding:
- ☐ Understand and able to apply
- ☐ Understand but find difficulty in application
- ☐ Not clear enough
- ☐ Do not understand at all

Reflections / Problems:

Sample 1



MY LEARNING LOG

Name: ( )

Date: 9-3-2007

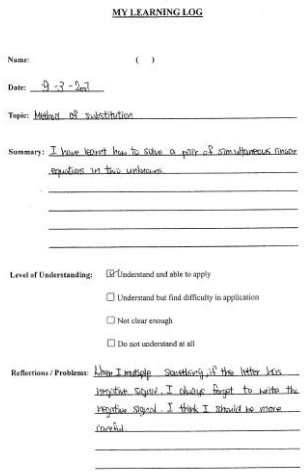
Topic: Method of substitution

Summary: Solve equations in two unknowns by using substitution. Simplify the simultaneous equations with two unknowns to an equation with only one unknown by substitution.

Level of Understanding:
- ☑ Understand and able to apply
- ☐ Understand but find difficulty in application
- ☐ Not clear enough
- ☐ Do not understand at all

Reflections / Problems: I known that an equation involves a fraction is not easy to solve. Sometimes I get a solution from equation ①, and then substitute it into ②. Now I known it was wrong. I should substitute it into ②.

Sample 2



MY LEARNING LOG

Name: ( )

Date: 9-3-2007

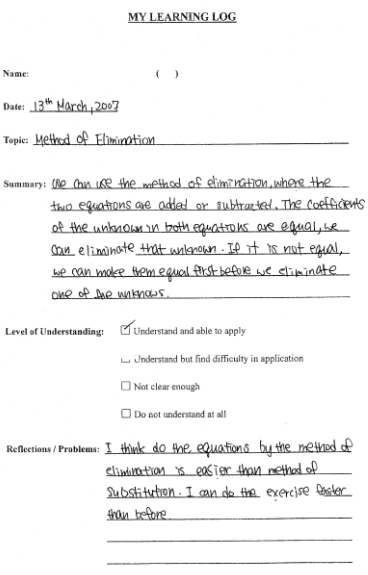
Topic: Method of substitution

Summary: I have learnt how to solve a pair of simultaneous linear equations in two unknowns.

Level of Understanding:
- ☑ Understand and able to apply
- ☐ Understand but find difficulty in application
- ☐ Not clear enough
- ☐ Do not understand at all

Reflections / Problems: When I multiple something, if the latter has negative signal, I always forget to write the negative signal. I think I should be more careful.

Sample 3



MY LEARNING LOG

Name: ( )

Date: 13th March, 2007

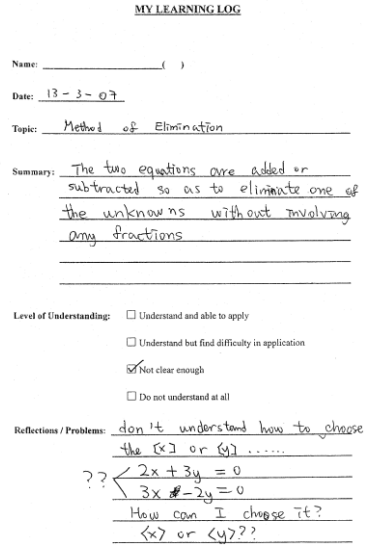
Topic: Method of Elimination

Summary: We can use the method of elimination, where the two equations are added or subtracted. The coefficients of the unknown in both equations are equal, we can eliminate that unknown. If it is not equal, we can make them equal first before we eliminate one of the unknows.

Level of Understanding:
- ☑ Understand and able to apply
- ☐ Understand but find difficulty in application
- ☐ Not clear enough
- ☐ Do not understand at all

Reflections / Problems: I think do the equations by the method of elimination is easier than method of substitution. I can do the exercise faster than before.

Sample 4



MY LEARNING LOG

Name: ( )

Date: 13-3-07

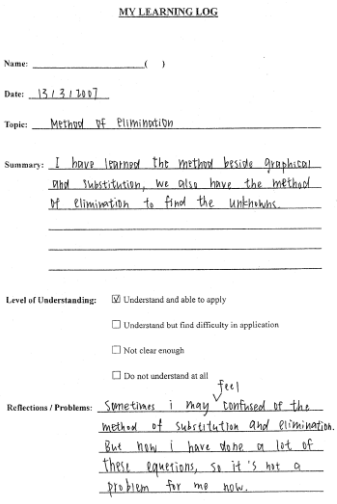
Topic: Method of Elimination

Summary: The two equations are added or subtracted so as to eliminate one of the unknowns without involving any fractions

Level of Understanding:
- ☐ Understand and able to apply
- ☐ Understand but find difficulty in application
- ☑ Not clear enough
- ☐ Do not understand at all

Reflections / Problems: don't understand how to choose the ⟨x⟩ or ⟨y⟩ .....
?? 2x + 3y = 0
3x − 2y = 0
How can I choose it?
⟨x⟩ or ⟨y⟩??

Sample 5



MY LEARNING LOG

Name: ( )

Date: 13/3/2007

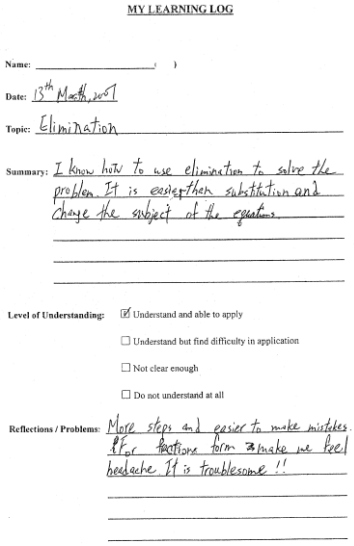
Topic: Method of Elimination

Summary: I have learnt the method beside graphical and substitution, we also have the method of elimination to find the unknowns.

Level of Understanding:
- ☑ Understand and able to apply
- ☐ Understand but find difficulty in application
- ☐ Not clear enough
- ☐ Do not understand at all

Reflections / Problems: Sometimes I may feel confused of the method of substitution and elimination. But now I have done a lot of these equations, so it's not a problem for me now.

Sample 6



MY LEARNING LOG

Name: _____ ( )

Date: 13th March, 2017

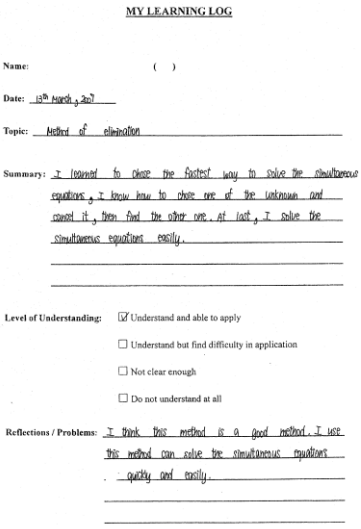
Topic: Elimination

Summary: I know how to use elimination to solve the problem. It is easier than substitution and change the subject of the equation.

Level of Understanding: ☑ Understand and able to apply
☐ Understand but find difficulty in application
☐ Not clear enough
☐ Do not understand at all

Reflections / Problems: More steps and easier to make mistakes for fractions form. Make me feel headache. It is troublesome !!

Sample 7



MY LEARNING LOG

Name: ( )

Date: 13th March, 2017

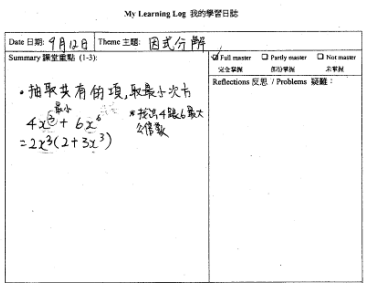
Topic: Method of elimination

Summary: I learned to chose the fastest way to solve the simultaneous equations. I know how to chose one of the unknown and cancel it, then find the other one. At last, I solve the simultaneous equations easily.

Level of Understanding: ☑ Understand and able to apply
☐ Understand but find difficulty in application
☐ Not clear enough
☐ Do not understand at all

Reflections / Problems: I think this method is a good method. I use this method can solve the simultaneous equations quickly and easily.

Sample 8



My Learning Log 我的學習日誌

Date 日期: 9月12日 Theme 主題: 因式分解

Summary 課堂重點 (1-3):

• 抽取共有的項，取最大次的

$4x^6 + 6x^4$ 最小

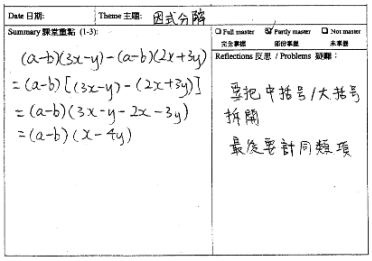
$= 2x^3(2 + 3x^3)$

*找出4跟6最大的倍數

Full master ☐ Partly master ☐ Not master
完全掌握 部份掌握 未掌握

Reflections 反思 / Problems 疑難：

Sample 9



Date 日期: Theme 主題: 因式分解

Summary 課堂重點 (1-3):

$(a-b)(3x-y) - (a-b)(2x+3y)$

$= (a-b)[(3x-y) - (2x+3y)]$

$= (a-b)(3x - y - 2x - 3y)$

$= (a-b)(x - 4y)$

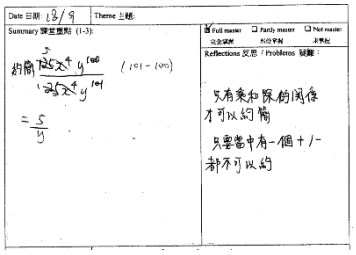
Full master ☐ Partly master ☑ Not master
完全掌握 部份掌握 未掌握

Reflections 反思 / Problems 疑難：

要把中括号/大括号拆開

最後要計同類項

Sample 10



Date 日期: 13/9 Theme 主題:

Summary 課堂重點 (1-3):

約簡 $\frac{25x^5y^{100}}{25x^4y^{101}}$ $(101 - 100)$

$= \frac{5}{y}$

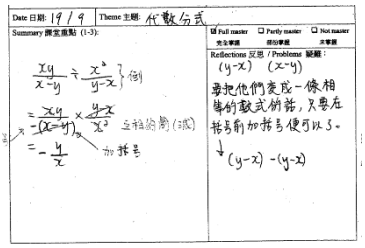
Full master ☐ Partly master ☐ Not master
完全掌握 部份掌握 未掌握

Reflections 反思 / Problems 疑難：

先有乘和除的関係才可以約簡

只要當中有一個 + / - 都不可以約

Sample 11



Date 日期: 19/9 Theme 主題: 代數分式

Summary 課堂重點 (1-3):

$\frac{xy}{x-y} \div \frac{x^2}{y-x}$ } 倒

$= \frac{xy}{-(x-y)} \times \frac{y-x}{x^2}$ 互相約簡(項)

$= -\frac{y}{x}$ 加括号

Full master ☐ Partly master ☐ Not master
完全掌握 部份掌握 未掌握

Reflections 反思 / Problems 疑難：

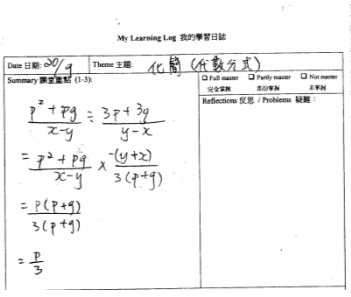
$(y-x)$ $(x-y)$

要把他們變成一條相等的數式的話，只要在括号前加括号便可以。

↓

$(y-x)$ $-(y-x)$

Sample 12



My Learning Log 我的學習日誌

Date 日期: 20/9 Theme 主題: 化簡 (代數分式)

Summary 課堂重點 (1-3):

$\frac{p^2+pq}{x-y} \div \frac{3p+3q}{y-x}$

$= \frac{p^2+pq}{x-y} \times \frac{-(y+x)}{3(p+q)}$

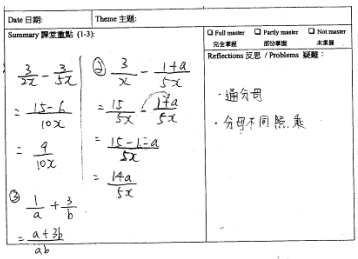
$= \frac{p(p+q)}{3(p+q)}$

$= \frac{p}{3}$

Full master ☐ Partly master ☐ Not master
完全掌握 部份掌握 未掌握

Reflections 反思 / Problems 疑難：

Sample 13



Date 日期: Theme 主題:

Summary 課堂重點 (1-3):

$\frac{3}{5x} - \frac{3}{5x}$

$= \frac{15-6}{10x}$

$= \frac{9}{10x}$

③ $\frac{1}{a} + \frac{3}{b}$

$= \frac{a+3b}{ab}$

② $\frac{3}{x} - \frac{1+a}{5x}$

$= \frac{15}{5x} - \frac{1+a}{5x}$

$= \frac{15-1-a}{5x}$

$= \frac{14a}{5x}$

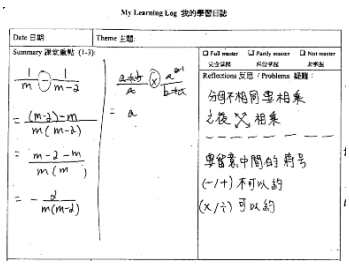
Full master ☐ Partly master ☐ Not master
完全掌握 部份掌握 未掌握

Reflections 反思 / Problems 疑難：

· 通分母

· 分母不同照乘

Sample 14



My Learning Log 我的學習日誌

Date 日期: Theme 主題:

Summary 課堂重點 (1-3):

$\frac{1}{m} \ominus \frac{1}{m-2}$

$= \frac{(m-2)-m}{m(m-2)}$

$= \frac{m-2-m}{m(m-2)}$

$= -\frac{2}{m(m-2)}$

$\frac{a+b}{a} \otimes \frac{a^2}{b+a}$

$= a$

Full master ☐ Partly master ☐ Not master
完全掌握 部份掌握 未掌握

Reflections 反思 / Problems 疑難：

分母不相同零相乘

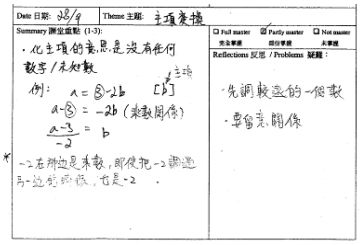
之後 ✕ 相乘

事實意中間的 符号

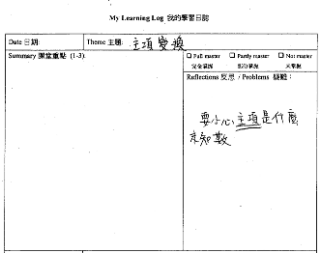
(-/+) 不可以約

(x/÷) 可以約

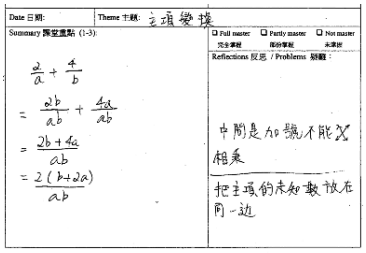
Sample 15



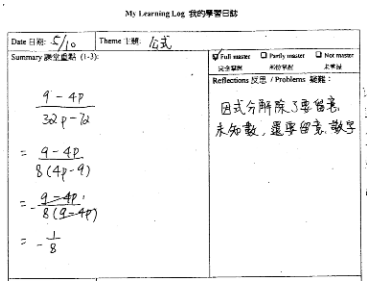
Sample 16



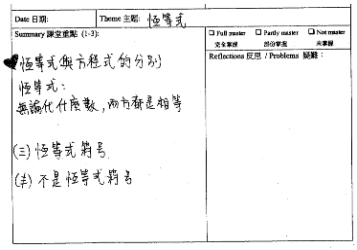
Sample 17



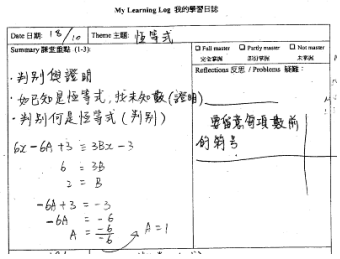
Sample 18



Sample 19



Sample 20



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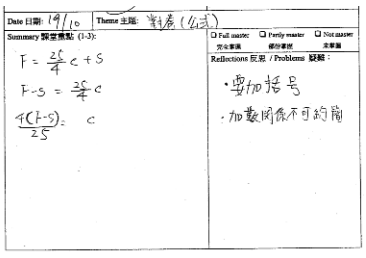

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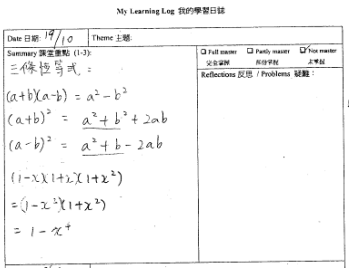

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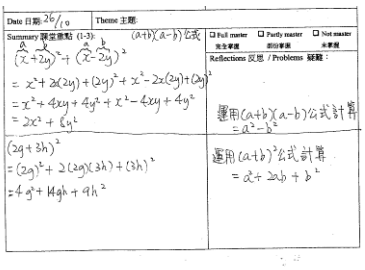

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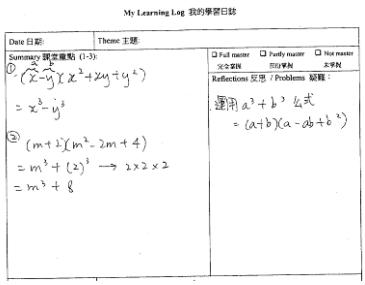

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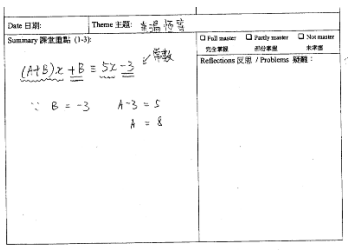
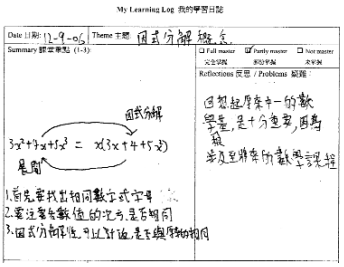


Sample 26



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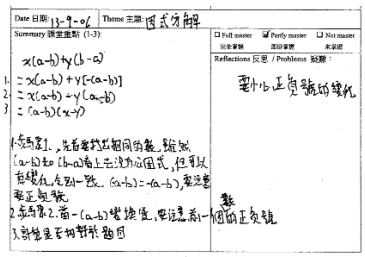
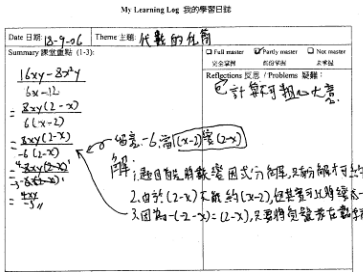


Sample 28



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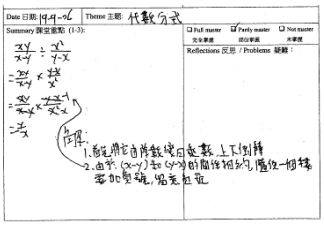
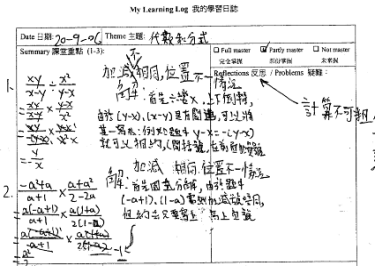


Sample 30



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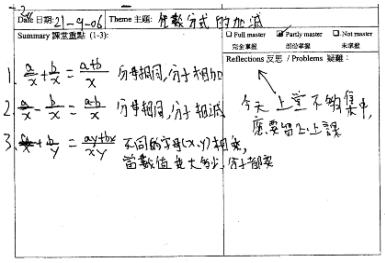

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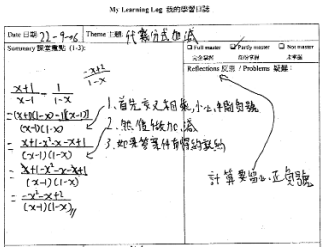

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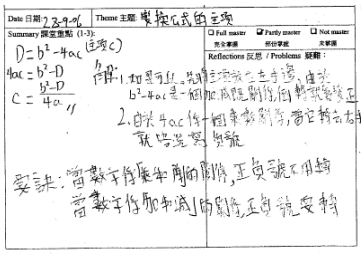

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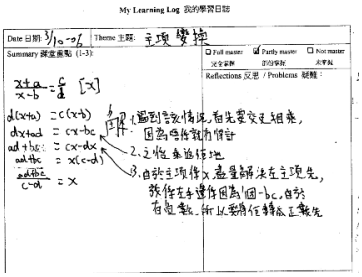

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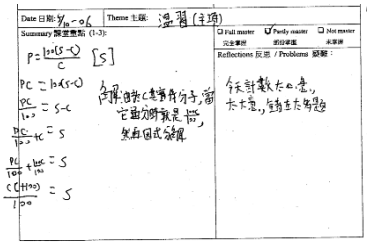

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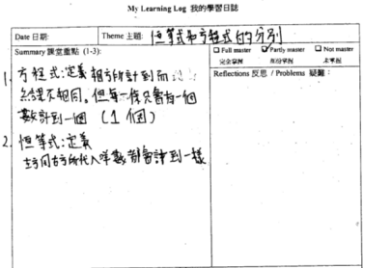

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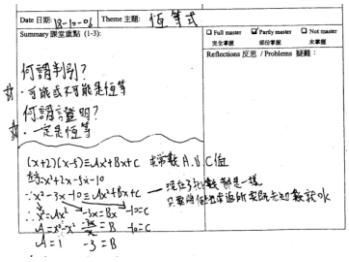
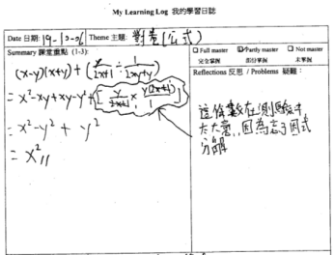
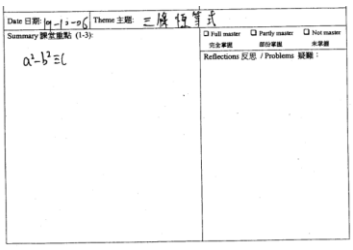


Sample 38

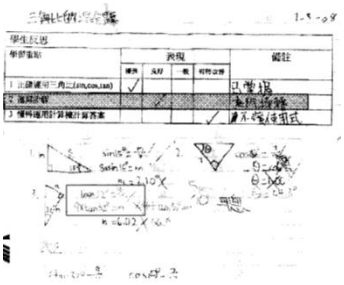


Sample 39



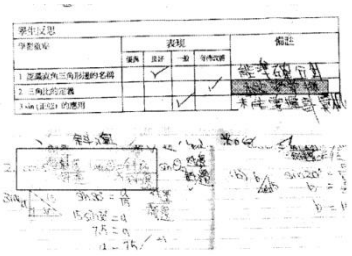
Sample 40

Sample 41

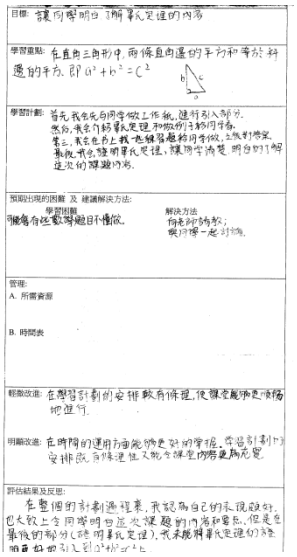


Sample 42

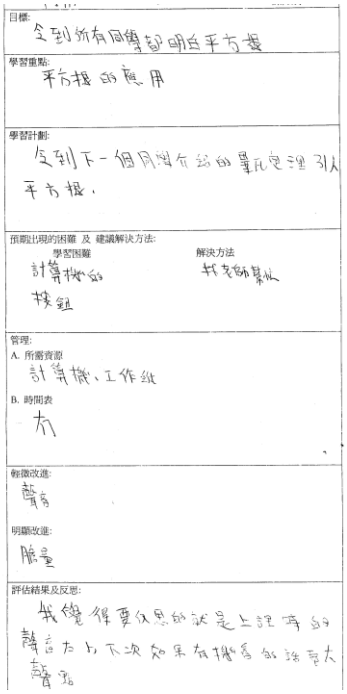
Sample 43



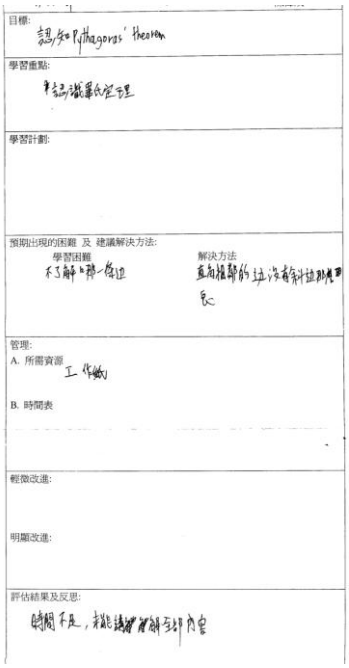
Sample 44



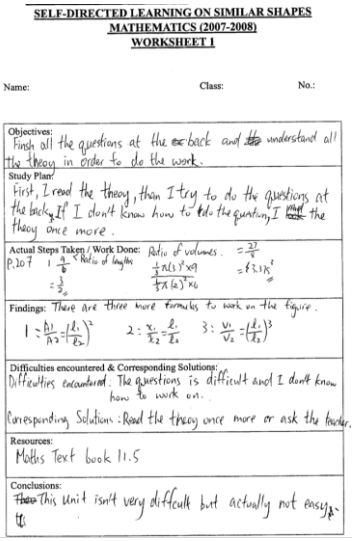
Sample 45



Sample 46



Sample 47



SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
Finish all the questions at the ~~ex~~back and ~~the~~ understand all the theory in order to do the work.

Study Plan:
First, I read the theory, then I try to do the questions at the back. If I don't know how to do the question, I ~~must~~ the theory once more.

Actual Steps Taken / Work Done:
P.207 1 $\frac{2}{8}$ Ratio of lengths Ratio of volumes. $= \frac{27}{8}$
$= \frac{1}{3}\pi(3)^2\times 9$ $= \frac{1}{3}\pi(2)^2\times 6$ $= \frac{27}{8}$

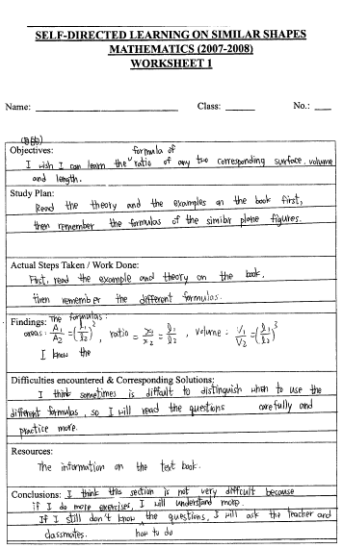
Findings: There are three more formulas to work on the figure.
$1 : \frac{A_1}{A_2} = \left(\frac{L_1}{L_2}\right)^2$ $2 : \frac{x_1}{x_2} = \frac{L_1}{L_2}$ $3 : \frac{V_1}{V_2} = \left(\frac{L_1}{L_2}\right)^3$

Difficulties encountered & Corresponding Solutions:
Difficulties encountered: The questions is difficult and I don't know how to work on.
Corresponding Solution: Read the theory once more or ask the teacher.

Resources:
Maths Text book 11.5

Conclusions:
~~Then~~ This unit isn't very difficult but actually not easy ~~to~~

Sample 48



SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: _____ Class: _____ No.: ___

Objectives:
I wish I can learn the formula of ratio of any the corresponding surface, volume and length.

Study Plan:
Read the theory and the examples on the book first, then remember the formulas of the similar plane figures.

Actual Steps Taken / Work Done:
First, read the example and theory on the book.
Then remember the different formulas.

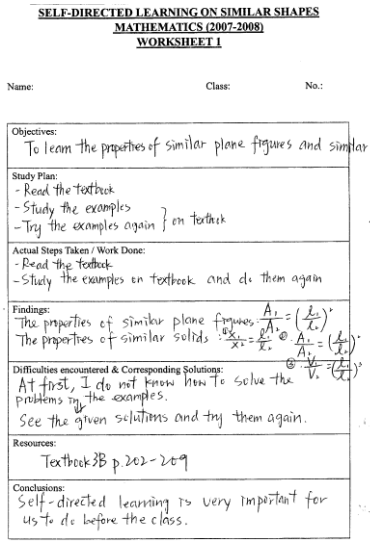
Findings: The formulas:
areas: $\frac{A_1}{A_2}=(\frac{l_1}{l_2})^2$, ratio $=\frac{2a}{2_{a_2}}=\frac{l_1}{l_2}$, volume: $\frac{V_1}{V_2}=(\frac{l_1}{l_2})^3$
I know the

Difficulties encountered & Corresponding Solutions:
I think sometimes is difficult to distinguish when to use the different formulas, so I will read the questions carefully and practise more.

Resources:
The information on the text book.

Conclusions: I think this section is not very difficult because if I do more exercises, I still understand more.
If I still don't know the questions, I will ask the teacher and classmates. how to do

Sample 49



SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
To learn the properties of similar plane figures and similar solids.

Study Plan:
- Read the textbook
- Study the examples
- Try the examples again } on textbook

Actual Steps Taken / Work Done:
- Read the textbook
- Study the examples on textbook and do them again

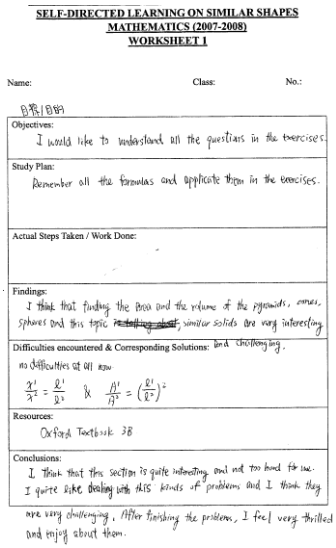
Findings:
The properties of similar plane figures $\frac{A_1}{A_2}=(\frac{l_1}{l_2})^2$
The properties of similar solids $\frac{a_1}{a_2}=\frac{l_1}{l_2}$ ② $\frac{A_1}{A_2}=(\frac{l_1}{l_2})^2$
③ $\frac{V_1}{V_2}=(\frac{l_1}{l_2})^3$

Difficulties encountered & Corresponding Solutions:
At first, I do not know how to solve the problems in the examples.
↓
See the given solutions and try them again.

Resources:
Textbook 3B p.202-209

Conclusions:
Self-directed learning is very important for us to do before the class.

Sample 50



SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

8月8日/8月9日

Objectives:
I would like to understand all the questions in the exercises.

Study Plan:
Remember all the formulas and applicate them in the exercises.

Actual Steps Taken / Work Done:

Findings:
I think that finding the area and the volume of the pyramids, cones, spheres and this topic ~~reminding about~~, similar solids are very interesting

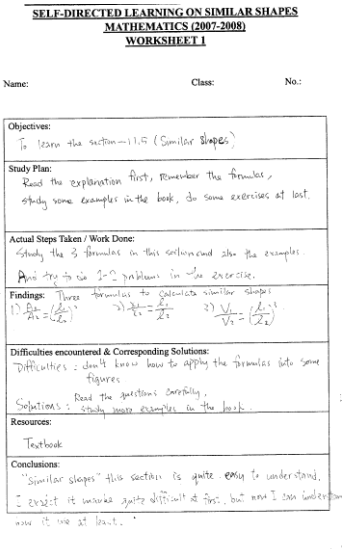
Difficulties encountered & Corresponding Solutions: and challenging.
no difficulties at all now

$\frac{a_1^2}{a_2^2}=\frac{l_1^2}{l_2^2}$ ⑧ $\frac{A_1^2}{A_2^2}=(\frac{l_1^2}{l_2^2})^2$

Resources:
Oxford Textbook 3B

Conclusions:
I think that this section is quite interesting and not too hard to me. I quite like dealing with this kinds of problems and I think they are very challenging. After finishing the problems, I feel very thrilled and enjoy about them.

Sample 51



SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
To learn the section 11.5 (Similar Shapes)

Study Plan:
Read the explanation first, remember the formulas, study some examples in the book, do some exercises at last.

Actual Steps Taken / Work Done:
Study the 3 formulas in this section and the examples.
Also try to do 1-2 problems in the exercise.

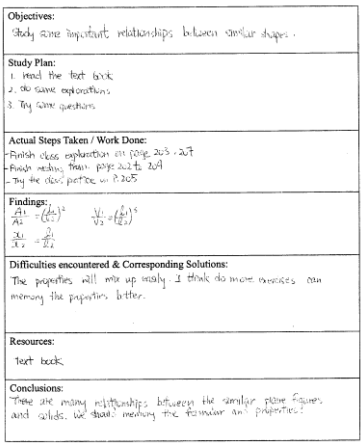
Findings: Three formulas to calculate similar shapes
1) $\frac{A_1}{A_2}=(\frac{l_1}{l_2})^2$ 2) $\frac{a_1}{a_2}=\frac{l_1}{l_2}$ 3) $\frac{V_1}{V_2}=(\frac{l_1}{l_2})^3$

Difficulties encountered & Corresponding Solutions:
Difficulties: don't know how to apply the formulas into some figures
Solutions: Read the questions carefully.
Study more examples in the book.

Resources:
Textbook

Conclusions:
"Similar shapes" this section is quite easy to understand. I expect it would quite difficult at first, but now I can understand now it not at least.

Sample 52



SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
Study some important relationships between similar shapes.

Study Plan:
1. read the text book
2. do some explorations
3. Try some questions

Actual Steps Taken / Work Done:
- Finish class exploration on page 203, 207
- Finish reading main page 202 to 209
- try the class practice on P.205

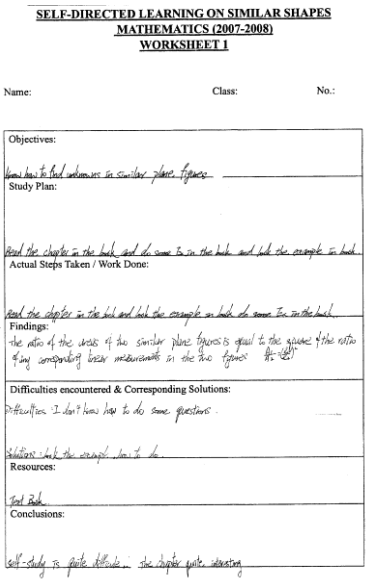
Findings:
$\frac{A_1}{A_2}=(\frac{l_1}{l_2})^2$ $\frac{V_1}{V_2}=(\frac{l_1}{l_2})^3$
$\frac{a_1}{a_2}=\frac{l_1}{l_2}$

Difficulties encountered & Corresponding Solutions:
The properties will mix up easily. I think do more exercises can memory the properties better.

Resources:
text book

Conclusions:
There are many relationships between the similar plane figures and solids. We should memory the formulas and properties!

Sample 53



SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
Learn how to find volumes in similar plane figures

Study Plan:
Read the chapter in the book and do some Ex in the book and look the example in book

Actual Steps Taken / Work Done:
Read the chapter in the book and look the example in book do some Ex in the book

Findings:
the ratio of the areas of the similar plane figures is equal to the square of the ratio of any corresponding linear measurements in the two figures. $\frac{A_1}{A_2}=(\frac{l_1}{l_2})^2$

Difficulties encountered & Corresponding Solutions:
Difficulties: I don't know how to do some questions.
Solutions: look the example how to do.

Resources:
Text Book

Conclusions:
Self-study is quite difficult, the chapter quite interesting

Sample 54

SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
understand how to calculate a similar plane figures

Study Plan:
read the equation, then try to do the exercise

Actual Steps Taken / Work Done:
read the equation then read one of the example, finally do your exercise

Findings:
The relationship between two similar plane figures

Difficulties encountered & Corresponding Solutions:
I don't understand some of the questions, so I read the examples more more and look into the dictionary for some difficult words.

Resources:
Maths text book

Conclusions:
Self-study is not easy.

Sample 55

SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
Learn more about similar shapes and learn self-directed learning.

Study Plan:
Read~~book~~ Cha. 11.5 in Book 3B and learn.

Actual Steps Taken / Work Done:
Look and learn in Cha 11.5 (P.202-209), look up dictionary for the words I don't know.

Findings:
There are similar plane figures and similar solid.

Difficulties encountered & Corresponding Solutions:
Not really know what is about after looking book 3B, take one more time to try to understand it.

Resources:
Exploring mathematics 3B

Conclusions:
Don't know what it is about.

Sample 56

SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
I hope I can understand all the questions in 11.5.

Study Plan:
1) Read the textbook and read the examples
2) discuss with my classmates
3) Try to do the exercise

Actual Steps Taken / Work Done:
1) Read the textbook and examples
2) try to do the class practice

Findings:
Area of similar Plane figures (1) / Area of similar Plane figures (2) = $\left(\frac{\text{length (1)}}{\text{length (2)}}\right)^2$

Difficulties encountered & Corresponding Solutions:
I can't really understand the solution above.
I don't know how to do this class practice.
But, at last, I

Resources:
From the text book

Conclusions:
I could really understand more if I have read the textbook myself. It is [illegible]

Sample 57

SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
Study some important relations between similar shapes which provides such calculations possible.

Study Plan:
① Study the examples of similar shapes in the textbook
② Remember the formulas
③ Practice by using the formulas

Actual Steps Taken / Work Done:
P.207 class explanation P.211 Ex.11E (1-2)
P.210 class practice

Findings:
$\frac{A_1}{A_2} = \left(\frac{l_1}{l_2}\right)^2$, $\frac{V_1}{V_2} = \left(\frac{l_1}{l_2}\right)^3$

Difficulties encountered & Corresponding Solutions:
Can't know the deeply meaning of the formulas.
I just remember the formulas only.

Resources:
Textbook

Conclusions:
I can't learn the new chapter by only look at the textbook.
Do more exercise and discuss with the Maths teacher will be better to learn clearly.

Sample 58

SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
I want to learn more about similar shapes and how to calculate them.

Study Plan:
I think I will go over the maths text book first. In addition, I will surf in the internet to get some information.

Actual Steps Taken / Work Done:
I had go over my text book once and surfed in the internet and asked my friends.

Findings:
$\frac{x_1}{x_2} = \frac{l_1}{l_2}$, $\frac{A_1}{A_2} = \left(\frac{l_1}{l_2}\right)^2$, $\frac{V_1}{V_2} = \left(\frac{l_1}{l_2}\right)^3$
It's not that difficult of similar shapes I think I need more practice.

Difficulties encountered & Corresponding Solutions:
Some examples in the text book are not clear enough. I have asked my friends the methods of the similar shapes

Resources:
Internet, my friends and maths text book.

Conclusions:
I think I can handle a little part on similar shapes

Sample 59

SELF-DIRECTED LEARNING ON SIMILAR SHAPES
MATHEMATICS (2007-2008)
WORKSHEET 1

Name: Class: No.:

Objectives:
Study some important relations between similar shapes which provides such calculations possible

Study Plan:
Read the section which is about similar shapes.
Look at the example and do some exercises

Actual Steps Taken / Work Done:
Some of the class practice

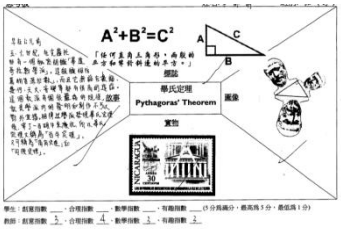
Findings:
Plane figure, $\frac{A_1}{A_2} = \left(\frac{l_1}{l_2}\right)^2$ Solid, $\frac{x_1}{x_2} = \frac{l_1}{l_2}$, $\frac{A_1}{A_2} = \left(\frac{l_1}{l_2}\right)^2$, $\frac{V_1}{V_2} = \left(\frac{l_1}{l_2}\right)^3$

Difficulties encountered & Corresponding Solutions:
Difficulties:
Don't understand the formulas and the lengthen explanation
Solutions:
Look up the dictionary and discuss the formulas with classmates

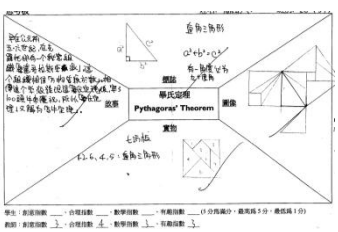
Resources:
Exploring Mathematics 3B, 12 nd edition

Conclusions:
It's better to do the self learning before the teach practices
It's not very difficult.

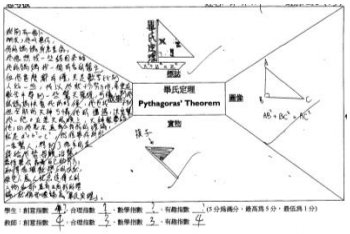
Sample 60



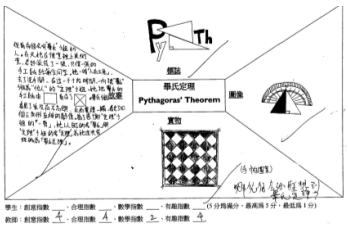
Sample 61



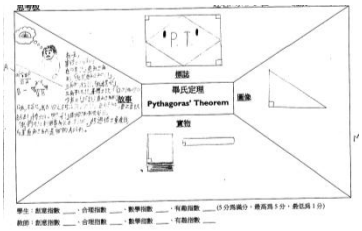
Sample 62



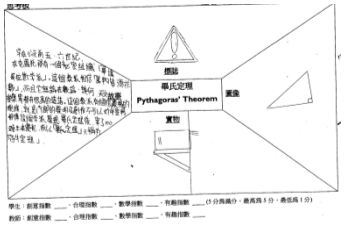
Sample 63



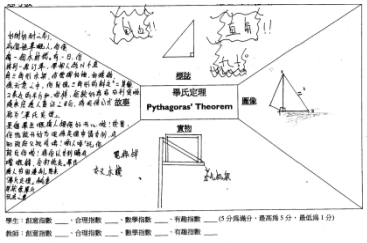
Sample 64



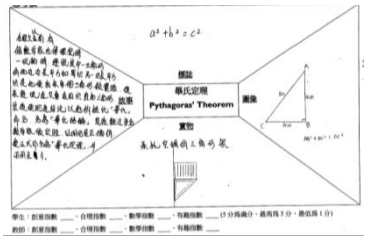
Sample 65



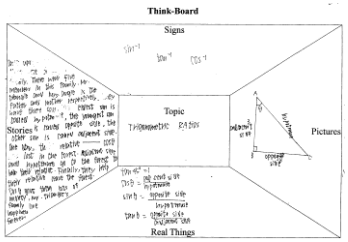
Sample 66



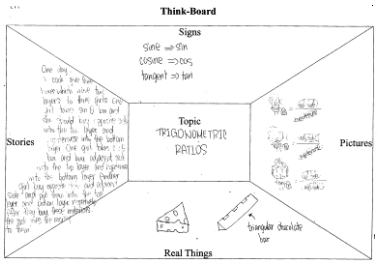
Sample 67



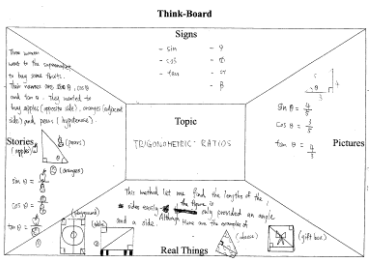
Sample 68



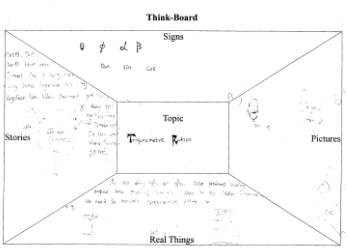
Sample 69



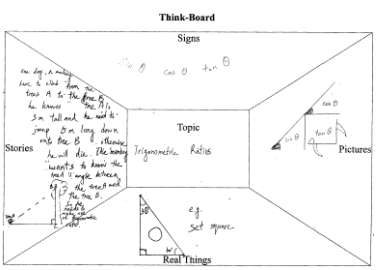
Sample 70



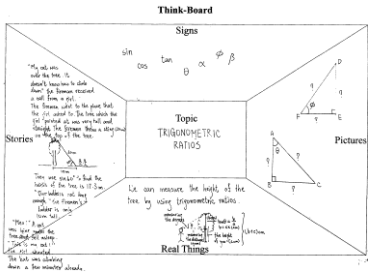
Sample 71



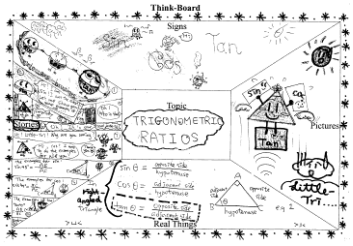
Sample 72



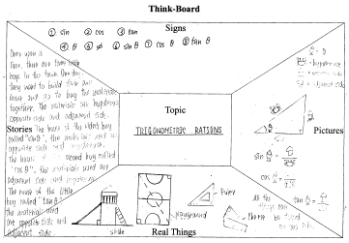
Sample 73



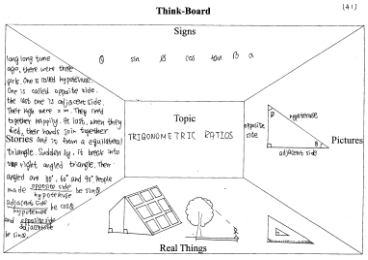
Sample 74



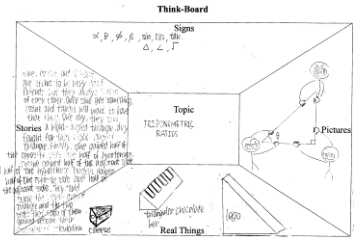
Sample 75



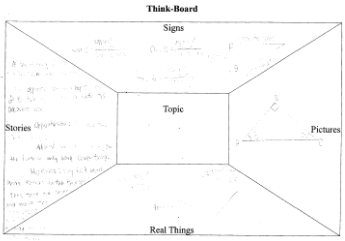
Sample 76



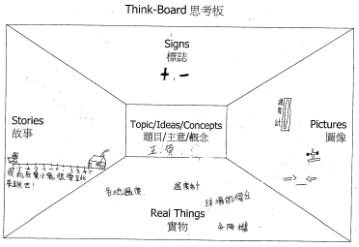
Sample 77



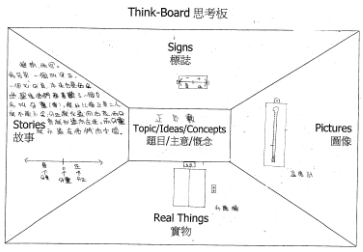
Sample 78



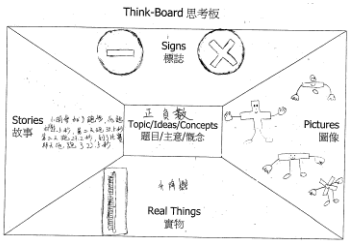
Sample 79



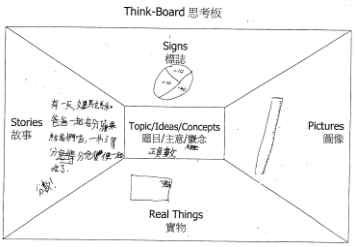
Sample 80



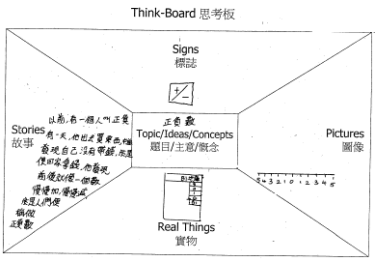
Sample 81



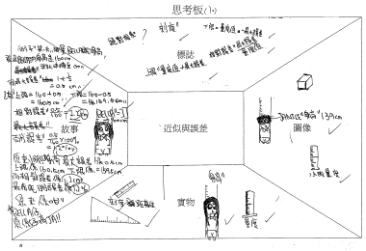
Sample 82



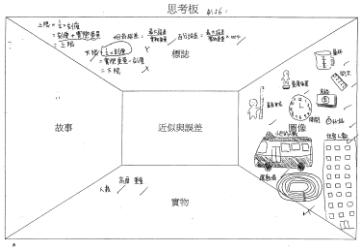
Sample 83



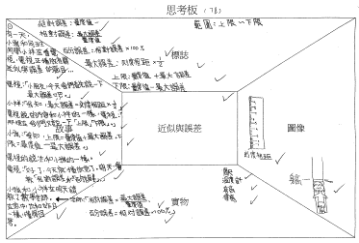
Sample 84



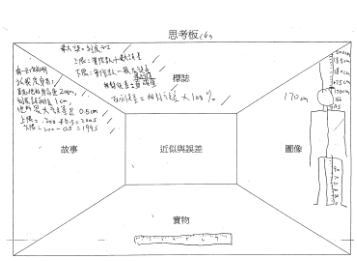
Sample 85



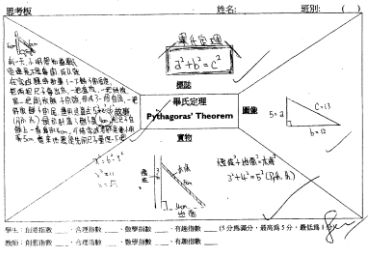
Sample 86



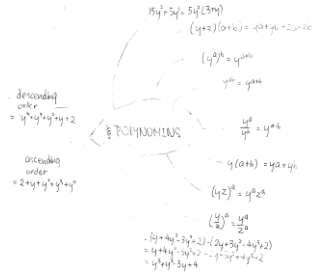
Sample 87



Sample 88



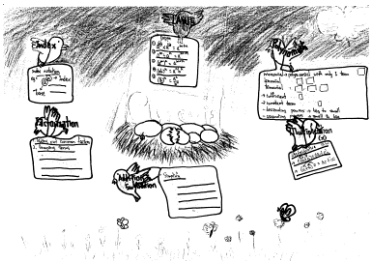
Sample 89



Sample 90

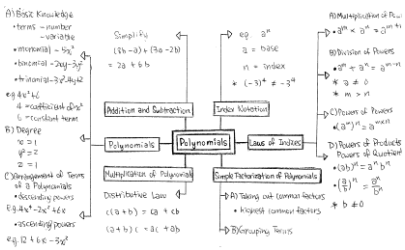
Sample 91

Sample 92

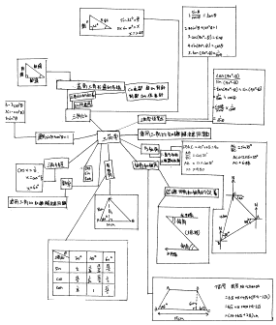


Sample 93

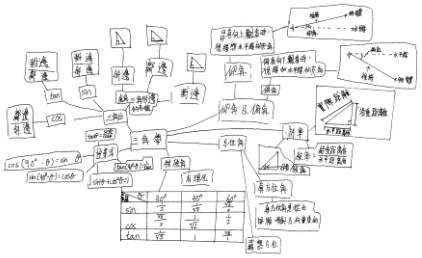
Sample 94



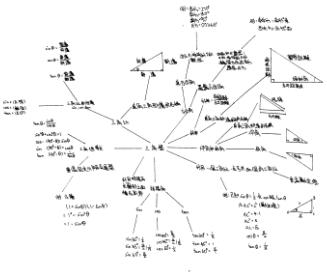
Sample 95



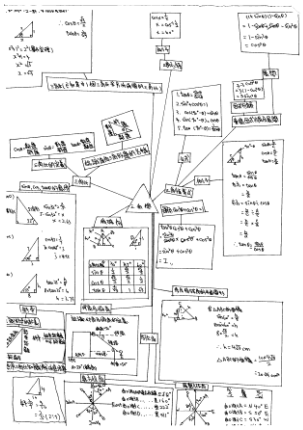
Sample 96



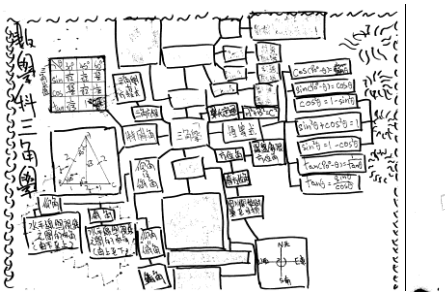
Sample 97



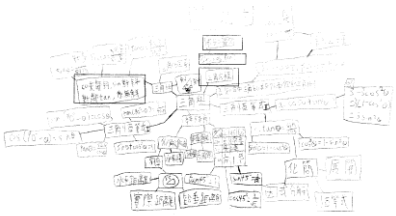
Sample 98



Sample 99



Sample 100



Sample 101

Appendix IV

The results of the two ratings of the 21 samples:

sample #	rating	SDL elements														no. of matches	no. of mismatches
		Learn1	Learn2	Learn3	Learn4	Self1	Self2	Self3	Self4	Meta1	Meta2	Meta3	Meta4	Moti1	Moti2		
1	1 st	0	0	0	0	1	1	0	1	1	0	0	1	0	0		
	2 nd	0	0	0	0	1	1	0	1	1	0	0	1	0	0	14	0
6	1 st	0	0	0	0	1	1	0	1	0	0	1	1	0	0		
	2 nd	0	0	0	0	1	1	0	1	0	0	0	1	0	0	13	1
11	1 st	1	0	1	1	0	1	0	1	0	0	0	0	0	0		
	2 nd	1	0	1	1	0	1	0	1	0	0	0	0	0	0	14	0
16	1 st	2	0	1	0	0	1	0	1	0	0	0	1	0	0		
	2 nd	2	0	0	0	0	1	0	1	0	0	1	1	0	0	13	2
21	1 st	0	0	1	0	0	0	0	1	0	0	0	1	0	0		
	2 nd	0	0	1	0	0	0	0	1	0	0	0	1	0	0	14	0
26	1 st	0	0	0	1	0	0	0	0	0	0	0	0	0	0		
	2 nd	0	0	0	1	0	0	0	0	0	0	0	0	0	0	14	0
31	1 st	1	0	1	1	1	1	0	1	0	0	0	1	0	0		
	2 nd	1	0	1	1	1	1	0	1	0	0	0	1	0	0	13	1
36	1 st	1	0	0	0	1	1	1	1	1	0	1	0	0	0		
	2 nd	1	0	0	0	1	1	1	1	1	0	1	0	0	0	14	0
41	1 st	0	0	0	1	1	1	1	1	1	0	0	0	0	0		
	2 nd	0	0	0	1	1	1	1	1	1	0	0	0	0	0	14	0
46	1 st	0	1	0	0	1	0	0	0	1	0	0	0	0	1		
	2 nd	0	1	0	0	0	0	0	0	1	0	0	0	0	1	13	1
51	1 st	0	0	0	1	0	1	1	0	0	0	0	0	1	1		
	2 nd	0	0	0	1	1	1	1	0	0	0	0	0	1	1	13	1
56	1 st	1	1	0	0	1	1	0	1	0	0	0	0	0	0		
	2 nd	1	1	0	0	1	1	0	1	0	0	0	0	0	0	14	0
61	1 st	0	0	0	1	0	0	0	1	0	0	0	1	0	0		
	2 nd	0	0	0	1	0	0	0	1	0	0	0	1	0	0	14	0
66	1 st	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	2 nd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0

71	1 st	0	0	1	1	0	0	0	1	0	1	1	1	1	0		
	2 nd	0	0	1	0	0	0	0	1	0	1	1	1	1	0	13	1
76	1 st	0	0	1	1	0	0	0	1	1	0	0	1	1	0		
	2 nd	0	0	1	1	0	0	0	1	1	0	0	1	1	0	14	0
81	1 st	0	0	1	0	0	0	0	1	1	0	1	1	0	0		
	2 nd	0	0	1	0	0	0	0	0	0	0	1	1	0	0	12	2
86	1 st	0	0	1	1	0	0	0	1	0	0	0	1	1	0		
	2 nd	0	0	1	1	0	0	0	1	0	0	0	1	1	0	14	0
91	1 st	1	0	1	1	2	1	1	1	1	0	1	1	1	0		
	2 nd	1	0	1	1	2	1	1	1	1	0	1	1	1	0	15	0
96	1 st	0	0	1	1	0	0	0	1	0	0	0	1	0	0		
	2 nd	0	0	1	1	0	0	0	1	0	0	0	1	0	0	14	0
101	1 st	1	0	1	1	0	0	0	1	0	0	0	1	0	0		
	2 nd	1	0	1	1	0	0	0	1	0	0	0	1	0	0	14	0
															Total	287	9

Appendix V

The results of coding all 101 samples:

	SDL elements													
sample #	Learn 1	Learn 2	Learn 3	Learn 4	Self 1	Self 2	Self 3	Self 4	Meta 1	Meta 2	Meta 3	Meta 4	Moti 1	Moti 2
1	0	0	0	0	1	1	0	1	1	0	0	1	0	0
2	1	0	0	0	1	1	1	1	1	1	1	0	1	0
3	1	0	1	1	1	1	1	1	1	0	1	0	0	0
4	1	0	0	0	1	1	1	1	1	1	1	1	1	0
5	1	1	0	0	0	2	0	1	1	1	0	0	0	0
6	0	0	0	0	1	1	0	1	0	0	1	1	0	0
7	1	0	0	0	1	1	1	1	1	1	1	0	0	0
8	1	0	0	0	1	1	0	1	1	1	1	0	1	0
9	0	0	1	1	0	1	0	0	0	0	0	0	0	0
10	0	0	1	1	0	1	0	1	0	0	0	0	0	0
11	1	0	1	1	0	1	0	1	0	0	0	0	0	0
12	1	0	1	1	0	1	0	1	1	0	0	0	0	0
13	0	0	0	1	0	0	0	0	0	0	0	0	0	0
14	0	0	1	1	0	0	0	0	0	0	0	0	0	0
15	1	0	1	1	0	0	0	1	0	0	0	0	0	0
16	2	0	1	0	0	1	0	1	0	0	0	1	0	0
17	0	0	0	1	0	0	0	0	0	0	0	0	0	0
18	1	0	1	1	0	0	0	1	0	0	0	0	0	0
19	1	0	1	0	0	1	0	1	1	0	0	0	0	0
20	0	0	1	1	0	0	0	0	0	0	0	0	0	0
21	0	0	1	0	0	0	0	1	0	0	0	1	0	0
22	1	0	1	1	0	0	0	1	0	0	0	0	0	0
23	0	0	1	1	0	1	0	0	1	0	0	0	0	0
24	1	0	1	1	0	0	0	1	0	0	0	0	0	0
25	1	0	1	1	0	0	0	1	0	0	0	0	0	0
26	0	0	0	1	0	0	0	0	0	0	0	0	0	0
27	1	0	1	1	0	1	0	1	1	0	1	0	1	1
28	1	0	1	1	0	1	0	1	1	0	0	0	1	0
29	1	0	1	1	0	1	0	1	1	1	1	0	1	0
30	1	0	1	1	0	1	0	1	1	0	1	0	0	0
31	1	0	1	1	1	1	0	1	0	0	0	1	0	0

32	1	0	1	0	0	1	0	1	0	0	1	0	1	1
33	1	0	1	1	0	1	0	1	1	0	1	0	1	0
34	1	0	1	1	0	1	0	1	1	1	1	1	1	0
35	1	0	1	1	0	1	0	1	1	1	1	1	1	0
36	1	0	0	0	1	1	1	1	1	0	1	0	0	0
37	0	0	0	1	0	1	0	1	1	0	0	1	0	0
38	1	0	1	1	0	1	0	1	1	0	0	1	1	0
39	0	0	1	0	0	1	1	1	1	0	1	0	1	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	1	1	1	1	1	1	0	0	0	0	0
42	0	0	0	1	1	1	1	1	1	0	1	0	0	0
43	0	0	0	1	1	1	1	1	1	0	1	1	0	0
44	0	0	1	1	1	1	0	1	1	0	1	0	0	0
45	1	1	1	1	1	0	0	1	0	0	0	0	1	0
46	0	1	0	0	1	0	0	0	1	0	0	0	0	1
47	0	0	0	0	0	0	0	1	1	0	0	0	0	0
48	1	1	1	1	0	1	0	0	1	0	1	0	1	1
49	0	0	0	1	1	1	0	0	1	0	1	0	1	1
50	1	0	1	1	1	0	0	0	1	0	0	0	1	1
51	0	0	0	1	0	1	1	0	0	0	0	0	1	1
52	2	1	0	1	1	1	0	0	2	0	0	0	1	0
53	1	1	1	2	0	0	0	1	0	0	1	0	0	1
54	0	1	0	1	1	0	0	1	1	0	0	0	1	0
55	1	1	0	1	1	0	0	0	1	0	0	0	1	1
56	1	1	0	0	1	1	0	1	0	0	0	0	0	0
57	1	0	0	0	1	0	0	0	1	0	0	0	1	0
58	1	0	0	0	1	1	0	0	1	1	0	0	0	0
59	1	1	0	0	1	0	0	0	0	1	1	0	1	0
60	1	1	0	0	1	0	0	0	1	0	1	0	1	0
61	0	0	0	1	0	0	0	1	0	0	0	1	0	0
62	0	0	1	1	0	0	0	1	0	0	0	1	0	0
63	0	0	0	1	0	0	0	1	0	0	0	1	0	0
64	0	0	0	0	0	0	0	0	0	0	0	1	0	0
65	0	0	0	0	0	0	0	0	0	0	0	1	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	1	0	0	0	1	0	0
68	0	0	1	1	0	0	0	1	0	0	0	1	0	0
69	0	0	1	1	0	0	0	1	0	0	0	1	1	0

70	0	0	1	1	0	0	0	1	0	0	0	1	1	0
71	0	0	1	1	0	0	0	1	0	1	1	1	1	0
72	0	0	1	0	0	0	0	1	0	0	0	2	0	0
73	0	0	1	0	0	0	0	0	0	0	1	1	1	0
74	1	0	1	1	0	0	0	1	0	0	1	1	1	0
75	0	0	1	1	0	0	0	1	0	0	0	1	1	0
76	0	0	1	1	0	0	0	1	1	0	0	1	1	0
77	0	0	1	0	0	0	0	1	0	0	0	1	1	0
78	0	0	1	0	0	0	0	1	0	0	0	2	1	0
79	0	0	1	1	0	0	0	1	0	0	0	1	0	0
80	0	0	1	0	0	0	0	1	0	0	0	1	1	0
81	0	0	1	0	0	0	0	1	1	0	1	1	0	0
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	1	0	0
85	0	0	1	1	0	0	0	1	0	0	0	1	1	0
86	0	0	1	1	0	0	0	1	0	0	0	1	1	0
87	0	0	1	1	0	0	0	1	0	0	0	1	1	0
88	0	0	1	1	0	0	0	1	0	0	0	0	0	0
89	0	0	1	1	0	0	0	0	0	0	0	0	1	0
90	0	0	1	1	0	0	0	1	0	0	0	1	0	0
91	1	0	2	1	1	2	1	1	1	0	1	1	1	0
92	0	0	1	1	5	5	0	1	1	0	1	1	1	0
93	0	0	1	1	0	0	0	1	0	0	0	1	1	0
94	0	1	1	1	0	0	0	1	1	0	0	1	1	1
95	0	0	1	1	0	0	0	1	0	0	0	1	0	0
96	0	0	1	1	0	0	0	1	0	0	0	1	0	0
97	0	0	1	1	0	0	0	1	0	0	0	1	0	0
98	4	0	1	1	0	0	0	1	0	0	0	1	1	0
99	1	0	1	1	0	0	0	1	0	0	0	1	1	0
100	1	0	1	1	0	0	0	1	0	0	0	1	0	0
101	1	0	1	1	0	0	0	1	0	0	0	1	0	0
	48	12	65	68	31	46	11	74	42	11	29	49	43	10

	Learn 1	Learn 2	Learn 3	Learn 4	Self 1	Self 2	Self 3	Self 4	Meta 1	Meta 2	Meta 3	Meta 4	Moti 1	Moti 2
Total	193				162				131				53	