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Relationship of creativity and critical thinking to pattern recognition among Singapore private school students

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ABSTRACT

Cognitive pattern recognition is known to be an important skill for academic subjects such as mathematics, science, languages, or even humanities. In this study, we investigate the relationships between creativity, critical thinking, and pattern recognition among 203 private school students in Singapore. The instruments used include a creativity test (modified Creativity Selected Elements Questionnaire), a Critical Thinking Test (modified Cornell Critical Thinking), and a pattern recognition test. The main data analysis is done using the SMART-PLS structural equation modeling software. The results of the study reveal that creativity is a weak predictor of pattern recognition ($\beta = 0.131$, p > 0.05, $f^2 = 0.024$) but critical thinking is a good predictor ($\beta = 0.517$, p < 0.05, $f^2 = 0.374$). An implication of the research outcome is that more training on critical thinking should be given to the students to improve their pattern recognition ability.

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Introduction

Students in Singapore who wish to sit the General Certificate of Education 'Ordinary' level examinations (commonly known as the GCE 'O' level examinations) are usually registered through public schools. However, there are some students who are not eligible to register via the public school route. They have to register as private candidates and take preparatory courses in private schools.

Generally, private school students do not fare as well as their public school counterparts in academic studies. While 99.9% of public school candidates passed the 2018 GCE 'O' level examinations, only 89.6% of private candidates were able to do so (Ang, 2019). In addition, a preliminary study shows that private school students lack the ability to recognize important patterns or trends and to develop connections embedded in various subjects.

A search of the literature reveals significant relationships between creativity and pattern recognition (Kazakoff et al., 2012; Kozhevniknov et al., 2013; Trinter et al., 2015), and between critical thinking and pattern recognition (Harris & Spiker, 2012; Ireland, 2008; Ozgen & Minsky, 2013). Therefore, one possible way to help the students is to identify and establish correlations between pattern recognition with cognitive abilities such as creativity or critical thinking, so that when teachers work on building up those cognitive abilities, the pattern recognition ability should hopefully improve as well. Both creativity and critical thinking are important higher-order cognitive skills needed for the twenty-first century (Norris, 2018). By establishing the relationships of creativity and critical thinking with pattern recognition, it is hoped that more can be done to enhance the academic performance of private school students. The results of analysis of the data collected are presented in this paper.

Background to the study

The Singapore educational system comprises compulsory education of 10 to 11 years, with six years of primary education and four to five years of secondary education. The majority of children register to enroll in Primary 1 at the age of seven, and at the end of their six years of primary school education they will sit the Primary School Leaving Examination (PSLE). The PSLE results will stream the children into three main streams in secondary schools: Express, Normal (Academic), and Normal (Technical).

Students who score better in their PSLE will usually enter into the Express stream, where they will embark on a fouryear course to prepare themselves for the GCE 'O' level examinations. Students who are less academically inclined will enter into the Normal (Academic) stream, where they will sit the GCE 'N' level examinations at the end of the fourth year, and if they perform well enough, they will be eligible to sit the GCE 'O' level examinations at the end of the fifth year. The Normal (Technical) stream caters for students who are academically very weak. At the end of the fourth year, Normal (Technical) students will sit the GCE 'N' level examinations, and their results will determine whether they continue their studies at the Institute of

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Technical Education (ITE) or leave the system and start working.

Foreign students who wish to sit the GCE 'O' level examinations in Singapore have two options to do so. They can sit the Ministry of Education (MOE) Admission Exercise for International Students (AEIS) entrance examinations. AEIS examinations assess the student's level of English proficiency, numerical ability, and reasoning ability (MOE, Singapore, Ministry of Education (MOE) & Singapore, 2016). Admission into public schools through AEIS is not guaranteed, however. It depends mainly on two factors: the performance of the candidate in the AEIS examinations and the number of vacancies in public schools. The other option is for foreign students to enroll themselves into private schools. In this case, the foreign students will register as private candidates to sit the examinations together with the mainstream Singapore students.

Private schools in Singapore accept mainly four types of student from diverse academic and cultural backgrounds onto their GCE 'O' level preparatory courses. The first type of student is foreigners who come from countries such as Malaysia, Indonesia, the Philippines, Vietnam, China, Kazakhstan, etc. The second type of student is local Singaporean students who have taken the GCE 'O' level examinations but did not do well enough to qualify for the courses that they wish to study at tertiary institutions (for example, polytechnics or junior colleges). The third type of student is people who sat the GCE 'N' level examinations but failed to be promoted to the fifth year at public secondary schools to take the GCE 'O' level examinations. The fourth type is young working adults who dropped out of the education system when they were younger for various reasons, but who now wish to continue their studies in search of better prospects.

The GCE 'O' level preparatory course entrance requirements for private schools are slightly different for the local and international students. Local students will need to complete at least secondary 3, the GCE 'N' level or equivalent academic standards while international students will need to complete middle school or its equivalent (Stalford Academy, 2019).

Statement of problem

The GCE 'O' levels examiners' reports in 2003, 2005, and 2010 indicated that students who sat the mathematics paper

in Singapore often had difficulty solving problems related to pattern recognition and generalization, such as the construction of a functional rule from a given pattern (Chua & Hoyles, 2014). Many students fail to recognize the patterns hidden in numerical sequences required to develop the generalized functional rules for the patterns.

A study was conducted on the performance of 104 Grade 8 students in Singapore with a focus on their success rates in pattern generalization tasks (Chua & Hoyles, 2014). The study found that about 70 percent of the students were able to construct the generalization rule for each pattern (Chua & Hoyles, 2014).

To examine the problem in more detail, a preliminary study using a simple pattern recognition test was administered to a group of 61 private school candidates (mean age of 17.1 years) in April 2016 and a group of 45 public school candidates (mean age of 16.1 years) in June and July 2016. All of the respondents were students who would be sitting their GCE 'O' level examinations in October 2016. The pattern recognition test comprised eight short multiple-choice questions. Table 1 shows the percentages of respondents who were able to identify the correct patterns for each of the eight test items.

At the end of the study, an independent samples *t*-test was conducted to compare the mean of the private candidates with that of the public candidates. Results revealed that the *t*-test was significant (t = -2.089, df = 104, p < 0.05). The mean difference value of -0.65 indicated that in the population from which the sample was drawn, students from public schools fared better at pattern recognition than private school students.

Despite the fact that most private school students have received several years of formal education, and pattern recognition and generalization has been part of the Singapore mathematics curriculum since primary school, their level of pattern recognition remains significantly weak compared to their counterparts in public schools. However, there is very little research addressing the issue, and no alternative solution has been developed (Chua & Hoyles, 2014).

One possible solution is to identify and establish new connections between pattern recognition and other cognitive factors. If we are able to establish a relationship between pattern recognition and other cognitive abilities, together with continuous training in pattern recognition by schools, it may be possible to improve the students' pattern recognition skills. Either the related cognitive abilities can be

Table 1. Private vs public candidates for preliminary study.

Private school candidates			Public school candidates		
Test item	No. of correct identifications	Percentages	Test item	No. of correct identifications	Percentages
1	48	78.7%	1	37	82.2%
2	47	77.0%	2	35	77.8%
3	55	90.2%	3	40	88.9%
4	35	57.4%	4	33	73.3%
5	44	72.1%	5	39	86.7%
6	44	72.1%	6	37	82.2%
7	44	72.1%	7	37	82.2%
8	50	82.0%	8	38	84.4%
Mean Score / 8 6.02		Mean Score / 8		6.67	
Sample size, $N = 61$		Sample size, $N = 45$	5		

nurtured or a suitable environment to promote the cognitive abilities can be created in schools to enhance the effectiveness of pattern recognition (Chiam, Hong, Ning, & Tay, 2014). A search of the literature shows potential relationships between pattern recognition and higher order thinking skills such as creativity and critical thinking (Henriksen, Cain, & Mishra, 2014; Raghunathan, 2013; Root-Bernstein, 2015).

Rationale of study

To enhance the overall academic performance of students, can we simply train the students in pattern recognition, assuming that pattern recognition is able to influence the results? Is it necessary for us to tap into other cognitive abilities to influence pattern recognition, and ultimately improve overall academic performance? The teaching of pattern recognition techniques during mathematics classes is inadequate to yield any significant results due to the limited time students spend on pattern recognition in the classroom. From the school's perspective, organizing pattern recognition workshops is neither economically viable nor feasible, as the concept has already been briefly taught during mathematics lessons. In addition, pattern recognition training sessions are generally attended by students who are taking the qualifying exams for programs such as the gifted education program, or by professional adults for work-related progress. Such coaching may not be appropriate for the 'O' level private school students. Therefore, the researcher feels that by exploring the relationships with pattern recognition of other cognitive abilities, such as creativity and critical thinking, more can be done to enhance the academic performance of private school students.

Research objectives

Specifically, this study aims to:

- Establish the significant correlation between private school students' creativity and their pattern recognition abilities.
- Establish the significant correlation between private school students' critical thinking skills and their pattern recognition abilities.

Research questions

Based on the above research objectives, two research questions are developed which this study aims to answer:

- 1. Do students who exhibit a higher level of creativity also demonstrate significantly better pattern recognition abilities?
- 2. Do students who exhibit a higher level of critical thinking also demonstrate significantly better pattern recognition abilities?

Main Hypotheses Being Tested

With the above two research questions, two hypotheses, H_A1 and H_A2 , are developed.

- *Hypothesis* H_A1 : There is a significant correlation between creativity and pattern recognition.
- *Hypothesis* H_A 2: There is a significant correlation between critical thinking and pattern recognition.

Literature review

Related theories and models

A good piece of research must be built on sound theories or models. This will ensure that the study is able to produce meaningful results applicable in the real-world context and of use to support future relevant projects. In this section, several theories and models selected for the study are discussed.

Selected theories and models for creativity

Creativity with innate and external elements

Nadarajan (2014) proposed the four innate elements of creativity: originality, ingenuity, resolution, and synthesis. Originality is defined as a novelty that is valuable, generative, and useful. Ingenuity refers to the smartness and innovativeness to come up with unique solutions. Resolution allows the creation of something which is valuable, logical, useful, and easily understood. Synthesis refers to linkages between two ideas that appear to be different.

The four external elements of creativity are replication, redefinition, reconstruction, and reinitiation (Nadarajan, 2014). Replication is the transfer of existing knowledge into a new context. Redefinition is the extension of knowledge into a totally new direction. Reconstruction refers to the introduction of a new development into an old redundant approach. Reinitiation is the development of a new idea that starts at a very different point from the current one and branches in a totally new and different direction.

Using the above eight creativity domains, Nadarajan developed the Creativity Selected Elements Questionnaire (CSEQ) as a creative psychological assessment tool. The development of the tool was based on the fundamental principles of the Creative Product Semantic Scale introduced by Besemer (cited in Cropley, 2000, p. 72) and the propulsion model (Sternberg, Kaufman, & Pretz, 2004). This study adopted and modified the CSEQ instrument to measure creativity.

Selected theories and models for pattern recognition

Pi, Liao, Liu, and Lu (2008) assert that current cognitive psychology has suggested three theories of pattern recognition: the theory of template (template matching models); the theory of prototype (prototype matching models); and the theory of feature (models with analysis of features). A fourth theory, the theory of sequence, is proposed here to address the academic demands of the Singapore mathematics syllabus, where students are required to recognize and generalize patterns by analyzing the given sequences.

Theory of template

The theory of template matching accepts without proof that the physical picture of an object is transmitted to a central processing unit in an endeavor to compare it directly to various stored patterns, which are called templates (Pi et al., 2008). Template matching theory is used frequently in machines and software applications for authentication purposes. In the human template matching process, our senses take in the external information and compare it with existing templates that have been stored in the memory from our prior life encounters.

Theory of prototype

Prototype matching is like a fuzzy version of template matching. It allows a person to compare the general characteristics of a particular item or subject (Pi et al., 2008). Once a set of general characteristics has been identified, the person can make a good guess at what the particular object or pattern is. Unlike template matching, in which comparisons are made to numerous templates based on the external input, prototype matching only requires the general characteristics to be determined before a pattern can be recognized.

Theory of feature

In feature analysis, humans try to match one or more features of a pattern or object with that stored in the memory (Pi et al., 2008). In this theory, each external input comprises a combination of critical features (or simpler mini-templates) which enable us to match with the correct pattern. Our brain simply combines the various features that it receives from the external environment and presents to us the best sensible picture as the pattern according to our prior experiences.

Theory of sequence

The theory of sequence is included to address the way that a person is able to recognize alphanumeric patterns by analyzing prior sequences. Theoretically, in order for a normal person to determine an alphanumeric pattern accurately, the given sequence should contain three or more prior items in the sequence so as to obtain the unit of repeat. The unit of repeat, according to Liljedahl (2004), is the smallest subset of elements in a pattern that can generate the pattern through successive generation. In fact, the greater the number of items in the given sequence, the more likely it is that a person is able to recognize the unit of repeat.

Selected model for critical thinking

The Cornell-Illinois model and Cornell Critical Thinking Tests

The Cornell-Illinois model of critical thinking was developed and subsequently improved by Robert Ennis (Kaupp & Frank, 2014). The model was based on three elements of critical thought—induction, deduction and value judging—as well as the four methods on which they are based: the results of inferences, observations, statements, and assumptions. These three modes of critical thought and the four methods are inter-related and were used as the guiding model to develop the Cornell Critical Thinking tests.

The Cornell Critical Thinking tests are designed to measure a wide range of critical thinking abilities and have been used extensively in education research. There are two levels, X and Z. Level X is chosen for this study as it is suitable for use with students from Grade 4 to 12. The test comprises 71 multiple-choice questions which assess critical thinking domains such as induction and deduction.

Theoretical framework of the study

In order to build a model suitable for structural equation modeling (SEM), we need to develop a theoretical framework based on sound theoretical foundations, supported by evidences gathered from past studies. This is essential, as a theoretical framework is built upon theories that have already been tested by researchers.

For creativity, the Creative Product Semantic Scale and the propulsion model are the fundamental theories on which the CSEQ is built. Besemer developed the Creative Product Semantic Scale, which is built on three dimensions: novelty, resolution, and elaboration and synthesis (cited in Cropley, 2000, p. 72). These dimensions have been assessed by qualified persons using a semantic-differential rating scale. Further studies by Besemer in 1998 confirmed the Creative Product Semantic Scale's ability to differentiate the level of creativity among products. The items in the Creative Product Semantic Scale achieved rather high reliabilities of alpha coefficients, between 0.69 and 0.87, with most of the coefficients above 0.80 (Besemer, cited in Cropley, 2000, p. 72).

The propulsion model presented by Sternberg et al. (2004) suggests eight creative contributions. The authors use the word 'propulsion' as a metaphor to explain the ways in which different areas of practice or industries in real life are propelled by these creative contributions. The eight creative contributions are replication, redefinition, forward incrementation, advance forward incrementation, redirection, reconstruction, reinitiation, and integration. Of the eight creative contributions, the CSEQ adopts four: replication, redefinition, re

For pattern recognition, the main theories involved will be the theory of feature matching, the theory of prototype matching, and the theory of sequence, described above. To measure pattern recognition, a measuring instrument has been developed and validated by a panel of experts as well as by 32 private school students.

The instrument chosen to measure critical thinking is the Cornell Critical Thinking test. The theory which developed the test was the Cornell-Illinois model of critical thinking. The Cornell-Illinois model of critical thinking is based on three elements of critical thought and the four methods on which they are based. Figure 1 below shows the Cornell-Illinois model, in which the three types of inference (critical thoughts) and the four bases for such inferences (methods) are inter-connected by the constantly present notion of attention to meaning (Kaupp & Frank, 2014).

Finally, the theoretical framework is formed as shown in Figure 2. The framework is later used to develop the SEM model for the study (Figure 3).

Review of past studies and development of hypotheses

The two hypotheses were developed based on literature reviews of past studies and identification of the problem. Three main latent variables are considered: creativity, critical thinking, and pattern recognition. Using the theoretical framework, Figure 4 shows the research hypotheses relating



Figure 1. The Cornell-Illinois model.

the relationships between creativity and pattern recognition, and between critical thinking and pattern recognition.

Development of hypotheses H_A1 and H_A2

In the field of psychology, there are many types of cognitive ability. Cognitive abilities are brain-based skills that we need in order to complete tasks of varying levels of difficulty. Examples of cognitive abilities are memory, visual perception, visual and spatial processing, creativity, critical thinking, mathematical ability, etc. This part of the literature review is interested in the relationships of creativity and critical thinking with one aspect of visual and spatial processing ability: pattern recognition. This section will present the various past studies and results contributing to the development of research hypotheses H_A1 and H_A2 , that there are significant correlations between creativity and critical thinking and pattern recognition.

Relationship between creativity and pattern recognition

This section presents several recent studies and written perspectives on the possible relationship between people's creativity and pattern recognition ability. The studies cover sectors such as primary school education, tertiary education and arts training.

Felix T. Hong quotes Simonton's chance configuration theory (Hong, 2013, p. 7), which divides a creative process into three phases: 'blind' variation, selection, and retention. In a sense, the pattern recognition process follows these



Figure 2. The theoretical framework.



Figure 3. The SEM model.



Figure 4. Model showing the research hypotheses.

three creative phases. Initially, a pattern is like a problem, and the objective is to find a suitable template (solution) that best fits the pattern. In order to do that, the solver must explore a variety of possible templates (variation). Only templates which are considered to have a high chance of a good match are selected (selection). After trying each template, the solution is obtained by settling on the correct or 'best fit' pattern (retention).

It is also no surprise that creative activities involving arts and crafts are able to develop cognitive skills such as observation, visual thinking, and the ability to form and recognize patterns. Arts training, in particular, stimulates scientific creativity which improves pattern recognition and geometric thinking skills (Root-Bernstein, 2015). Therefore, it has been suggested that arts education should be integrated with science to produce students capable of creative participation in a science-dominated society (Root-Bernstein & Root-Bernstein, 2013). Alongside arts and crafts, the use of speech and language is another example of pattern recognition and the creativity of the brain (Raghunathan, 2013). The human brain has an excellent capacity to form recognizable patterns in the midst of chaos. For example, when reading is done too quickly, key data can sometimes be overlooked. When such errors occur, the brain uses its creativity to discover new patterns in the sentences and attempt to continue the process of reading.

Kozhevniknov, Kozhevniknov, Chen, and Blazhenkova (2013) investigate the relationship between different dimensions of creativity and dimensions of visualization abilities and styles. A sample of 24 undergraduates was recruited for the first study and a further 75 undergraduates participated in the additional experiment. The results show that object visualization is closely related to artistic creativity, and spatial visualization to scientific creativity.

Henriksen and his group of researchers (Henriksen, Cain, et al., 2014) dug deeper into the concepts relating patterning to creativity. In their opinion, pattern recognition leads to pattern selection and, finally, pattern formation. As a cognitive skill, pattern formation is a creative move which is more challenging than pattern recognition and selection. In general, the authors regarded pattern recognition, selection, and formation as 'pattern thinking', which can be meaningfully applied to invite more creative thinking. In another paper (Henriksen, Mehta, & Mishra, 2014, p. 9), they cite the views of Michele and Robert Root-Bernstein that creative scientists and artists generally use a key set of cognitive skills that cut across disciplinary boundaries. These skills encapsulate the ways in which creative people and effective learners think. One such skill is patterning.

The study of mathematics creativity and patterning is not restricted to the study done by Mann (2005). Trinter, Moon, and Brighton (2015) studied a sample of five second graders and discovered that mathematically creative students are able to manifest their talents in creative ways. When engaged in problem-solving activities, mathematically creative students are able to switch from computation to visual to symbolic to graphical pattern representations as and when appropriate. They are better at figuring out patterns embedded in problems and use original approaches to solve the problems.

Relationship between critical thinking and pattern recognition

The relationship between critical thinking and pattern recognition has been investigated and discussed in several important sectors. In particular, healthcare education, science education, and entrepreneurial education have seen several studies conducted.

In the area of nursing education, Welk (2002) suggests in her study of practical applications that pattern recognition should be promoted among nursing students by inviting students in classroom and post-conference situations to share and critically review examples of clinical situations. This critical thinking activity can provide the structure of a fastthinking activity in pattern learning, which is important for clinical practice. Ireland (2008) also discusses in her paper that, through the use of reflective journaling, nursing students' critical thinking skills can be enhanced by improving pattern recognition ability and relationship formation. In this sense, although critical thinking is not directly used as a predictor for pattern recognition, it is clearly implied that a relationship does exist between the two cognitive abilities.

In terms of using concept mapping to improve nurses' critical thinking skills, Wilgis and McConnell (2008) use Benner's theoretical framework (Benner, 1984) to highlight that nurses' critical thinking and decision-making skills improve by developing pattern recognition. Three years later, Chen, Liang, Lee, and Liao (2011) published a study on the use of concept map teaching to promote nursing students' critical thinking. The quasi-experiment involved 47 students forming the experimental group and 48 students forming the control group, and two questionnaires were administered: the Critical Thinking Scale (CTS) and the Approaches to Learning and Studying Inventory (ALSI). Using SPSS version 13 to conduct the data analysis, it was found that the deep approach was positively correlated with overall critical thinking (r = 0.26, p = 0.01) and inference (r = 0.41, p = 0.001). The deep approach involves pattern recognition and critical examination of the logic of argument.

In science education, it is also of great importance that we inculcate critical thinking skills in our younger generation. The enhancement of critical thinking skills will improve the ability to recognize patterns, and pattern recognition is an important cognitive ability in the study of science because, regardless of the scientific field, patterns will inevitably exist. Postiglione mentions that "any exercise that correlates this skill [critical thinking] to a predictable pattern will provide much-needed reinforcement" (Postiglione, 1987, p. 28).

The relationship between critical thinking and pattern recognition can also be found in entrepreneurship education, particularly in opportunity recognition. In their report, Ozgen and Minsky (2013) mention that opportunity recognition involves pattern recognition as a cognitive process. It is through pattern recognition that individuals are able to identify connections between independent events, leading to the formulation of ideas for new ventures. Dyer, Gregersen, and Christensen (2008) assert that critical thinking is one of the cognitive abilities contributing to the opportunity recognition process (cited in Ozgen & Minsky, 2013, p. 50).

Harris and Spiker (2012) study on intelligence analysis identifies 11 critical thinking skills that have the largest influence on intelligence analysis. The researchers attempted to map these 11 critical thinking skills into four separate intelligence analysis functions: assess and integrate information, organize information into premises, develop hypotheses, and test hypotheses. In particular, within the function organizing information into premises, the ability to recognize patterns and relationships is an identified critical thinking skill (Harris & Spiker, 2012).

In the Singapore education context, the teaching of critical thinking has been incorporated into mathematics, science, and humanities curricula for many years. In particular, the mastery of mathematics requires students to critically analyze problems. Sometimes, students are also expected to recognize any embedded patterns in the problems and/or solutions so that similar solutions can be used to solve similar problems. At the same time, pattern recognition is an examinable topic under the Singapore mathematics curriculum framework (Kaur, 2013; Ng, 2016; Singapore Examination & Assessment Board, 2016). Based on the above discussion, there are sufficient past evidences to suggest that significant relationships do exist between creativity, critical thinking, and pattern recognition.

Methods

The focus of this study is to investigate the relationships of creativity and critical thinking with pattern recognition ability among private school students studying in Singapore. Given the research questions and the nature of the study, the research methodology will be based on correlation design using quantitative data analysis. It is hoped that the study will reveal significant correlations between the variables of the creativity and critical thinking domains and the two pattern recognition variables, FP (feature-prototype) and SE (sequence-logic). The main software used in this study is Smart PLS 2.0.

The participants

The main participants were 203 private candidates sitting their GCE 'O' levels examinations in either 2018 or 2019. They included local and international students between the ages of 16 and 19 studying at private schools in Singapore. Prior to the main data collection, another 61 private school students and 45 public school students participated in the 2016 preliminary study of differences in pattern recognition abilities. A separate small group of 32 students also helped in the process of validation of the instruments, the results of which are not discussed in this paper. Hence, a total of 341 students participated in this study.

Variables of concern

Dependent variable

The dependent variable in this study is the cognitive pattern recognition ability of private school students studying in Singapore.

Predictor variables

There are two main predictor variables in this study: creativity and critical thinking. These two variables are the cognitive abilities that have been identified, through the review of literature, as possibly having significant relationships with pattern recognition.

The instruments

Creativity test: CSEQ

For this study, the CSEQ creative psychological assessment instrument was used to measure the level of creativity of students. The original CSEQ contains a total of 40 items. After the content validation process, the modified instrument was left with 29 items to measure the elements of originality, ingenuity, reconstruction, reinitiation, redefinition, and replication. Redefinition and replication were subsequently removed after factor analysis. A sample of the test is shown in Appendix A.

Cornell Critical Thinking Test

To measure the level of critical thinking ability, the Cornell Critical Thinking test Level X was chosen, being modified and adapted according to the Singapore context. A sample page of the modified and validated Critical Thinking test (based on Cornell Critical Thinking test Level X) is shown in Appendix B. Permission was obtained from The Critical Thinking Company, the authorized distributor of the Cornell Critical Thinking test Level X, to modify the instrument to make it more relevant to the Singapore context. The original Cornell Critical Thinking test Level X contains a total of 76 items, separated into four sections. After the content validation process, the test was shortened to 31 items with only two sections, measuring the elements of induction and deduction.

Pattern recognition test

A thorough search of the literature reveals that there is currently no pattern recognition test that is able to carry out the precise assessment that this study requires. Therefore, a pattern recognition test had to be customized and developed based on several criteria. Firstly, the level of difficulty had to be matched to that of the targeted sample, who are all private school students sitting their GCE 'O' level examinations. Secondly, the items had to be constructed to assess the respondents' ability to recognize patterns through identifying features, prototypes, or sequences. Thirdly, the instrument had to be reliable and valid. The final pattern recognition test after content validation comprised three multiple-choice items and six fill-in-the-blank items to measure the feature-prototype and sequence-logic elements (Appendix C).

Content validation process of the instruments

To determine content-related validity of the instruments, this project adopted a five-step approach with the help of a panel of experts and private school students. The panel of experts included lecturers with PhDs who had been involved in related work and/or professionals who had sufficient knowledge about the cognitive abilities.

Step 1. The first step is to provide the panel of experts the first draft of the instruments. The experts are asked to give comments or make any changes they feel are necessary to improve on the content validity of the instruments. The validation process involves three experts for each instrument. Depending on their profiles, some of the experts are involved to validate more than one instrument.

Step 2. When all the comments or feedbacks from the experts are received, the changes are made and a second draft is sent out for the experts to rate each item in the instrument that they have validated. In addition, for each instrument, one more expert, who did not take part in the validation process but with relevant expertise, is also invited to rate the items.

Step 3. When all the ratings are received, the content validity indices (CVIs) are calculated. Further revisions are made according to the results of the indices.

Step 4. All the experts are then requested to indicate if they agree with the overall content validity of the final draft. All experts in the panel signed off to indicate their agreement.

Step 5. The instrument is field-tested using a small number of 32 private school students who are taking the GCE 'O' levels but do not belong to the samples who are involved in the main data collection process. Further amendments are carefully made accordingly to their responses and comments. The instruments are then administered to 203 private school students to finally establish the validity and reliability.

In step 3, subject-matter experts are asked to rate the items in each instrument in terms of its relevancy to the construct to be measured, using a 4-point ordinal scale as 1: not relevant, 2: somewhat relevant, 3: quite relevant and 4: highly relevant. The CVI for each item is then calculated at the item level and scale level.

In order to calculate the item level CVI (I-CVIs), the ratings are split into two broad categories, merging rating scales of '1: not relevant' and '2: somewhat relevant' into 'Not Relevant' and combining rating scales of '3: quite relevant' and '4: highly relevant' into 'Relevant' (Zamanzadeh et al., 2015). The I-CVI gives the degree of agreement on the relevancy of the item, with a number range between 0 and 1. In order to calculate the I-CVIs, the number of experts who gave the ratings as '3: quite relevant' or '4: highly relevant' is divided by the total number of experts who rated the item (Zamanzadeh et al., 2015).

Interpretation of I-CVIs: If the I-CVI is higher than 79 percent, the item is accepted. If it is between 70 and 79 percent, it needs revision. If it is less than 70 percent, it is eliminated (Zamanzadeh et al., 2015).

The scale-level CVI for the entire scale (S-CVI) is defined as the proportion of items being given a rating of 'quite relevant' and 'highly relevant' by all raters involved. One simple way of calculating S-CVI is to obtain the average of all the I-CVIs. Polit and Beck mentioned that many researchers had proposed an S-CVI of 0.80 or higher for the instrument to be considered acceptable (Polit & Beck, 2006). Tables 2–5 illustrate the calculations of the CVIs for the various instruments. Four experts are involved in the content rating process for each of the instrument.

Instrument: Pattern recognition test

At step 3 to establish the content validity of the instrument, four subject matter experts were invited to give their ratings on the relevance of the instrument to measure pattern recognition ability of the students. The I-CVIs as well as the S-CVI for the pattern recognition instrument are then calculated. Items with I-CVIs of 0.75 are revised while items with I-CVIs less than 0.75 are eliminated (Table 2).

After further revisions from step 3 (with items 2, 9, and 10 removed), the members in the panel are then presented

with the final copy of the pattern recognition test. At step 4, all the experts eventually agreed and signed off that the content of the test is valid and relevant to measure the pattern recognition ability of the students.

Instrument: Creativity test (CSEQ)

Similarly, to establish the content validity of the instrument to measure creativity, four subject matter experts were invited to give their ratings on the relevance of the instrument. The

ltems	Relevant (with rating '3' or '4')	Not Relevant (with rating '1' or '2')	I-CVIs	Interpretations
1.	4	0	1.00	Accepted
2.	2	2	0.50	Eliminated
3.	4	0	1.00	Accepted
4.	4	0	1.00	Accepted
5.	3	1	0.75	Needs revision
6.	4	0	1.00	Accepted
7.	4	0	1.00	Accepted
8.	3	1	0.75	Needs revision
9.	2	2	0.50	Eliminated
10.	2	2	0.50	Eliminated
11.	3	1	0.75	Needs revision
12.	3	1	0.75	Needs revision

S-CVI (after removal of eliminated items): 0.89.

dified).
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ltems	Relevant (with rating '3' or '4')	Not relevant (with rating '1' or '2')	I-CVIs	Interpretations
1.	3	1	0.75	Needs revision
2.	4	0	1.00	Accepted
3.	2	2	0.50	Eliminated
4.	3	1	0.75	Needs revision
5.	4	0	1.00	Accepted
6.	3	1	0.75	Needs revision
7.	4	0	1.00	Accepted
8.	2	2	0.50	Eliminated
9.	4	0	1.00	Accepted
10.	3	1	0.75	Needs revision
11.	3	1	0.75	Needs revision
12.	3	1	0.75	Needs revision
13.	4	0	1.00	Accepted
14.	4	0	1.00	Accepted
15.	4	0	1.00	Accepted
16.	4	0	1.00	Accepted
17.	4	0	1.00	Accepted
18	3	1	0.75	Needs revision
19.	3	1	0.75	Needs revision
20.	3	1	0.75	Needs revision
21.	3	1	0.75	Needs revision
22.	3	1	0.75	Needs revision
23.	4	0	1.00	Accepted
24.	4	0	1.00	Accepted
25.	4	0	1.00	Accepted
26.	4	0	1.00	Accepted
27.	4	0	1.00	Accepted
28.	4	0	1.00	Accepted
29.	3	1	0.75	Needs revision
30.	4	0	1.00	Accepted
31.	4	0	1.00	Accepted
32.	4	0	1.00	Accepted
33.	4	0	1.00	Accepted
34.	4	0	1.00	Accepted
35.	4	0	1.00	Accepted
36.	3	1	0.75	Needs revision
37.	- 3	1	0.75	Needs revision
38.	4	0	1.00	Accepted
39.	3	1	0.75	Needs revision
40.	4	0	1.00	Accepted
	·	-		

S-CVI (after removal of eliminated items): 0.90.

Table 4. CVIs for Critical Thinking Test.						
Sections	Relevant (with rating '3' or '4')	Not Relevant (with rating '1' or '2')	I-CVIs	Interpretations		
Section I	Section I (items 1 and 2 are omitted as they are examples)					
3.	4	0	1.00	Accepted		
4.	4	0	1.00	Accepted		
5.	4	0	1.00	Accepted		
6.	3	1	0.75	Needs revision		
7.	4	0	1.00	Accepted		
8.	4	0	1.00	Accepted		
9.	4	0	1.00	Accepted		
10.	4	0	1.00	Accepted		
11.	3	1	0.75	Needs revision		
12.	4	0	1.00	Accepted		
13.	4	0	1.00	Accepted		
14.	3	1	0.75	Needs revision		
15.	4	0	1.00	Accepted		
16.	4	0	1.00	Accepted		
Section I	ll (item 17 is omitted as it is an example)					
18	4	0	1.00	Accepted		
19.	4	0	1.00	Accepted		
20.	4	0	1.00	Accepted		
21.	4	0	1.00	Accepted		
22.	4	0	1.00	Accepted		
23.	3	1	0.75	Needs revision		
24.	4	0	1.00	Accepted		
25.	4	0	1.00	Accepted		
26.	4	0	1.00	Accepted		
27.	4	0	1.00	Accepted		
28.	4	0	1.00	Accepted		
29.	4	0	1.00	Accepted		
30.	4	0	1.00	Accepted		
31.	4	0	1.00	Accepted		
Section I	III (item 32 is omitted as it is an example)					
33.	4	0	1.00	Accepted		
34.	4	0	1.00	Accepted		
35.	4	0	1.00	Accepted		
36.	4	0	1.00	Accepted		
37.	3	1	0.75	Needs revision		
38.	4	0	1.00	Accepted		
39.	4	0	1.00	Accepted		
40.	4	0	1.00	Accepted		
41.	4	0	1.00	Accepted		
42.	4	0	1.00	Accepted		
43.	4	0	1.00	Accepted		
44.	4	0	1.00	Accepted		
45.	3	1	0.75	Needs revision		
46.	4	0	1.00	Accepted		
Section I	V (item 47 is omitted as it is an example)	C C		, leep tea		
48.	4	0	1.00	Accepted		
49.	4	0	1.00	Accepted		
50.	4	0	1.00	Accepted		
51.	4	0	1.00	Accepted		
52.	4	0	1.00	Accepted		
53.	4	0	1.00	Accepted		
54.	4	0	1.00	Accepted		
55.	4	0	1.00	Accepted		
56	т Л	Õ	1.00	Accented		
57	4	õ	1.00	Accepted		
2.	·	-		, accpica		

S-CVI: 0.97.

I-CVIs as well as the S-CVI are then calculated to check for further revisions. Items with I-CVIs of 0.75 are revised while items with I-CVIs less than 0.75 are eliminated (Table 3).

After further revisions from step 3, with two items removed (item 3 and 8), the members in the panel are then presented with the final copy of the creativity test (modified CSEQ). At step 4, all the experts eventually agreed and signed off that the content of the test is valid and relevant.

Instrument: Critical Thinking Test

Last but not least, to establish the content validity of the instrument to measure critical thinking, four experts in

critical thinking were invited to give their ratings on the relevance of the instrument. The I-CVIs as well as the S-CVI are then calculated to check if further revisions are necessary. Again, items with I-CVIs of 0.75 are revised while items with I-CVIs less than 0.75 are eliminated (Table 4).

After further revisions from step 3 (with no item being removed), the members in the panel are then presented with the final copy of the Critical Thinking Test. At step 4, all the experts eventually agreed and signed off that the content of the Critical Thinking Test is valid and relevant to measure the critical thinking skills of the students.

Table 5. Reliability sum	mary for indicators.			
Creativity				
Indicators	Loadings	Indicator reliability (>0.4, >0.7 preferred)	Composite reliability (>0.7)	AVE (>0.5)
Ingenuity	0.819	0.67	0.8666	0.6193
Originality	0.7436	0.55		
Reconstruction	0.8154	0.66		
Reinitiation	0.7672	0.59		
	Average:	0.61929374		
Critical Thinking	-			
Indicators	Loadings	Indicator reliability (>0.4, >0.7 preferred)	Composite Reliability (>0.7)	AVE (>0.5)
Deduction	0.888	0.788544	0.873	0.7746
Induction	0.8722	0.76073284		
	Average:	0.77463842		
Pattern Recognition	-			
Indicators	Loadings	Indicator reliability (>0.4, >0.7 preferred)	Composite reliability (>0.7)	AVE (>0.5)
Feature-Prototype	0.7923	0.62773929		
Sequence-Logic	0.8952	0.80138304	0.833	0.7146
. 5	Average:	0.714561165		

Table 6. Latent variable correlations and sqrt (AVE) for discriminant validity.

	Creativity	Critical thinking	Pattern recognition
Creativity	0.78695616		
Critical thinking	-0.0081	0.880113629	
Pattern recognition	0.1269	0.5161	0.845340168
Latent variables correl	ations		
CREATIVITY	1	0	0
CRITICAL_THK	-0.0081	1	0
PATTERN_RECOG	0.1269	0.5161	1

The bold numbers are the square root of AVEs and values of AVEs are obtained using the factor loadings. A run of the bootstrap function in smart pls shows that all the factor loadings have t > 1.96, p < 0.05.

A pilot study was then conducted using a small group of 32 private school students who were not involved in the final study. The responses from the students were marked. Exploratory factor analysis was conducted and, depending on the opinions of the panel of experts, some of the items were regrouped, rewritten, or even discarded. The instruments were then administered to 203 private candidates. The validity and reliability of the instruments were finally established using SmartPLS. Table 5 shows the values of the indicator reliabilities, composite reliability and the Average Variance Extracted (AVE).

Validity and reliability of the instruments

For indicator reliability, a value of 0.70 or higher is generally preferred, with minimum acceptable level of 0.40 (Wong, 2013). From Table 5, all the indicator reliabilities registered values above 0.40, with the lowest value as 0.55. Hence, indicator reliability is achieved. Bagozzi and Yi (1988) suggested that internal consistency reliability is considered fairly high if the composite reliability is larger than 0.70 (cited in Wong, 2013). From Table 2, all the composite reliabilities are above 0.80, showing that internal consistency reliability is also achieved. Bagozzi and Yi (1988) also suggested that to achieve convergent validity, the AVE of each latent variable has to be higher than 0.5 (cited in Wong, 2013). In this case, convergent validity is established as the AVE for all the three latent variables are above 0.50. It is suggested that, to achieve discriminant validity, the square root of AVE of each latent variable should be greater than the correlations among the latent variables (Wong, 2013).

With reference to Table 6, the magnitudes of all the latent variable correlations are less than the square root of AVE. Therefore, discriminant validity is confirmed.

Data collection and the SEM model

Data collection

The responses from 203 students studying the GCE 'O' level preparatory course in four Singapore private schools were collected in March 2018 and February to April 2019. All the data collection sessions were conducted in classroom settings, where every student was required to complete the whole questionnaire within a period of 1–1.5 hours. The students were allowed to take short breaks if they felt the need to visit the toilet. At the end of each session, students who had completed the full questionnaire were given \$10 vouchers as small tokens of appreciation.

The SEM model

As the study was mainly based on SEM, the software chosen to conduct the data analysis was SmartPLS. After conducting the exploratory factor analysis, the final SEM model is shown in Figure 3.

In the SEM model in Figure 3, the PATTERN_RECOG construct represents the pattern recognition ability, with two indicators: feature-prototype and sequence-logic. The CREATIVITY construct comprises four indicators—ingenuity, originality, reconstruction, and reinitiation—while the critical thinking construct CRITICAL_THK consists of two indicators: deduction and induction. Figure 5 shows the path coefficients after the PLS algorithm is run.

Results and discussions

Hypotheses H_A1 and H_A2 (combined effect analysis)

For hypotheses H_A1 and H_A2 , we are testing to see if there are significant correlations between creativity and critical thinking and pattern recognition, according to the coefficient of determination, R^2 , being around 0.67 (substantial), 0.33 (moderate), or 0.19 (weak) (Chen & Lee, 2013; Shanmugapriya & Subramanian, 2015). Based on the structural equation model in Figure 5, the coefficient of determination is 0.284. This implies that the two latent variables (CREATIVITY and CRITICAL_THK) combined explain 28.4 percent of the variance of pattern recognition



Figure 5. The SEM model after running the PLS algorithm.

(PATTERN_RECOG), showing a moderate explanatory power.

Hypothesis H_A1

Hypothesis H_A1 tests the relationship between creativity and pattern recognition. The inner model in Figure 5 suggests that CREATIVITY has a weak effect on PATTERN_RECOG ($\beta = 0.131$). After bootstrapping of the final structural equation model, the path coefficient is non-significant (t = 1.014, p > 0.05), which implies that the hypothesized path relationship between CREATIVITY and PATTERN_RECOG is statistically insignificant at the 5 percent level.

Effect size of creativity variable (f^2)

Previously, effect size has been used as a factor to determine the appropriate sample size for this study using SEM. In this section, the effect size f^2 is examined to determine if the omission of an exogenous variable (e.g., creativity) affects the endogenous construct substantially (i.e., pattern recognition) (do Nascimento & da Silva Macedo, 2016). This is necessary because it gives us an idea of the overall contribution of the variable in the research.

Based on manual calculation using the formula proposed by Hair, Hult, Ringle, & Sarstedt in 2014 (cited in do Nascimento & da Silva Macedo, 2016, p. 299):

$$f^2 = \frac{R^2 included - R^2 excluded}{1 - R^2 included}$$

the effect size of each latent variable can be calculated.

In the path model of Figure 5, PATTERN_RECOG indicates an R² of 0.284. However, the corresponding R² excluding CREATIVITY is 0.267. As a result, the calculated f^2 is 0.024. Taking into consideration that f^2 values of 0.02, 0.15, and 0.35 show a small, medium, and large effect respectively (Hair, Hult, Ringle, & Sarstedt, 2014), the effect of the CREATIVITY construct is considered to be very small.

Hypothesis H_A2

Hypothesis H_A2 tests the relationship between critical thinking and pattern recognition. The SEM model in Figure 5 suggests that CRITICAL_THK has a stronger effect on PATTERN_RECOG than CREATIVITY ($\beta = 0.517$). Similarly, after bootstrapping, the path coefficient is significant (t = 6.595, p < 0.05). The hypothesized path relationship between CRITICAL_THK and PATTERN_RECOG is statistically significant at the 5 percent level.

Effect size of critical thinking variable (f^2)

The corresponding R^2 excluding CRITICAL_THK is 0.016. The calculated f^2 for critical thinking is 0.374, indicating that the effect of CRITICAL_THK construct has a large effect.

We conclude that CREATIVITY is a poor predictor of PATTERN_RECOG and CRITICAL_THK is a very good predictor of PATTERN_RECOG. Hypothesis H_A1 is not supported, but hypothesis H_A2 is supported.

Predictive relevance (Q^2) and effect size (q^2)

It is also necessary that we assess the level of predictive relevance of the model (q^2) , using Stone-Geisser's Q^2 value (Garson, 2016). SmartPLS software is able to generate the Q^2 values using the blindfolding technique. The process of blindfolding is an iterative procedure that systematically and selectively removes values in the data set to predict the relevance of the model; the procedure should only be applied to reflective models (Garson, 2016). The procedure is applied to the PATTERN_RECOG construct using the omission distance of D = 7, as suggested by Hair (Hair, Hult, Ringle, & Sarstedt, 2016) (cited in Doss, 2017, p. 196).

The formula to calculate the effect size of predictive relevance, denoted by q^2 (cited in do Nascimento & da Silva Macedo, 2016, p. 299) is given by:

$$q^{2} = \frac{Q_{incl}^{2} - Q_{excl}^{2}}{1 - Q_{incl}^{2}}$$

To calculate q^2 for the CREATIVITY construct on PATTERN_RECOG, the values of Q^2_{excl} and Q^2_{incl} were obtained using the blindfolding procedure. Table 7 presents the results.

Based on Table 7, when the Q²_{incl} value of the endogenous construct in a reflective SEM model is larger than zero, it indicates that there is predictive relevance for the particular construct (Hair et al., 2014). In this case, the endogenous construct PATTERN_RECOG shows a Q²_{incl} of 0.199, which implies that the SEM model has a medium-large predictive relevance for this construct. At the same time, for the calculation of relative effect size, q^2 , it can be observed that q^2 for the predictive relevance of CREATIVITY for PATTERN_RECOG registers a very small positive value (q² = 0.0162). This means that there is very little predictive relevance of CREATIVITY for PATTERN_RECOG. However, the q^2 effect size for the predictive relevance of CRITICAL_THK for PATTERN_RECOG registers a positive value of 0.235 (where 0.02 is small, 0.15 medium, and 0.35 large). The value of 0.235 indicates that CRITICAL THK has a medium-large effect on producing the Q^2 predictive relevance for PATTERN_RECOG (Hair et al., 2014).

Further analysis of the relationships between pattern recognition, creativity, and critical thinking

The relationships between pattern recognition, creativity, and critical thinking can be further investigated at the indicator level. Statistics based on the data collected point to there being a significant relationship between critical thinking and pattern recognition, and a non-significant relationship between pattern recognition and creativity. A separate SEM model is developed to study further the significance of the relationships by looking at the indicators. Figure 6 shows the model.

In the above model, the left side shows the original six indicators from the CREATIVITY construct, while the right side presents the two indicators from the CRITICAL_THK construct. The middle portion has the two indicators belonging to the PATTERN_RECOG construct. The PLS algorithm was run. Figure 7 indicates the various path coefficients.

From Figure 7, the coefficients of determination for the sequence-logic and feature-prototype indicators are 0.275 and 0.188 respectively. This implies that the six indicators from the CREATIVITY construct and the two indicators



Figure 6. Structural equation model for Indicators.



Figure 7. Structural equation model for indicators with path coefficients.



Figure 8. Structural equation model for indicators after bootstrapping.

from the CRITICAL_THK construct combined explain 27.5 percent and 18.8 percent respectively of the variance of the sequence-logic and feature-prototype indicators. All eight indicators therefore have a moderate or weak explanatory power to explain the variance of the sequence-logic and feature-prototype indicators (Chen & Lee, 2013; Shanmugapriya & Subramanian, 2015).

More importantly, the significance of the relationships between the various indicators is studied by running the bootstrapping function in SmartPLS. Figure 8 above shows the values of the t-statistics for the various relationships between the different indicators after bootstrapping.

In particular, it can be observed that the deduction indicator from the CRITCAL-THK construct has significant relationships with sequence-logic ($\beta = 0.227$, t = 2.086 > 1.96, p < 0.05) and feature-prototype ($\beta = 0.324$, t = 2.891 > 1.96, p < 0.05) of the PATTERN_RECOG construct. At the same time, the induction indicator from the CRITICAL_THK construct exhibits a significant relationship with the sequence-logic indicator ($\beta = 0.351$, t = 3.609 > 1.96, p < 0.05), but not with the feature-prototype indicator ($\beta = 0.111$, t = 0.982 < 1.96, p > 0.05). None of the indicators from the CREATIVITY construct exhibits a significant relationship with the construct relationship with the PATTERN_RECOG indicators.

Conclusions

In this paper, the results of the study to determine the relationships between creativity and critical thinking and pattern recognition are presented. Two hundred and three Singapore private school students took part in the main body of the study. Data analysis revealed that creativity does not have a significant relationship with pattern recognition, with a small effect size and little predictive relevance. However, critical thinking exhibited a significant relationship with pattern recognition, with a large effect size and medium-large predictive relevance for pattern recognition. It can also be observed that the deduction indicator for critical thinking has significant relationships with sequence-logic and feature-prototype of pattern recognition. At the same time, the induction indicator for critical thinking exhibits a significant relationship with the sequence-logic indicator but not with the feature-prototype indicator.

Based on the research findings, it is necessary that more studies be conducted to examine closely the relationship between critical thinking and pattern recognition, as this study has revealed a significant relationship between these two variables. In addition, the effects of moderating and mediating variables should be identified and examined. At the same time, it is recommended that a similar study to the one discussed in this paper be conducted on public school students to determine the significance of the relationships among the three cognitive abilities in the public school domain so as to benefit more students.

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Appendix A: Sample of the modified creativity test (CSEQ)

The Creativity Selected Elements Questionnaire (CSEQ) Instrument [20 minutes approximately]

Please answer all questions by checking your relevant choice in the blank space below the choice.

1. Have you tried traveling on a different route to reach the same destination?

1 – Not at all	2 – seldom	3 – Often	4 – All the time

2. Have you ever chosen an entirely new solution to solve an old repetitive problem?

1 – Not at all	2 – Seldom	3 – Often	4 – All the time
3. Have you new probl	ı chosen an ol em?	d solution to	solve an entirely
1 – Not at all	2 – Seldom	3 – Often	4 – All the time
4. Imagine, in cross a fast frame. Dur tives to cro	the absence of ar flowing river on a ing the time of co ss the river instead	ny other resource a fallen tree log nsideration, do y d of using the fai	es, you are trying to within a given time- you think of alterna- llen tree log?
1 – Not at all	2 – seldom	3 – Often	4 – All the time
5. Have you e tact names	ever thought how and phone numbe	you can rememl ers without any f	ber a thousand con- form of gadget aid?
1 – Not at all	2 – Seldom	3 – Often	4 – All the time

6. Have you ever considered analyzing a problem by viewing it under different scenarios?

1 – Not at all	2 – Seldom	3 – Often	4 – All the time

7. Have you ever wondered whether the performance of any popular K-pop group can be replicated (copied) in your own country?

1 – Not at all	2 – Seldom	3 – Often	4 – All the time

8. Have you ever tried redefining 'water' as 'H2O' or 'Sky Juice' in your daily conversation?

1 – Not at all	2 – Seldom	3 – Often	4 – All the time

Appendix B: Part of the Modified Critical Thinking Test

(Modified with permission from Cornell Critical Thinking Test Level X)

Section I

What happened to the first group?

The first task for your group is to find out what happened to the first group of explorers. Your group has landed on the island of Arenmia and has just discovered the metal huts put up by the first group. From the outside, the huts appear to be in good condition. It is a warm day and the sun is shining. The trees, rocks, grass, and birds make Arenmia appear identical to the Kingdom of Argo. You and the medical officer are the first to arrive at the group of huts. You call out, but there is no reply from anyone.

The medical officer suggests, "Maybe they're all dead." You try to find out if he is right

Listed below are some facts you learn. You must decide whether each fact supports the medical officer's idea or suggests that the medical officer's idea is mistaken, or neither.

For each fact, mark one of the following on your answer sheet:

A. This fact **supports** the medical officer's idea that everyone in the first group is dead.

B. This fact goes against the medical officer's idea.

C. Neither: this fact does not help us decide.

Example 1 (例子1)

1.	You ao	into	the f	irst hu	t. Ever	vthina	is	covered	bv a	thick	aver	of dust.
•••						,			~, ~		~,~.	

Is this fact for or against the medical officer's idea, or neither? It certainly isn't enough to prove him right, but it does give some support. If a fact supports the medical officer's idea, you should mark A on your answer sheet. Circle **A** for item 1.

Example 2 (例子2)

2. Other members of your group discover the first group's ship nearby.

The answer is C. Knowing that the first group's ship has been discovered doesn't help you decide one way or the other. Since this fact doesn't help you decide whether the medical officer is right or wrong, C is correct.

Here is a list of facts. For each one, mark A, B, or C. If you have no idea which to circle, leave a blank and go on to the next one. Consider each fact in the order in which it is numbered. Work carefully, and do not return to a problem once you have passed it.

Circle your answers.

3.	There are ten huts. You go into the second hut and again find that eventthing is covered by a thick layer of dust	A/B/C
4.	You go into the third hut. There is no dust on the cooking stove.	A/B/C
5.	You find a can opener by the cooking stove in the third hut.	A/B/C

Appendix C: the pattern recognition test

Sequence-Logic Pattern Recognition [Max 18 points]

- What is the next number in the series: 2, 3, 6, 18, 108, _____?
 (i) 124 (ii) 126 (iii) 137 (iv) 1008 (v) 1944
- 2) What is the next number in the series: 3, 6, 11, 18, 27, 38, 51, 66, _____?
 (i) 79 (ii) 81 (iii) 83 (iv) 89 (v) 117
- 3) Identify the correct picture in the sequence below:



4) If **SOLDERING** can be encrypted as **RNK EFS HMF**, how can you code the word **ALUMINIUM**?

- 5) What are the next two numbers in the series: 5, 13, 24, 38, 55, _____, ____?
- 6) Analyze the following number pattern. Write down, as simply as possible, the expression that represents the nth term of the sequence.

n = 1	2	3	4		n
1	4	9	16		(i)
0	3	8	15		(ii)
1	7	17	31		(iii)
-1	0	3	8		(iv)
	n = 1 1 0 1 -1	$\begin{array}{cccc} n = 1 & 2 \\ 1 & 4 \\ 0 & 3 \\ 1 & 7 \\ -1 & 0 \end{array}$	$\begin{array}{ccccccc} n=1 & 2 & 3 \\ 1 & 4 & 9 \\ 0 & 3 & 8 \\ 1 & 7 & 17 \\ -1 & 0 & 3 \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

- (i) The expression that represents the nth term of Pattern 1 is: _____
- (ii) The expression that represents the nth term of Pattern 2 is:
- (iii) The expression that represents the nth term of Pattern 3 is:
- (iv) The expression that represents the nth term of Pattern 4 is: _____

Feature-Prototype Pattern Recognition [Max 19 points]7) Part of a seven letter word below has been masked out. Identify the word. All letters are block capitals.



For Q8 and Q9: By matching the elements in the prototype to form specific English letters, write down as many capital letters as you can form.

- For each letter, you can use some or all of the elements, but you can only use each element once.
- You are not allowed to rotate, flip, or change the orientation of the elements. Use them as they are.
- One point is awarded for each correct letter and one point is deducted for each wrong letter. The minimum score is zero.

8) The prototype set below contains three elements: two slanted lines and one vertical line. How many capital letters can you match and form?



9) The prototype set below contains five elements: two horizontal lines, two vertical lines, and one curve. How many capital letters can you match and form?



END OF TEST