Investigating the Development of Reasoning Abilities Among Bruneian Physics Students After 1 Year Exposure to Cambridge International Advanced Level Program

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Abstract. The aim of this study is to investigate the development of different reasoning abilities among Bruneian physics students after undergoing one year of Cambridge International Advanced level (‘A’ level) programme. This particular study administered pre and post questionnaires, namely, verbal critical reasoning, spatial ability and abstract reasoning. These questionnaires were distributed among ‘A’ level physics students from four out of six, sixth form centres. There were 173 students (73 male and 100 female students) who participated in the study. Non-parametric tests (i.e. Wilcoxon Signed-Rank Test and Mann Whitney U) were conducted on the pre-test and post-test scores of verbal critical reasoning, spatial ability and abstract reasoning and their corresponding gain scores due to violation of normality and presence of outliers in the data. Wilcoxon Signed-Rank Test revealed that there were significant differences in the spatial reasoning score and abstract reasoning score from pre-test to post-test. Meanwhile Mann Whitney U test indicated that male students outperformed female students in abstract reasoning during pre-test and post-test. Thus for this particular sample, there is an increase in students’ abstract reasoning abilities and spatial reasoning abilities. A further investigation might be needed in exploring the reasoning abilities scores of the students with their ‘A’ level results to make a stronger claim for this study.

1. Introduction
There is a growing interest in using psychometric test as one of the means for job recruitment amongst most large companies and small-medium enterprises (SMEs). Hence it is no surprise the occurrences of this phenomenon are also observed in higher educational institutions such as colleges and universities. For instance, The Graduate Record Examination (GRE) is an admission requirement for many graduate schools in the United States and in other English-speaking countries. This test measure verbal reasoning, quantitative reasoning, critical thinking, and analytical writing skills that are not related to any specific field of study. Another similar type of test also been meted out among United Kingdom’s universities such as University of Leeds and Cardiff University. They adapted UKCAT content and preparation as part of admission requirement. UKCAT is mainly a psychometric test which include basic arithmetic, reading and writing ability, along with character, and personal and social attitudes. In addition, Israel higher education also has used standardized test called psychometric entrance exam which heavily weighed for university admission as a large body of research indicating that the Psychometric Entrance Test has a high predictive ability. Hence our study...
is utilising psychometric tests to determine Bruneian physics students’ reasoning abilities that focus on verbal reasoning ability, spatial ability and abstract reasoning.

In this section, the definitions used for verbal critical reasoning, spatial reasoning ability and abstract reasoning will be elaborated. As the instruments used in this study were adopted from Newton and Bristoll [1], the definitions stated by these authors were used.

1.1. Verbal critical reasoning
Verbal critical reasoning is one’s ability to understand, manipulate, interpret analytically and logically make sound conclusions based on information provided [1]. It is important to note that verbal reasoning is not similar to reading, however, mastering critical reading is a requirement for verbal reasoning as mentioned by Burton, Welsh, Kostin and VanEssen [2].

1.2. Spatial ability
Spatial reasoning ability is defined as one’s ability to visualize and manipulate two-dimensional or three-dimensional shapes or patterns [1]. It encompasses matching shape, rotating shape, combining shapes, viewing cube in three-dimensions, and manipulating of other solid shapes in two and three dimensions.

1.3. Abstract reasoning
Abstract reasoning is very much related to general intelligence where one’s ability to see relationships and co-relationships (i.e. symbols and patterns) with no pre-requisite knowledge on language or mathematics [1].

1.4. Previous studies
Colom, Contreras, Arend, Leal and Santacreu [3] discussed several meta-analyses on gender differences in verbal ability and spatial ability performances. It was commonly found that females tend to out-perform their males counterpart in verbal ability test while the males tend to outperform the females in spatial ability test. However, their study found that males outperformed females in both the verbal reasoning test and spatial ability test which contradicted the meta-analyses trend on gender differences on verbal reasoning ability. They contributed the reason of this finding was due to the verbal reasoning tasks that they used in their study required spatial ability to solve it.

Most of the literature mentioned that spatial reasoning is one of the cognitive domains that has a consistent trend where male students tend to outperformed female students [4-6]. In Ganley, Vasilyeva and Dulaney’s study [4], they found that spatial ability especially mental rotation ability was more dominant in male students as compared to female students. In the case of abstract reasoning, very limited research papers that looked into the area of physics or science subjects for secondary students can be found. Nonetheless the instrument used to measure the abstract reasoning ability for this study was based on Spearman’s two-factor theory of intelligence [7].
Based on the discussion of the literature above, this study was guided by two research questions which are as follow:

RQ 1: Are there any differences among the students’ performance on verbal critical reasoning, spatial ability and abstract reasoning tests from pre-test to post-test?
RQ 2: Are there any differences between male and female students’ performances of the three tests?

2. Method
This particular study administered pre and post questionnaires, namely, verbal critical reasoning, spatial ability and abstract reasoning. These questionnaires were distributed among ‘A’ level physics
students from four out of six, form six centres. There were 173 students (73 male and 100 female students) who participated in the study. The pre-test were administered at the beginning of the year (February) before the students officially started their ‘A’ level course. The post-test was conducted towards the end of the year, which was in November, after they sat for their final year examination. Each school agreed to a specific date to administering the pre and post-test. The test papers were collected at the end of the each session.

During the pre-test, 391 students involved in the study. However, only 173 students sat for both pre and post-test. Students who had not sat for the post-test were not included in the data analysis of this study. The consent form and the three tests were bundled together and were given identification numbers. The identification numbers were coded accordingly to the students’ name which can be found in the consent form. This is the coding procedure to ensure anonymity of the students. The same procedure was also applied during the post-test session.

3. Data analysis
A non-parametric tests were conducted on the pre-test and post-test score of verbal critical reasoning, spatial ability and abstract reasoning and their corresponding gain scores. By inspecting the boxplot of the pre-test score of verbal critical reasoning and spatial ability, there were several outliers observed and none for abstract reasoning pre-test score. In terms of normality, the pre-test score of verbal critical reasoning and spatial ability showed violation to normality by graphical (histogram and Q-Q normal plot) and numerical (Shapiro Wilk test) inspection using SPSS. While pre-test score of abstract reasoning only violated normality via numerical inspection (Shapiro Wilk). Similar patterns were observed in the post-test score of the three tests. While for the gain score of the three tests, the boxplot showed several outliers for the gain score of spatial ability and abstract reasoning and none for the gain score of verbal critical reasoning. In terms of normality, the gain score of spatial ability and abstract reasoning showed violation to normality via graphical (histogram) and numerical (skewness and kurtosis and Shapiro Wilk test) inspection using SPSS. While the gain score of verbal critical reasoning only showed violation of normality via numerical inspection. Thus Wilcoxon Signed-Rank Test is used to analyse the data to answer research question 1 (RQ 1) and Mann Whitney U Test to answer research question 2 (RQ 2).

4. Findings
This section will describe the findings of the students’ performances on verbal reasoning test, spatial reasoning test and abstract reasoning test. Table 1 and Table 2 below indicated the significant p value (below 0.05) of Wilcoxon Signed Rank test and Mann Whitney U test respectively.

Table 1. Wilcoxon Signed Rank test for spatial ability and abstract reasoning ability.

|                | Spatial_total_post-test | Abstract_total_post-test |
|----------------|-------------------------|---------------------------|
| Spatial_total_pre-test | Z = -5.982<sup>b</sup>  | Z = -6.812<sup>b</sup>   |
| Asymp. Sig. (2-tailed) | .000                    | .000                      |

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.
Table 2. Mann Whitney U test for spatial ability and abstract reasoning ability for pre-test and post-test result.

|             | Spatial_total_pretest | Spatial_total_post | Abstract_total_pretest | Abstract_total_post |
|-------------|-----------------------|--------------------|------------------------|---------------------|
| Mann-Whitney U | 2899.000              | 2938.500           | 2969.000               | 2940.500            |
| Wilcoxon W   | 7949.000              | 7988.500           | 8019.000               | 7990.500            |
| Z            | -2.314                | -2.194             | -2.100                 | -2.189              |
| Asymp. Sig.  | .021                  | .028               | .036                   | .029                |

a. Grouping Variable: Sex

4.1. Students’ verbal reasoning performance
There were 38 students who managed to score less in their post-test than in their pre-test and 85 students managed to score higher in post-test compared to their pre-test. While 50 students had the same score in pre-test and post-test. However, Wilcoxon signed rank test showed no significant difference in the verbal reasoning score from the pre-test to the post-test.

4.2. Students’ spatial reasoning performance
There were 43 students who scored less in their post-test compared to their pre-test scores and 113 students scored higher in their post-test compared to their pre-test. While 17 students had the same score in pre-test and post-test. A Wilcoxon signed-rank test showed that over the span of a year upon the exposure of doing ‘A’ level programme, there is a significant difference in the spatial reasoning score from the pre-test (Mdn = 35) to the post-test (Mdn = 38), Z = 5.85, p < .001, r = .45

4.3. Students’ abstract reasoning performance
There were 44 students who scored less in their post-test compared to their pre-test scores and 112 students scored higher in their post-test compared to their pre-test. While 17 students had the same score in pre-test and post-test. A Wilcoxon signed-rank test showed that over the span of a year upon the exposure of doing ‘A’ level programme, there is a significant difference in the abstract reasoning score from the pre-test (Mdn = 14) to the post-test (Mdn = 15), Z = 6.81, p < .001, r = .52

4.4. Students’ performances based on gender
A Mann Whitney U test was conducted on the students’ gain score in comparing between male and female students achievement. It was found that there was no statistical significant difference in students gain score in terms of gender. However, Mann Whitney U test showed that there were a significant difference in spatial ability test score and abstract reasoning test score for the pre-test and post-test between male and female students.

A Mann Whitney U test indicated that for spatial ability pre-test score, male students (Mdn = 36) performed better compared to the female students (Mdn = 34), U = 2899, p = .021, r = .18. In the case of the post-test, Mann-Whitney test indicated that for spatial ability score, male students (Mdn= 38) also performed better compared to the female students (Mdn = 37), U = 2939, p = .028, r = .17.

On the other hand, for abstract reasoning pre-test score, Mann Whitney U test indicated that the male students (Mdn = 15) performed better than female students (Mdn = 13), U = 2969, p = .036, r = .16. While for the post-test score, male students (Mdn = 16) also performed better compared to the female students (Mdn = 15), U = 2941, p = .029, r = .17

5. Discussion
As discussed in the finding section, the verbal critical reasoning result did not indicate a significant improvement from pre-test to post-test. Furthermore there was no gender differences in the sample’s performance for verbal reasoning. This finding seemed to contradict with most of the literature in terms of gender differences in the verbal reasoning performance score. Unlike our finding for the spatial ability score, it was in line with most of the literature [3,4] where male students performed better than the female counterparts in the pre-test and post-test. However there were no gender differences observed in terms of gain score from pre-test to post test for verbal critical reasoning, spatial ability and abstract reasoning.

As for the reasoning abilities development, the students demonstrated growth in terms of spatial ability and abstract reasoning ability over the course of one year of undergoing Cambridge International Advance Level Programme. Caution need to be taken in interpreting these results as there could be other factors that might contribute to the differences of the pre-test and post-test result. Hanifah et al [8] demonstrated this possibility of other contributing factors in their studies. A further investigation might be needed in exploring the reasoning abilities scores of the students with their ‘A’ level results to make a stronger claim for this study.

6. Conclusion
Our study indicated that there were significant differences in the physics students’ score for spatial ability and abstract reasoning but not for verbal critical reasoning ability after undergoing one year of Cambridge International Advance Programme. As to gender differences in performance, it was observed that male tend to performed better than female in spatial ability test and abstract reasoning test. This finding concurred with the reported literature [4-6].

References
[1] Newton P and Bristoll H 2009(online) Spatial ability practice test 1 Psychometric Success (www.psychometric-success.com)
[2] Burton N W, Welsh C Kostin I & Essen T. 2009. Toward a definition of verbal reasoning in higher education. ETS Research Report Series 2.
[3] Colom R, Contreras J, Arend I, Garcia Leal O and Santacreu J 2004 The Psychological Record 54 365
[4] Ganley C M, Vasilyeva M and Dulaney A 2014 Child Development 85 1419
[5] Miller D I and Halpern D F 2011 Proc. of the Ann. Meeting of the Cognitive Science Society 33(33)
[6] Linn C M and Petersen C A 1985 Child Development 56 1479
[7] Psychometric success 2007(online) Abstract Reasoning Tests (http://www.psychometric-success.com/aptitude-tests/abstract-reasoning-tests.htm)
[8] Hanifah 2018 J. Phys. Conf. Ser. 947 012014