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A Multi-Strand Test for Assessing Year 4 Pupils' Proficiency in Area Formulae

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Abstract

The objectives of this study are to develop a multi-strand test for assessing Year Four pupils' proficiency in area formulae and to determine their levels of proficiency in the area formula of a square, rectangle and triangle, respectively. The researchers will employ a cross-sectional survey research design and cluster sampling will be used to select a sample from a population of Year 4 pupils who are studying in all public schools in the state of Penang, Malaysia. However, at this stage of the study, the paper only reports the results of the pilot test involving a sample of sixty-seven Year 4 pupils who have learned the area formulae from a public primary school in Penang. The results of the pilot test indicate that among the five strands of proficiency in each of the area formulae, adaptive reasoning shows the highest percentage of pupils who are not proficient and among the three area formulae, adaptive reasoning in the area formula of a triangle shows the highest percentage of pupils who are not proficient. But, among the five strands of proficiency in the area formula of a square, rectangle and triangle, procedural fluency, conceptual understanding and productive disposition show the highest percentage of pupils who are very proficient, respectively. Overall, the area formula of a rectangle shows the highest percentage of pupils who are very proficient (59.7%). But, the area formula of a triangle shows the highest percentage of pupils who are still not proficient (31.3%). The results of the pilot study seem to indicate that the multi-strand test is able to assess the levels of proficiency in the area formula of a square, rectangle and triangle, respectively. The results imply that more attention should be given to the strand of adaptive reasoning in the teaching, learning and assessment of the area formulae in order to improve the pupils' adaptive reasoning in the area formulae.

Keywords

Mathematical Proficiency, Area Formulae, Multi-Strand Test, Rectangle, Square: Triangle

1. Introduction

The study of area formulae forms an important part of the Malaysian primary school mathematics curriculum because it offers an opportunity for learning and applying other mathematical concepts and skills such as number operations, geometrical ideas, and notions of function. It is also important because of the practicality and perva-

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siveness of area formulae in so many aspects of everyday life [1]. In view of the importance, Malaysian Year Four pupils begin to learn how to find the area of rectangles, squares and triangles using square grid and formulae in the primary school mathematics curriculum [2]. In Year Five, they learn how to calculate the area of composite two-dimensional shapes involving squares, rectangles and triangles [3]. Finally, in Year Six, they learn how to calculate the area of composite two-dimensional shapes involving two or more quadrilaterals and triangles as well as to solve problems in real context involving area of two-dimensional shapes [4].

It is hoped that as they progress from Year 4 to Year 6, all pupils should become increasingly proficient in area formulae. Proficiency in area formulae should enable them to continue their study of area in particular and mathematics in general in secondary school and beyond. It should also enable them to cope with the mathematical challenges of everyday life [5]. In Malaysia, Year Six pupils' proficiency in area formulae is assessed in the Mathematics papers of the Primary School Achievement Test, which is a national examination taken by all pupils at the end of their sixth year in primary school before they leave for secondary school.

2. Statement of the Problem

2.1. Primary School Achievement Test

But, in the Mathematics papers of the Primary School Achievement Test, the Malaysian Examinations Syndicate reported that Year Six pupils made various types of mistakes in answering questions involving area formulae. For example, the common mistakes made by Year Six pupils in calculating the area of a shaded region consisting of two right-angled triangles were: i) calculating the area of a triangle using the area of a rectangle; ii) calculating the area of one of the two right-angled triangles; or iii) calculating the perimeter of the shaded region [6]. These reports indicate that in general Malaysian Year Six pupils' lacked proficiency in the area formulae, particularly the area formula of a triangle.

2.2. Trends in International Mathematics and Science Study 2011

Moreover, in the Trends in International Mathematics and Science Study (TIMSS) 2011, Malaysian Form Two students' performance in the two TIMSS released items involving area formulae was unsatisfactory. For the first released item (ID_M052084) on calculating the area of a square with a given perimeter of 36 cm, only 40% of Malaysian students were able to answer it correctly. As a result, their performance was ranked 27th and the percent correct was significantly lower than the international average of 47%. For the second released item (ID_M032623) on finding the area of a shaded region in cm^2 using the area of a rectangle minus the area of a right-angled triangle, only 29% of Malaysian students were able to answer it correctly. Consequently, their performance was ranked 23rd and the percent correct was significantly lower than the international average of 36% [7]. These results indicate that in general Malaysian Form Two students' proficiency in area formulae is unsatisfactory.

According to the Malaysian Ministry of Education [8], however, Malaysia aspires to be ranked in the top third of countries in terms of mathematics performance in TIMSS within 15 years. One of the ways to achieve this aspiration is that all pupils at least should be mathematically proficient in area formulae starting from the earliest year of schooling in which they begin to learn the formulae, that is Year 4 in primary school. As defined by the National Research Council [5], mathematical proficiency has five intertwined strands namely conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. Yet, to date there is no available test for assessing Year 4 pupils' proficiency in area formulae in Malaysia that takes into account all the five strands of mathematical proficiency. Thus, there is an urgent need to develop a multi-strand test for assessing Year 4 pupils' proficiency in area formulae so that appropriate diagnosis and intervention programs can be provided by teachers to improve their pupils' proficiency in area formulae starting from the earliest schooling year of learning the formulae, that is Year 4 in primary school.

3. Objectives of the Study

The objectives of this study are to develop a multi-strand test for assessing Year Four pupils' proficiency in area formulae and to determine their levels of proficiency in the area formula of a square, rectangle and triangle, respectively. Specifically, this study aims to address the following research questions:

1. What are the levels of proficiency in the area formula of a square among Year 4 pupils?

2. What are the levels of proficiency in the area formula of a rectangle among Year 4 pupils?
3. What are the levels of proficiency in the area formula of a triangle among Year 4 pupils?

4. Methodology

4.1. Research Design and Sampling

The researchers will employ a cross-sectional survey research design as it is effective for providing an overview of the current Year 4 pupils' levels of proficiency in area formulae in a population [9]. Cluster sampling will be used to select a sample from a population of Year 4 pupils who are studying in all the public schools in the state of Penang, Malaysia. At this stage of the study, however, the paper only reports the results of the pilot test involving a sample of sixty-seven Year 4 pupils who have learned the area formulae from a public primary school in Penang. There were 34 boys and 33 girls in the sample who are of mixed abilities.

4.2. Instrument

A multi-strand test for assessing Year 4 pupils' proficiency in area formulae was developed by the researchers based on the National Research Council's [5] mathematical proficiency framework and the Malaysian Year 4 Mathematics Curriculum and Assessment Standard Document of the Primary School Standard Curriculum [2]. Hence, in this study, Year 4 pupils' proficiency in area formulae is defined as comprising five intertwined components or strands: 1) *conceptual understanding*-comprehension of the area formula of a square, rectangle and triangle; 2) *procedural fluency*-skill in carrying out the procedures of the area formula of a square, rectangle and triangle flexibly, accurately, efficiently and appropriately; 3) *strategic competence*-ability to formulate, represent and solve mathematical problems involving the area formula of a square, rectangle and triangle; 4) *adaptive reasoning*-capacity for logical thought, reflection, explanation and justification of solutions to problems involving the area formula of a square, rectangle and triangle; and 5) *productive disposition*-habitual inclination to see the area formula of a square, rectangle and triangle as sensible, useful and worthwhile, coupled with a belief in diligence and one's own efficacy [5].

The multi-strand test consists of three subtests, namely: 1) Area formula of a square; 2) Area formula of a rectangle; and 3) Area formula of a triangle. Each subtest comprises five items for assessing the five strands of proficiency in the area formula of a square, rectangle and triangle, respectively. The first, second, third, fourth and fifth items in each subtest assess the strands of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition, respectively. The fifth item in each subtest consists of five sub-items for assessing the five aspects of productive disposition, namely sensible, useful, worthwhile, diligence and one's own efficacy.

The test was validated by a panel of three experienced primary school mathematics teachers and a scoring rubric was subsequently developed by the researchers. For the first four strands of proficiency in each subtest, the range of scores are: 0 (Not Proficient); 1 (Slightly Proficient); 2 (Quite Proficient); 3 (Proficient); and 4 (Very Proficient). For the last strand of proficiency in each subtest, the range of scores for each sub-item are: 0 (Not Proficient); 1 (Slightly Proficient); 2 (Quite Proficient); 3 (Proficient); and 4 (Very Proficient). Therefore, the range of total scores for the last strand of proficiency in each subtest are: 0 (Not Proficient); 1 - 5 (Slightly Proficient); 6 - 10 (Quite Proficient); 11 - 15 (Proficient); and 16 - 20 (Very Proficient).

After obtaining the approval letters to conduct the study from the Ministry of Education and Penang State Education Department, the validated multi-strand test was piloted in the primary school to determine the reliability of the test. **Table 1** shows the values of Cronbach's alpha for the three subtests and the overall multi-strand test. The high values of Cronbach's alpha indicate a high degree of internal consistency of the items in all the subtests and the overall test.

Table 1. Cronbach's alpha for the multi-strand test of proficiency in area formulae.

Multi-Strand Test of Proficiency in Area Formulae	Items	Cronbach's Alpha
Area formula of a square	1, 2, 3, 4, 5a, 5b, 5c, 5d and 5e	0.97
Area formula of a rectangle	6, 7, 8, 9, 10a, 10b, 10c, 10d and 10e	0.95
Area formula of a triangle	11, 12, 13, 14, 15a, 15b, 15c, 15d and 15e	0.97
Overall	Items 1 to 15e	0.98

5. Results

The results of the pilot test are discussed according to the research questions of the study. **Table 2** shows the Year 4 pupils' levels of proficiency in the area formula of a square. Among the five strands of proficiency, adaptive reasoning shows the highest percentage of pupils who are not proficient (62.7%) whereas procedural fluency shows the highest percentage of pupils who are very proficient (55.2%). Overall, 47.8% are very proficient in the area formula of a square while 9.0% are still not proficient.

Table 3 shows the Year 4 pupils' levels of proficiency in the area formula of a rectangle. Among the five strands of proficiency, adaptive reasoning shows the highest percentage of pupils who are not proficient (61.2%) while conceptual understanding shows the highest percentage of pupils who are very proficient (74.6%). Overall, 59.7% are very proficient in the area formula of a rectangle whereas 9.0% are still not proficient**.**

Table 4 shows the Year 4 pupils' levels of proficiency in the area formula of a triangle. Among the five strands of proficiency, adaptive reasoning also shows the highest percentage of pupils who are not proficient (97.0%) whereas productive disposition shows the highest percentage of pupils who are very proficient (52.2%). Overall, 43.3% are very proficient in the area formula of a triangle while 31.3% are still not proficient.

Table 2. Levels of proficiency in the area formula of a square.

	Conceptual understanding		Procedural fluency		Strategic competence		Adaptive reasoning		Productive disposition		Overall	
	N	%	N	%	N	%	N	%	N	%	N	%
Not proficient	16	23.9	22	32.8	30	44.8	42	62.7	11	16.4	6	9.0
Slightly proficient	9	13.4	0	0	0	0	0	0	11	16.4	21	31.3
Quite proficient	7	10.4	4	6.0	3	4.5	3	4.5	7	10.4	1	1.5
Proficient	4	6.0	4	6.0	27	40.3	13	19.4	6	9.0	7	10.4
Very proficient	31	46.3	37	55.2	7	10.4	9	13.4	32	47.8	32	47.8
Total	67	100.0	67	100.0	67	100.0	67	100.0	67	100.0	67	100.0

Table 3. Levels of proficiency in the area formula of a rectangle.

	Conceptual understanding		Procedural fluency		Strategic competence		Adaptive reasoning		Productive disposition		Overall	
	N	%	N	%	N	%	N	%	N	%	N	%
Not proficient	12	17.9	14	20.9	14	20.9	41	61.2	9	13.4	6	9.0
Slightly proficient	2	3.0	0	0	0	0	1	1.5	4	6.0	8	11.9
Quite proficient	1	1.5	6	9.0	0	0	13	19.4	4	6.0	0	0
Proficient	2	3.0	4	6.0	13	19.4	5	7.5	14	20.9	13	19.4
Very proficient	50	74.6	43	64.2	40	59.7	7	10.4	36	53.7	40	59.7
Total	67	100.0	67	100.0	67	100.0	67	100.0	67	100.0	67	100.0

Table 4. Levels of proficiency in the area formula of a triangle.

	Conceptual understanding		Procedural fluency		Strategic competence		Adaptive reasoning		Productive disposition		Overall	
	N	%	N	%	N	%	N	%	N	%	N	%
Not proficient	24	35.8	30	44.8	28	41.8	65	97.0	16	23.9	21	31.3
Slightly proficient	3	4.5	0	0	1	1.5	0	0	6	9.0	5	7.5
Quite proficient	1	1.5	0	0	2	3.0	1	1.5	3	4.5	2	3.0
Proficient	5	7.5	36	53.7	2	3.0	0	0	7	10.4	10	14.9
Very proficient	34	50.7	1	1.5	34	50.7	1	1.5	35	52.2	29	43.3
Total	67	100.0	67	67	67	100.0	67	100.0	67	100.0	67	100.0

6. Discussion and Conclusion

Among the five strands of proficiency in each area formula, adaptive reasoning shows the highest percentage of pupils who are not proficient (above 60.0%). This result is expected because the item on adaptive reasoning in each subtest assessed Year 4 pupils' capacity for logical thought, reflection, explanation and justification of solutions to non-routine problems involving the area formula of a square, rectangle and triangle [5]. For example, the item on adaptive reasoning in the area formula of a square required Year 4 pupils to draw as many squares as possible with an area of 36 cm^2 and explain their answers. Among the three area formulae, adaptive reasoning in the area formula of a triangle shows the highest percentage of pupils who are not proficient (97.0%). In general, pupils are able to display reasoning ability when a) they have a sufficient knowledge base; b) the task is understandable and motivating; and c) the context is familiar and comfortable [10]. Thus, the results suggest that the Year 4 pupils in this sample might not have a sufficient knowledge base of the area of a triangle, the item on adaptive reasoning in the area of a triangle was not understandable and motivating, or the context of the item is not familiar and comfortable for them [10]. This implies that more attention should be given to the strand of adaptive reasoning in the teaching, learning and assessment of the area formulae in order to improve the pupils' adaptive reasoning in the area formulae, in particular adaptive reasoning in the area formula of a triangle.

However, among the five strands of proficiency in the area formula of a square, rectangle and triangle, procedural fluency (55.2%), conceptual understanding (74.6%) and productive disposition (52.2%) show the highest percentage of pupils who are very proficient, respectively. Overall, the area formula of a rectangle shows the highest percentage of pupils who are very proficient (59.7%) whereas the area formula of a triangle shows the highest percentage of pupils who are still not proficient (31.3%). These results concur with the reports of the Malaysian Examinations Syndicate [6] that, in general, Malaysian Year Six pupils' lacked proficiency in the area a of a triangle. This implies that more emphasis should be given to the teaching, learning and assessment of the area formula of a triangle in order to improve the pupils' proficiency in the area formula of a triangle.

In conclusion, the results of the pilot study seem to indicate that the multi-strand test is able to assess the levels of proficiency in the area formula of a square, rectangle and triangle respectively. More emphasis should be given to the five strands of proficiency in the area formulae in the teaching, learning and assessment of the area formulae, especially the strand of adaptive reasoning. It is hoped that the multi-strand test will be able to provide a more appropriate diagnosis of Year Four pupils' proficiency in the area formulae so that effective intervention programs could be provided by teachers to improve their pupils' performance in all the five strands of proficiency in the area formulae starting from the earliest schooling year of learning the formulae. That is, all Year pupils should be able to understand, compute, solve, reason and possess a productive disposition towards the area formulae. This should enable them to continue their study of area in secondary school and beyond as well as enable them to cope with the mathematical challenges of everyday life [5].

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