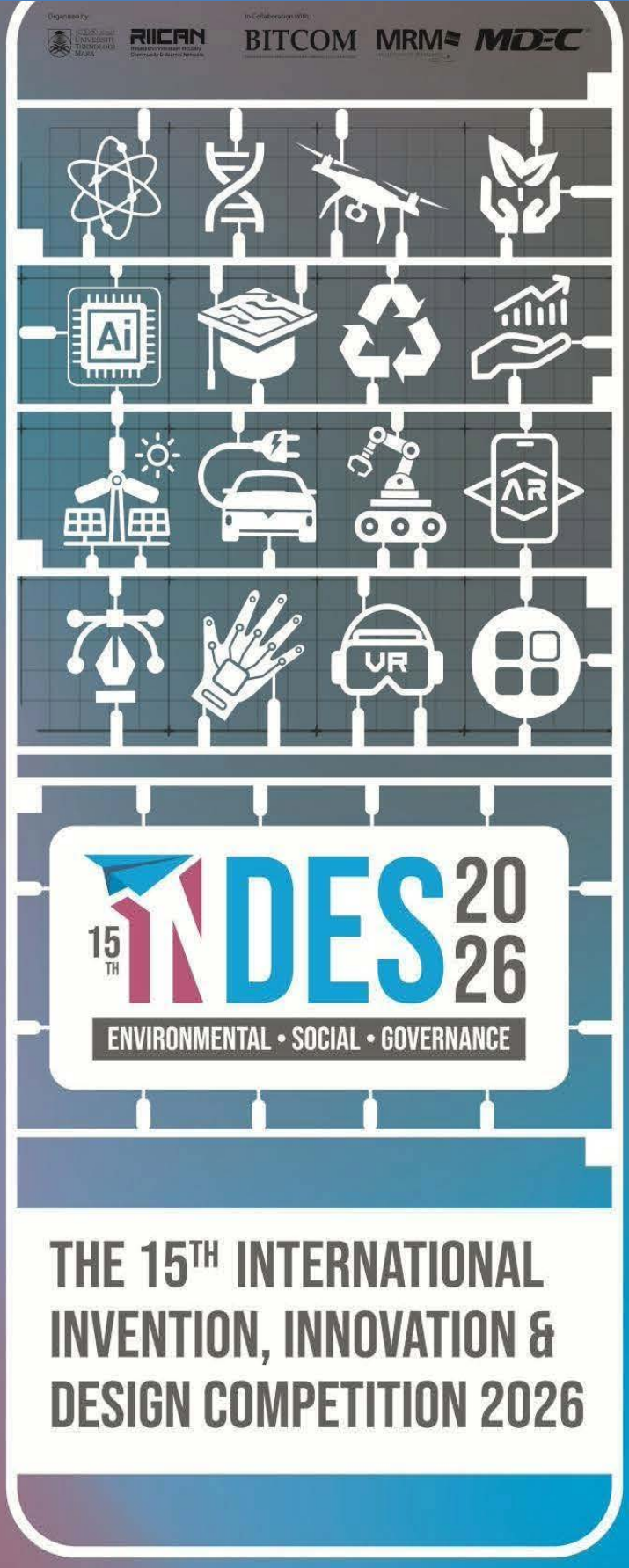


E-BOOK OF

EXTENDED ABSTRACT

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THE 15th INTERNATIONAL
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AN INNOVATIVE DIAGNOSTIC INSTRUMENT FOR ASSESSING STUDENTS' REASONING IN QUADRATIC FUNCTIONS

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ABSTRACT

Reasoning refers to the capacity for critical thinking, problem-solving, and adapting to new ideas independently of prior knowledge, and it is fundamental to the learning process. However, existing assessments in quadratic functions tend to emphasise procedural accuracy rather than reasoning processes, limiting teachers' ability to evaluate students' conceptual understanding. This study aimed to develop and validate a reasoning-based assessment instrument grounded in the Structure of the Observed Learning Outcome (SOLO) taxonomy to evaluate the reasoning levels of Form Four students. The instrument utilizes a superitem test format, focusing on four reasoning processes, recognizing patterns, manipulating symbols, drawing logical inferences, and making generalizations across the content domains of quadratic expressions, equations, and graphs. A pilot study was conducted with 100 Form Four students from four secondary schools in Penang. Data were analyzed using the Rasch Partial Credit Model through WINSTEPS software to examine the instrument's psychometric properties. Findings from the pilot study confirmed the instrument's high degree of measurement consistency, yielding a personal reliability of 0.90 and an item reliability of 0.95. The separation indices further indicated that the instrument could effectively distinguish between different levels of student ability and stable item difficulty. While the results demonstrated that students could successfully navigate unistructural and multistructural tasks, they revealed significant challenges at relational and extended abstract levels. This study provides a validated diagnostic tool for educators to identify specific reasoning gaps and informs the development of differentiated instructional strategies to foster higher-order thinking in the secondary mathematics curriculum.

Keywords: Reasoning, Quadratic Functions, Assessment Instrument, SOLO taxonomy, Rasch model, Form Four Students

1. INTRODUCTION

Reasoning is a fundamental cognitive process that allows students to think critically and justify their understanding in unfamiliar contexts. In the Malaysian Secondary School Standard Curriculum (KSSM), quadratic functions are a foundational topic introduced in Form Four that requires students to bridge algebraic and graphical representations. Mastery of this topic is essential for success in higher-level mathematics, such as calculus and mathematical modeling. Despite its importance, persistent challenges remain. Many Malaysian students struggle to reason effectively about quadratic functions, often relying on rote procedures and memorized algorithms rather than demonstrating true conceptual understanding. This difficulty is reflected in international assessments like TIMSS, where a decline in performance suggests a weakness in process-based reasoning skills.

Current assessment practices in schools frequently reward correct procedural answers but fail to evaluate the underlying reasoning processes. Consequently, there is a critical need for a valid and reliable diagnostic instrument that explicitly targets reasoning levels. This study addresses this gap by developing an assessment tool grounded in the SOLO taxonomy and the superitem test format to capture the depth of student understanding in quadratic expressions, equations, and graphs.

2. METHODOLOGY

This study adopted a quantitative, cross-sectional survey-based research design to develop and validate an assessment instrument for measuring reasoning in quadratic functions. A pilot study was conducted among 100 Form Four students from four secondary schools in the Timur Laut district of Penang, comprising three National-type Secondary Schools (SMJK) and one National Secondary School (SMK). These participants represented a diversity of mathematical abilities and school types to ensure the findings reflected the broader target population. The primary research instrument was a structured written test developed based on the SOLO taxonomy, which categorizes student reasoning from surface to deep understanding. The test utilized a superitem format, where item clusters were built from shared mathematical stems covering expressions, equations, and graphs to capture the progression of reasoning levels (unistructural, multistructural, relational, and extended abstract). Students completed the test individually within a standardized duration of one hour and thirty minutes. Data from the pilot study were analyzed using the Partial Credit Rasch Model through WINSTEPS software (Version 5.10.4.0). This modern measurement approach was employed to evaluate the instrument's psychometric properties, specifically examining item and person reliability, separation indices, item fit, and item polarity. The use of Rasch analysis ensured that item difficulty and student ability were estimated on a common logit scale, providing a rigorous foundation for validating the instrument before its application in the larger main study.

3. FINDINGS

The pilot study ($N = 100$) provided strong psychometric evidence for the instrument's effectiveness. Analysis using the Rasch Partial Credit Model via WINSTEPS software demonstrated high measurement consistency, with a Person Reliability of 0.90 and an Item Reliability of 0.95, shown in Table 3.1 and Table 3.2. The person separation index of 2.93 indicated that the instrument can effectively distinguish between three distinct levels of student ability, while the item separation of 4.33 confirmed a stable item difficulty hierarchy. Furthermore, all 36 items exhibited positive point-measure correlation values (0.00 to 0.67), as shown in Table 2, confirming that every item aligns with the intended construct of reasoning.

Table 3.1 *Reliability and Separation Index of the Person*

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	44.0	34.6	1.34	.27	1.02	.01	.96	.01
SEM	1.3	.2	.09	.00	.05	.12	.08	.10
P.SD	13.3	2.4	.91	.05	.46	1.22	.77	.98
S.SD	13.4	2.4	.91	.05	.46	1.23	.77	.99
MAX.	70.0	36.0	3.00	.48	2.59	3.04	5.30	3.25
MIN.	7.0	26.0	-2.33	.24	.26	-2.36	.22	-1.86
REAL RMSE	.29	TRUE SD	.86	SEPARATION	2.93	PERSON RELIABILITY	.90	
MODEL RMSE	.27	TRUE SD	.87	SEPARATION	3.22	PERSON RELIABILITY	.91	
S.E. OF PERSON MEAN = .09								

Table 3.2 *Reliability and Separation Index for Item*

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	122.3	96.0	.00	.28	1.01	.09	.97	.00
SEM	9.4	1.2	.28	.03	.03	.15	.04	.13
P.SD	55.6	6.8	1.65	.19	.16	.89	.25	.80
S.SD	56.3	6.9	1.67	.19	.16	.91	.25	.81
MAX.	247.0	100.0	3.05	.75	1.43	2.23	1.52	1.70
MIN.	31.0	74.0	-3.15	.08	.73	-1.63	.41	-1.88
REAL RMSE	.35	TRUE SD	1.61	SEPARATION	4.58	ITEM	RELIABILITY	.95
MODEL RMSE	.34	TRUE SD	1.62	SEPARATION	4.80	ITEM	RELIABILITY	.96
S.E. OF ITEM MEAN = .28								

Table 3.2 *Item Statistics: Correlation Order*

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	ITEM	G
13	81	100	-.30	.28	1.43	2.23	1.42	1.70	.00	.39	75.0	83.5	Q13	0
2	98	100	-3.15	.75	1.14	.42	1.50	.76	.13	.24	98.0	98.0	Q2	0
14	98	100	-3.15	.75	1.13	.41	.95	.30	.17	.24	98.0	98.0	Q14	0
9	95	100	-2.08	.50	1.21	.64	1.14	.42	.22	.33	94.0	95.1	Q9	0
33	84	100	-.55	.30	1.18	.90	1.21	.83	.22	.38	84.0	86.0	Q33	0
1	96	100	-2.35	.55	1.12	.41	.98	.22	.24	.31	96.0	96.0	Q1	0
25	82	100	-.38	.28	1.15	.82	1.18	.80	.24	.39	82.0	84.3	Q25	0
5	71	98	.29	.25	1.12	.95	1.10	.66	.27	.38	73.5	76.3	Q5	0
21	96	99	-2.67	.62	1.14	.43	.47	-.49	.30	.28	97.0	97.0	Q21	0
17	67	99	.54	.23	1.07	.73	1.01	.11	.32	.38	67.7	72.6	Q17	0
6	95	100	-2.08	.50	1.02	.18	.89	.03	.32	.33	96.0	95.1	Q6	0
29	87	100	-.84	.33	1.02	.14	1.05	.27	.35	.38	90.0	88.6	Q29	0
32	47	81	1.13	.24	.95	-.62	.93	-.50	.41	.35	65.4	66.4	Q32	0
10	90	100	-1.19	.36	1.03	.19	.72	-.67	.42	.37	89.0	91.1	Q10	0
11	66	99	3.05	.14	.96	-.27	.95	-.20	.43	.40	52.5	47.4	Q11	0
28	31	83	2.06	.24	.88	-1.63	.83	-.89	.43	.31	78.3	66.0	Q28	0
7	167	98	.98	.13	1.16	1.29	1.16	1.28	.43	.52	40.8	44.4	Q7	0
22	96	100	-2.35	.55	.81	-.31	.62	-.38	.45	.31	96.0	96.0	Q22	0
24	87	74	2.28	.09	1.01	.13	1.10	.38	.48	.49	33.8	39.7	Q24	0
36	159	80	1.10	.11	1.18	1.15	1.52	1.54	.51	.57	41.3	41.5	Q36	0
12	160	90	1.90	.10	1.21	1.40	1.10	.65	.52	.57	28.9	35.9	Q12	0
18	90	100	-1.19	.36	.81	-.63	.65	-.91	.54	.37	93.0	91.1	Q18	0
8	95	83	2.44	.10	.85	-.90	.94	-.16	.55	.51	39.8	40.8	Q8	0
4	191	96	1.54	.09	1.10	.67	1.09	.53	.55	.57	30.2	40.6	Q4	0
3	157	100	.88	.14	.89	-.87	.92	-.56	.55	.47	54.0	48.4	Q3	0
19	184	99	1.08	.12	1.04	.32	1.06	.35	.56	.57	40.4	45.7	Q19	0
16	247	96	1.62	.09	1.25	1.56	1.10	.48	.58	.65	41.7	38.7	Q16	0
15	185	99	.97	.13	.98	-.09	.97	-.13	.58	.56	47.5	50.0	Q15	0
30	92	100	-1.48	.40	.73	-.87	.67	-.66	.59	.36	95.0	92.7	Q30	0
23	197	97	.73	.15	.92	-.45	.92	-.42	.61	.56	54.6	57.7	Q23	0
20	223	93	1.21	.08	1.02	.18	.99	.07	.61	.62	26.9	30.4	Q20	0
26	91	100	-1.33	.38	.73	-.94	.41	-1.69	.64	.37	94.0	91.9	Q26	0
35	200	95	.62	.12	.84	-1.19	1.03	.20	.64	.59	43.2	40.6	Q35	0
34	84	100	-.55	.30	.75	-1.31	.56	-1.88	.64	.38	88.0	86.0	Q34	0
31	213	99	.48	.12	.87	-.97	.85	-.84	.65	.60	49.5	45.0	Q31	0
27	200	99	.73	.13	.86	-.92	.82	-1.09	.67	.59	56.6	48.6	Q27	0
MEAN	122.3	96.0	.00	.28	1.01	.09	.97	.00			67.5	68.0		
P.SD	55.6	6.8	1.65	.19	.16	.89	.25	.80			24.3	23.5		

4. CONCLUSION

This research successfully developed and validated a reasoning-based instrument for quadratic functions, providing a robust framework for assessing cognitive depth through the SOLO taxonomy. The pilot study findings confirm that the instrument is both reliable and valid for identifying specific reasoning gaps among Form Four students. The high reliability indices (0.90 and 0.95) suggest that the superitem format is an effective tool for moving beyond procedural testing toward a more nuanced evaluation of conceptual understanding. This study contributes to Malaysian mathematics education by providing a diagnostic tool that aligns with the KSSM curriculum's goal of fostering higher-order thinking skills, laying a solid foundation for the subsequent large-scale study.

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