DEVELOPMENT OF A PICTORIAL REPRESENTATION MEASUREMENT TOOL SPECIFICALLY FOR BLIND STUDENTS IN JUNIOR HIGH SCHOOL

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Abstract: *Pictorial representation skills are crucial for blind individuals to understand and interpret visual information. This study aimed to develop and validate a reliable and informative instrument that can measure these skills in blind junior high school students. Grounded in cognitive theory and existing research on spatial reasoning, visualisation, and communication in blind individuals, the study developed four description-type geometric concept tasks involving interpreting and describing geometric shapes, spatial relationships, and data visualisations. These tasks were specifically chosen to encompass diverse aspects of pictorial representation, allowing for a comprehensive assessment of students' abilities. Content validity was established using the Aiken formula, which demonstrated strong alignment between the tasks and the targeted constructs, specifically by exceeding the recommended cut-off score for item-to-total correlations. Internal consistency, assessed using Cronbach's Alpha, was acceptable at 0.823. Item difficulty and discrimination analyses revealed a moderate level of difficulty for all tasks, indicating an appropriate challenge while ensuring differentiation among students. Furthermore, all tasks showed good discrimination power, effectively distinguishing between students with different levels of pictorial representation skills. This validated instrument provides a valuable tool for educators and researchers working with blind students. It can be used to (i) assess individual strengths and support the development of pictorial representation skills in blind students, and (ii) design and adapt instructional materials to cater to diverse needs. However, it is important to acknowledge the limitations of this pilot study, including the small sample size. Future research with a larger and more representative sample is necessary to fully validate the psychometric properties of the instrument and confirm its generalisability across different settings and populations.*

Keywords: *instrument development, pictorial representation, blind student, validity, reliability*

INTRODUCTION

Representation is a fundamental skill that is essential for all students, including those who are blind. Representation plays a crucial role in enhancing understanding of scientific concepts and improving problem-solving abilities (Cheng, 2002). Representation can be categorised into internal and external forms (G. A. Goldin, 1998; G. A. Goldin & Shteingold, 2001; Janvier et al., 1993). External representation refers to the tangible forms of representation that can be directly observed, such as verbal, visual, and symbolic representations (G. Goldin, 2002; G. A. Goldin, 1998). Verbal representations involve expressing ideas through writing or words, while visual representations include pictures, diagrams, and graphs. Symbolic representations consist of equations, operation signs, and algebraic symbols. Visual representation, in particular, is highly recommended for blind students as it aids in understanding and translating mathematical problems (van Garderen et al., 2018). It provides a means to describe relationships, hierarchies, and processes (Kartika & Mutmainah, 2019). Visual representations also facilitate comprehension of geometry concepts and the relationships between geometric objects (Mesquita, 1998). There are three types of visual representations: pictorial representations, accurate schematic visual representations, and inaccurate schematic visual representations (Boonen et al., 2014).

Unlike sighted individuals who typically visualise spatial stimuli and use visual mental images for drawing tasks (Pantelides et al., 2015; Szubielska, 2014), congenitally blind individuals develop alternative strategies. Drawing from memory offers them imagined frames into their non-visual (abstract) mental maps, which act as a bridge between cognition, knowledge, and drawing (Konkle & Oliva, 2011). More importantly, while blind individuals activate vision-related brain regions commonly during drawing (Amedi et al., 2008; Cacciamani & Likova, 2017), it does not imply that they have visual imagery per se. Spatial cognition, the core of drawing, works independently of senses, so these brain regions can be engaged without requiring visual imagery for drawing. Interestingly, congenitally and adventitiously blind individuals may differ in how they construct these representations. Those born blind often favour egocentric (body-centred) frameworks, while those who lose their vision later may prefer allocentric (object-centred) ones (Pasqualotto et al., 2013; Pasqualotto & Proulx, 2012; Ruggiero et al., 2012). This suggests that they use different ways of constructing representations of their surroundings.

Size, by definition, is a property, and spatial cognition can be accessed through various non-visual modalities beyond sight, including tactile exploration and verbal descriptions (Loomis et al., 2013). The representation of size in the mental imagery of blind individuals remains a topic of debate. Some studies report difficulties with accurately estimating object angular size at different distances for congenitally blind individuals (Arditi et al., 1988; Vanlierde & Wanet-Defalque, 2005), while others find no such deficit (Wnuczko & Kennedy, 2014). This discrepancy suggests potential differences in size representation between those born blind and those who lose their vision later in life. Notably, Vanlierde & Wanet-Defalque (2005) also reported that late-onset blind individuals performed better in size estimation and seemed to represent familiar objects more accurately than congenitally blind individuals. This suggests that visual experience, even if limited, plays a role in refining object size representation.

Extensive research has explored the ability of blind individuals to recognise two-dimensional embossed images and create images through haptic (tactile) exploration (D'Angiulli et al., 1998; Magee & Kennedy, 1980; Vinter et al., 2012). Several studies also demonstrate their ability to recognise geometric shapes (Heller et al., 2006) and identify everyday objects in embossed/tactile images produced use of any techniques (Mascle et al., 2022; Vinter et al., 2020). However, existing qualitative research often lacks clear, standardised research instruments with defined measurement mechanisms. This gap limits the ability to systematically assess and compare different findings across studies. For example, Wu et al. (2022) reported that blind individuals required more time to identify larger and medium-sized embossed images, potentially due to familiarity with the size of the actual object. Therefore, the authors recommended designing hand-sized images, but other studies have yielded conflicting results regarding the optimal image size for haptic perception (Kennedy & Bai, 2002; Wijntjes et al., 2008). Szubielska et al. (2019) reported that blind individuals recognised images based on memory more easily if they represented larger objects (i.e., furniture size) compared to smaller objects (i.e., hand size).

Blind individuals begin engaging with pictorial representations early on, improving their understanding based on their experiences (Warren, 2009). The present study aims to develop and validate a task-based instrument specifically designed to assess how blind junior high school students engage with and interpret visual information through spatial reasoning within the context of flat-shape geometry. While research suggests blind individuals can master geometric concepts, they may face challenges in spatial visualisation and reasoning compared to sighted students (Pritchard & Lamb, 2012). Given the importance of these skills for daily life, our study focuses on developing tasks targeting these specific aspects of pictorial representation. The chosen tasks will involve analysing and manipulating flat-shape representations through tactile and verbal means, allowing for a comprehensive assessment of the spatial reasoning and visual information interpretation skills of students within the framework of a specifically designed measurement system.

The learning and understanding of geometry material are crucial for blind students, considering the practical applications of geometric concepts in daily life. Therefore, it is necessary to assess blind students' representational abilities to determine their level of mastery of geometric concepts. It is important to ensure that the results of measuring blind students' representational abilities are accurate and consistent. Reliable measurement results can be obtained through multiple measurements of the same subject, ensuring consistency and reliability (Budiyono, 2015). Additionally, the validity of the measurement instrument must be established, demonstrating that the instrument accurately measures what it is intended to measure (Azwar, 2011, 2012). Content validity is also an important aspect of measuring and assessing blind students' representational abilities (Retnawati, 2016). Content validity, which involves analysing the instrument's representativeness of the domain being measured, can be assessed by experts. The present study discusses the importance of measuring and assessing blind students' representational abilities, as well as the validity of measurement instruments. Furthermore, the study presents a geometric concept task instrument that is specifically developed to measure the image representation of blind students in junior high school.

METHOD

Participants

The study included sight participants with confirmed blindness (six congenitally and two adventitiously/acquired). All were recruited from Special Schools (SLBs) for blind students in the Malang city area (East Java, Indonesia), ensuring consistent educational and environmental experiences. Participants satisfied the following criteria: (1) blindness from birth or acquired without other disabilities, (2) average mathematics report card score of at least 70 (out of 100) on Braille-printed tests, and (3) demonstrated Braille literacy confirmed through teacher interviews and school evaluation records. SLBs provide tailored support, including Braille resources, assistive technologies, specialised infrastructure (e.g., tactile paths), and diverse labs (e.g., music, orientation and mobility, computer) to foster participants' interests and skills. All participants had parents with normal vision. Among the two adventitiously blind participants, ASY had glaucoma, leading to complete vision loss by age 6 years, and LNT experienced progressive visual field loss due to unspecified diseases, resulting in total vision loss by age 10 years. Further details about the participants are presented in Table 1.

Table 1. *Characteristics of Participants*

No.	Initial of Participant's Name	Age (Year)	Sex	Average score on a math test	School (SLBs name)	Blindness History
1.	PTR	12	Female	76	ABD Negeri Kedungkandang	Congenital
2.	HNN	12	Female	82.5	Yayasan Putra Pancasila	Congenital
3.	ELM	14	Female	78	Bakti Luhur	Congenital
4.	CHT	15	Female	85	Bakti Luhur	Congenital
5.	SML	16	Male	81	Bakti Luhur	Congenital
6.	YHN	15	Male	75	Bakti Luhur	Congenital
7.	LNT	13	Female	80	Bakti Luhur	Adventitial (Acquired)
8.	ASY	13	Female	80	Dharma	Adventitial (Acquired)

Instrument

The research instrument developed was a geometric concept essay assignment with a focus on two-dimensional shapes, consisting of 4 questions. Each essay question consisted of several task items. In the first item, students were asked to feel and carefully identify the two-dimensional shape image presented in the question. Students were asked to describe the characteristics of the information related to the shape image. This task item was developed to measure the students' understanding of two-dimensional shapes. In the second item, students were asked to redraw the raised image they had felt using bamboo sticks. The bamboo sticks provided varied in length from 5 to 10 cm and had a diameter of 0.25 cm. The research instrument also included real (actual) objects resembling flat shapes of the geometric concept assignment questions in order to facilitate the blind students' understanding of two-dimensional shapes, as the rater suggested. This is consistent with the argument made by Erin & Koenig (1997) suggesting that blind people benefit from real objects to understand concepts. To refine this instrument, the actual objects were crafted from used cardboard into two-dimensional shapes, as shown in Figure 1.

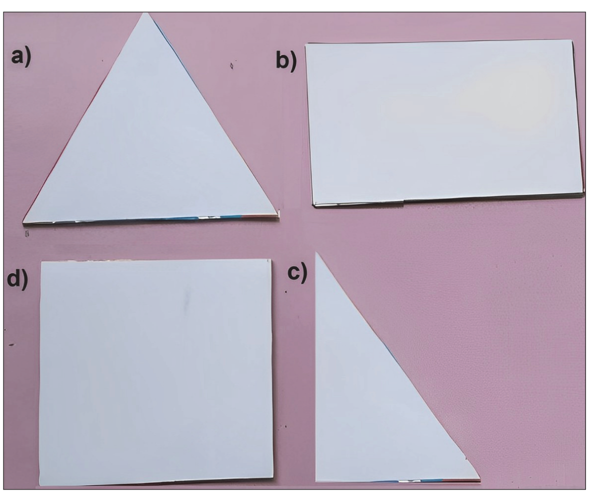
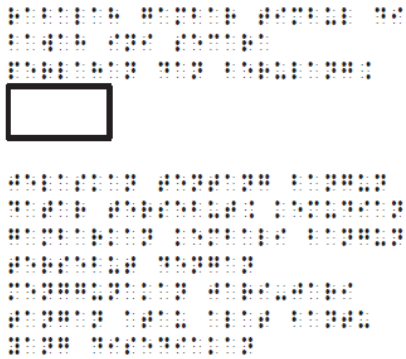
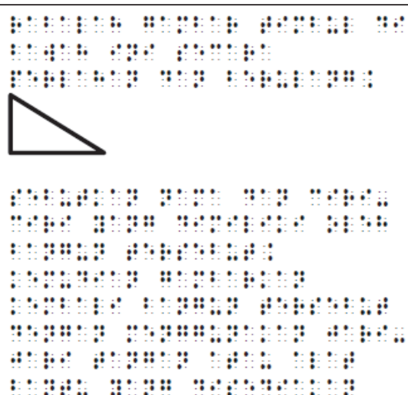
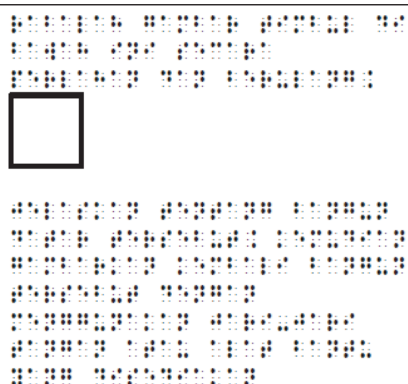
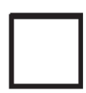
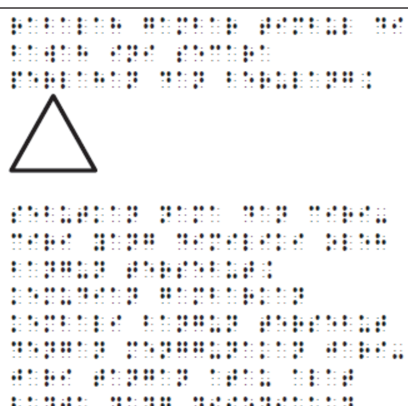


Figure 1. *Examples of real objects represented in two dimensions: (a) equilateral triangle, (b) rectangle, (c) right triangle, and (d) square.*

Furthermore, the rater also provided suggestions for improving the instrument, suggesting replacing the terms "reconstruction" with "create or make", since these terms were more easily understood by the participants themselves. The revised instrument sheet (Table 2) incorporated several features to support blind students' understanding of flat shapes. First, the tasks were specifically designed for their needs and printed in Braille. Second, the sheet included tactile embossed images of the shapes, allowing students to explore the shapes through touch. Crucially, the tasks incorporated prompts and activities that encouraged students to "re-describe" the shapes in various ways. This could involve writing descriptions on Braille paper, using tactile tools to explore different aspects of the shape, or even creating stories that describe the shape's function or compare it to familiar objects. These diverse "re-description" activities aimed to deepen the student's understanding of the shape's properties and relationships.

This geometric concept task instrument was piloted in four schools that were selected based on their alignment with the participant criteria outlined in section 2.1. A total of eight blind students participated in the trial during the odd semester of the 2022/2023 academic year. These students were enrolled in the following schools: SLB Dharma Malang (1 student), SLB Putra Pancasila Foundation Malang (1 student), SLB Bakti Luhur Malang (5 students), and SLB ABD Kedungkandang Malang (1 students). During the instrument testing phase, researchers analysed the participant responses to assess their understanding of the tasks. This assessment involved evaluating participants' ability to describe and re-draw/build these images based on touch. The instrument utilises a standardised scoring guideline integrated within the question text to evaluate performance on each question. Each question carries a maximum score of 25, with a total of four questions. These questions are further subdivided into multiple activity items. Therefore, the scoring guidelines are detailed as follows: 10 points for accurate naming and description of the tactile image, 10 points for successfully re-drawing the previously sensed flat shapes, and 5 points for creating a good angular precision image using the provided tools. The geometric concept task instrument, originally developed by researchers and subsequently improved based on suggestions from the raters, is presented in detail in Table 2 below.

Table 2. *Final geometric concept task instruments after refining based on rater suggestions*

Item	Instrument description in Braille	Instrument description
1.		Feel the embossed image below slowly and repeatedly.  Explain what you understand regarding this *two-dimensional figure*! Then, re-draw the shape using the tools provided!
2.		Feel the embossed image below slowly and repeatedly.  What is the name of this *two-dimensional figure*? Furthermore, mention the characteristics it has! Then, re-draw the shape using the tools provided!
3.		Feel the embossed image below slowly and repeatedly.  Explain what you understand regarding this *two-dimensional figure*! Then, re-draw the shape using the tools provided!
4.		Feel the embossed image below slowly and repeatedly.  What is the name of this *two-dimensional figure*? Furthermore, mention the characteristics it has! Then, re-draw the shape using the tools provided!

Experimental procedure

This study adopts a development research approach to create an instrument for assessing a blind individual's understanding of pictorial representations. The research model is adapted from the framework developed by Mardapi (2008) and it encompasses the following steps: (1) Formulating task specifications, (2) Writing tasks, (3) Reviewing tasks, (4) Conducting task trials, (5) Analysing task items, (6) Refining tasks, and (7) Assembling tasks. The assignment review process involved analysing the tasks for potential errors and inconsistencies. Data collection was carried out based on the written tasks.

The data analysis techniques used included content validity, reliability, level of difficulty, discriminating power, and the ability to represent blind students. The developed geometric concept tasks instrument was then converted into Braille and administered to three raters for content validity assessment using expert judgement techniques. The following steps were implemented to prove the content validity of geometric concept assignments: (1) giving assignments complete with a grid, alternative solutions, and scoring rubrics to the raters; (2) considering the suggestions given by the raters, including the suitability of the components of the task instrument with the indicators, the indicators with the instrument items, the clarity of the sentences used in the instrument items, alternative solutions, the usage of sentences in a way that they do not cause double interpretation for the reader, the writing format, symbols, and the clarity of the images; (3) making improvements to the assignment instrument based on the suggestions given by the raters; (4) asking the raters to evaluate the content validity of the assignment items, namely assessing the suitability of the instrument items with the indicators. The assessment used a Likert scale (disagree = 1, disagree = 2, agree = 3, and strongly agree = 4; Likert, 1932). Finally, the rater agreement index was calculated using the Aiken index (Equation 1). The Aiken index is a score used to show the agreement of the raters' assessment of the content validity of an instrument item (Aiken, 1980).

$$V = \frac{\sum s}{n(c-1)} \quad (1)$$

where V is the rater agreement index regarding the content validity of the instrument items, s is the score given by each rater minus the lowest score in the category used, ($s = r - 1_0$, where r = rater's choice category score and 1_0 is the lowest score in the scoring category), n is the number of raters, and c is the number of categories selected by the rater. Furthermore, the rater agreement index is explained by referring to the content validity criteria according to Table 3 as follows (Retnawati, 2016) :

Table 3. *Content validity criteria*

Rater agreement index	Content validity description
$0.0 \leq V < 0.4$	Low
$0.4 \leq V \leq 0.8$	Medium
$0.8 < V \leq 1.0$	High

The following process is a theoretical study of each of these geometric concept tasks. The three raters also carried out the review process. A theoretical study was carried out by paying attention to three aspects: material, construction, and language (Pusat Penilaian Pendidikan, 2019).

The reliability instrument task was estimated by *Cronbach's Alpha* coefficient, obtained by equation 2 (Budiyono, 2015).

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\sum s_i^2}{s_t^2}\right) \quad (2)$$

where r_{11} is the reliability, k is the number of questions, $\sum s_i^2$ is the total variance score of each question, and s_t^2 is the total variance.

The instrument meets the criteria of being reliable if Cronbach's Alpha value is between 0.6 and 1.0 (Hair JR et al., 2010). In addition to assessing participant performance, the researchers also analysed the instrument's discriminant validity, examining both item difficulty and the ability to differentiate between participants with varying abilities.

RESULTS AND DISCUSSION

Validity of content

Following the development of the instrument, the researcher constructed statement items using a Likert scale and subsequently conducted the content validity process. These statements were adapted from the content validity assessment sheet developed by Ratnawati (2016). The present study employed the expert judgement technique to assess the content validity of the geometric concept task instruments for blind students.

Three raters with expertise in mathematics education and inclusive education for blind students were asked to review the instrument developed by the researcher. The results of the review showed that the initial instrument developed by the researcher was not good enough. There were several suggestions for improving the tasks, such as replacing the word "*reconstruct*" with the word "*re-draw*" or another word with the same meaning so that it would be easier for blind students to understand. In addition, the raters suggested that the geometric concept tasks should be equipped with real objects that have the same shape as the shapes in the tasks. These objects would serve as a complement to the raised print images. This would make it easier for the students to understand the tasks provided.

The researcher made revisions according to the suggestions given by the raters. After the revisions were completed, the instrument was given back to the raters to assess each item. The results of the assessment were analysed using Aiken's formula to determine the content validity of each item.

Table 4. *Results of the Aiken index analysis*

Item number	Rater score (R_1)	Rater score (R_2)	Rater score (R_3)	V	Description
1.	4	4	4	1.0	High validity
2.	4	4	4	1.0	High validity
3.	4	4	4	1.0	High validity
4.	4	4	4	1.0	High validity

Based on Table 4, it can be observed that each instrument task has a rater agreement index of 1.0, indicating that the tasks on the instrument developed have high content validity. Three raters conducted the instrument's theoretical study by scoring each test item. The assessment results by the three raters showed that the score of each criterion for the geometric concept task was 3 or 4. This suggests that the three raters agreed (even strongly agreed) on all the criteria for reviewing the assignment. In other words, the tasks that have been prepared are optimal.

Since each instrument met the validity criteria, the instruments were ready to be piloted. The piloting process was conducted on 8 blind students who met the previously established criteria (see Section 2.1). Based on the pilot test data, further analysis was conducted to determine the reliability, difficulty level, and discrimination power of the instrument.

Reliability

Reliability is the degree of consistency between two scores obtained from measuring the same object, even if different measuring instruments and scales are used (Mehrens & Lehmann, 1973; Reynold et al., 2010). In the present study, the reliability of geometric concept task instruments for blind students was measured using the Cronbach's Alpha coefficient, which was calculated as follows:

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\sum s_i^2}{s_t^2}\right) = \left(\frac{4}{4-1}\right)\left(1 - \frac{41.96}{109.64}\right) = 0.823$$

The Cronbach's Alpha coefficient was found to be 0.823 (i.e., the value is > 0.60). This indicates that the geometric concept task instruments developed have high reliability, as they fall within the range mentioned in Section 2.3 ($0.6<r_{11}<1.0$; Hair JR et al., 2010). This implies that the instruments can produce stable (Rudner, 1994) and consistent (Mehrens & Lehmann, 1973) measurement results, even if they are used to measure the same thing at different times, with different testers or scorers, or with different test items that measure the same parameters and have the same item characteristics. Therefore, the geometric concept task instruments developed meet the reliability requirements and can be used for our research.

Degree of difficulty

The difficulty level (or difficulty index) of a test item represents the degree of difficulty for that item for participants. In other words, the difficulty level measures how challenging a test item is for participants or test respondents (Susetyo, 2015). To calculate the difficulty level for each task item, scores were corrected and assigned to each task for each participant, then the total and the average score for each participant was calculated. A summary of these steps is shown in Table 5.

Table 5: *Summary of Values and Average Values for Each Participant*

School Name	Participant	Task 1	Task 2	Task 3	Task 4	Total value	Average Value for Participant
SLB Dharma	ASY	12	13	12	13	50	12.5
SLB Yayasan Putra Pancasila	HNN	15	8	15	7	45	11.25
SLB Bakti Luhur	YHN	15	7	6	8	36	9
	LNT	9	9	9	10	37	9.25
	SML	7	7	7	8	29	7.25
	ELM	4	5	5	4	18	4.5
SLB ABD Kedungkandang	CHT	7	8	7	8	30	7.5
	PTR	6	7	6	6	25	6.25
Average Value for Each Task		9.375	8.000	8.375	8.000	33.75	

Next, the difficulty level for each task was calculated. The complete calculations are as follows:

$$P_1 = \frac{\bar{S}_1}{S_{maks}} = \frac{9.375}{25} = 0.375$$

$$P_2 = \frac{\bar{S}_2}{S_{maks}} = \frac{8}{25} = 0.320$$

$$P_3 = \frac{\bar{S}_3}{S_{maks}} = \frac{8.375}{25} = 0.335$$

$$P_4 = \frac{\bar{S}_4}{S_{maks}} = \frac{8}{25} = 0.320$$

A summary of the difficulty level for each task item is shown in Table 5.

Table 6. *Difficulty Level Indices*

Task Number	Difficulty Level Index (P)	Category
1	0.375	Medium
2	0.320	Medium
3	0.335	Medium
4	0.320	Medium

Based on the analysis of the difficulty level of the task items in Table 6, all four tasks were found to have a moderate difficulty level. This is because the difficulty level index (P) of the four tasks falls within the range of $0.30 \leq P \leq 0.70$ (Surapranata, 2009). Therefore, the developed tasks are considered to be in the good category, since they are neither too easy nor too difficult. Tasks that are too easy can impede the participant's problem-solving abilities, while overly difficult tasks can diminish motivation and may lead to feelings of despair.

Differentiating power

Discriminatory power is the ability of a task to distinguish between participants with high and low competencies (Daryanto, 2010). It is an important aspect of test instrument development because it allows for the differentiation of high- and low-performing test takers. This instrument includes a built-in method for calculating the discriminatory power index for each developed task item. For description-based tasks, the calculation follows the formula developed by Budiyono (2015). For example, Table 7 presents the student's competency scores used to calculate the discriminatory power of assignment/question number 1.

Table 7. *Student competency scores used to calculate the discriminatory power of question number 1.*

	Student Id Number								**Total**
	1	2	3	4	5	6	7	8	
Value of question number 1 (*X*)	12	15	15	9	7	4	7	6	75
Total Score of Student (*Y*)	50	45	36	37	29	18	30	25	270
XY	600	675	540	333	203	72	210	150	2783
X^2	144	225	225	81	49	16	49	36	825
Y^2	2500	2025	1296	1369	841	324	900	625	9880

The discriminatory power index (D) for instrument number 1 was calculated as follows:

$$D_1 = r_{pbis} = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)}} = \frac{(8)(2783)-(75)(270)}{\sqrt{((8)(825)-(75)^2)((8)(9880)-(270)^2)}} = 0.821$$

Using the same method, the D values for instrument number 2 was found to be 0.837, while the D values for instrument number 3 was 0.850, and that of instrument number 4 was 0.801. The summary values for the discriminatory power index for each task are listed in Table 8.

Table 8. *Discriminatory Power Index of the instrument.*

Question/task Number	Discriminatory Power Index (D)	Category
1	0.821	Good
2	0.837	Good
3	0.850	Good
4	0.801	Good

The analysis shows that all four tasks have good discriminatory power because their discriminatory power index values (D) are ≥ 0.30 (Budiyono, 2015), indicating that the tasks that have been developed have the ability to distinguish and measure the competencies possessed by each participant.

Pictorial representation of blind students

Pictorial representation is an important skill in mathematics that allows students to express mathematical ideas visually. In the present study, the ability of blind students to represent images was measured using four geometric concept essay questions that focused on two-dimensional shapes. Each essay question consisted of several task items. In the first item, students were asked to feel, identify, and describe images of two-dimensional shapes. This item could provide an overview of the student's understanding of two-dimensional shapes themselves. In the second item, students were asked to draw or recreate a relief image using bamboo pieces. This item could provide an overview of the student's ability to produce observable representations of two-dimensional shapes.

Based on the difficulty levels of the instrument tasks (Table 5), individual scores were obtained for each participant, ranging from 18 to 50. The average score was 33.75 with a standard deviation of 10.47. Although it was not designed to assess individual differences, these results suggest that this instrument can effectively evaluate blind students' representations of flat shapes in their creations. Supporting this hypothesis, Figures 2 and 3 present two examples of representational results from students with congenital (YHN) and adventitious (LNT) blindness. Both YHN and LNT were able to successfully create a square representation, although the precision of the corners varied (Fig. 3 a, b). This remains within acceptable ranges, as previous research has documented limitations in blind individuals' ability to accurately estimate the angular size of objects (Arditi et al., 1988; Vanlierde & Wanet-Defalque, 2005).

Interestingly, our observations revealed subtle differences between the students, particularly in their speed and approach to constructing the square. For example, compared to YHN, LNT tended to be more expressive and quicker to recognise the bamboo pieces, leading to faster construction. This may be partially explained by YHN's history of acquiring blindness at the age of 10 years, suggesting that residual experiences from his sighted years may have influenced his confidence and initial understanding of objects such as the bamboo pieces. This is consistent with previous research by Vanlierde & Wanet-Defalque (2005) who found that individuals with adventitious blindness often perform better in size estimation tasks and representation of familiar objects compared to those with congenital blindness. Further supporting our findings, other research suggests that adventitious blindness may be associated with a preference for an allocentric (object-centred) frame of reference when constructing representations, while congenitally blind individuals tend to favour an egocentric (body-centred) frame (Pasqualotto et al., 2013; Pasqualotto & Proulx, 2012; Ruggiero et al., 2012).

However, considering the final near-identical square representations shown in Figures 3 (a) and (b), we propose that the remaining visual experiences of individuals who become blind later in life may primarily contribute to refining their understanding of objects, rather than significantly impacting the final outcome of their flat shape representations.

In general, Figures 2 and 3 further highlight the respective abilities of blind students (congenital and adventitious) to develop and utilise their skills in order to build pictorial representations. These findings are consistent with extant research (D'Angiulli et al., 1998; Magee & Kennedy, 1980; Vinter et al., 2012) that has demonstrated the general capacity of visually impaired individuals to recognise two-dimensional tactile representations and create images through tactile exploration. Given the results, we believe our instrument offers several advantageous features, including the use of full Braille in both question text and embossed image examples, easy-to-understand instructions, and the presence of tangible objects similar to the flat shapes, all of which effectively aid students in solving flat-shape representation problems. While our findings promising (Fig. 2 and 3), they cannot be generalised to all blind individuals. Therefore, further research with a larger sample, focused observation on specific aspects of flat-shape creation like tactile exploration and angle estimation, and in-depth reviews for each participant would be necessary to further understand the pictorial representation abilities of blind students in general.

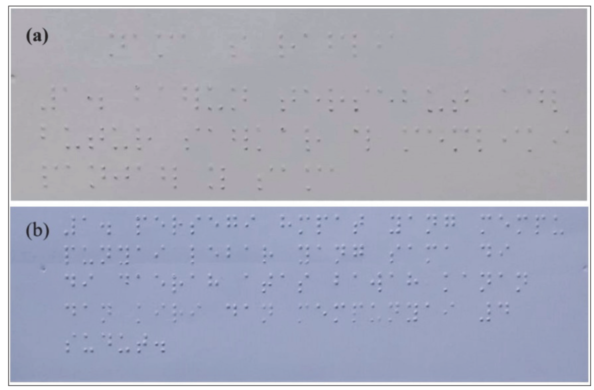


Figure 2. *Responses of two students, (a) YHN and (b) LNT, to question number 3 within the initial item (Explain what you understand regarding these two-dimensional figures!).*

YHN's definition - "A square is a flat shape that has four sides of the same length" - accurately captures the key properties. While LNT's statement - "a square is a flat shape with sides of the same size" - essentially conveys the same concept, but demonstrates a more limited understanding in its omission of the specific term "length." Although both answers are deemed acceptable, the students' representations highlight the potential for further refinement in their understanding of geometric terminology.

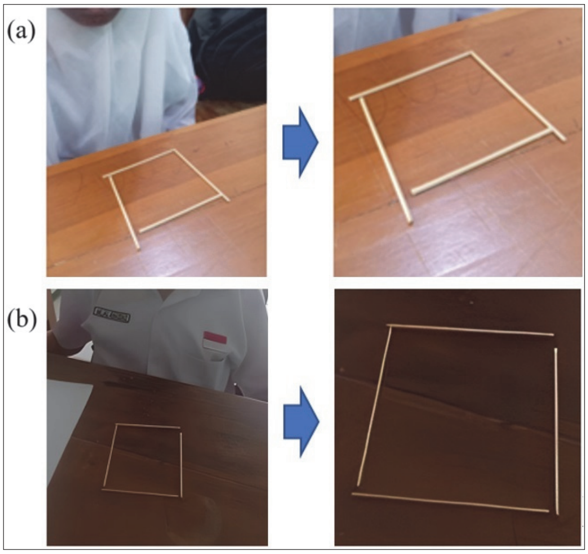


Figure 3. *Student responses, (a) YHN and (b) LNT, to question number 3 within the last item: "Re-draw the shape using the tools provided!"*

While the representations in Figures 3(a) and 3(b) generally demonstrate successful construction of squares as per the task's instructions, they also reveal the students' challenges in maintaining precise corner accuracy.

RESEARCH LIMITATIONS AND IMPLICATIONS

This study has several limitations that must be considered. (i) Small sample size - This study included only used 8 junior high school students with blindness and no other reported disabilities. This is due to the specific criteria that were determined in the study, namely that participants must have good language and communication skills, as well as relevant types of blindness. However, this small sample size may make the results of the study less representative of the actual situation.

(ii) Limited scope of material - The instrument developed in this study is limited to two-dimensional flat shapes. Therefore, further research is needed to develop this instrument in order to include other geometric concepts. These findings have the potential to both influence the development of evaluation instruments specific to the blind students' pictorial representations and guide the creation of tools tailored to their needs and characteristics, ultimately revealing further relevant information about the abilities of blind students.

CONCLUSION

Based on the improvements made to the test instrument and the findings derived from the pictorial representation activities, we conclude that the instrument for measuring these abilities in blind students from junior high school are valid. All four tasks achieve a V value of 1.0, indicating very strong content validity. Additionally, the Cronbach's Alpha coefficient of 0.823 demonstrates that the instrument meets the criteria for reliability. Furthermore, the instrument is equipped with indexes of difficulty and discriminating power. The difficulty level index of each task falls within the medium range (0.320-0.375), suggesting that they have a medium level of difficulty and are appropriate for the target age group. Meanwhile, the discriminating power of each task ranges from 0.801 to 0.850, demonstrating good differentiation between the abilities of individual student. Therefore, this final project instrument presents a promising option for measuring the abilities of blind students who do not have any other disabilities to pictorially represent flat material/objects.

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