A Construct Validity of Spatial Literacy Instrument

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Abstract. To measure spatial literacy skills, a good instrument is needed. Therefore, this study aims to 1) compile the construct of a spatial literacy ability test instrument for prospective mathematics teacher students, 2) to do validation of the construct to see the index of validity and reliability. Content validation using the V Aiken formula and the Cronbach Alpha coefficient were used to test the validity and reliability. The results showed that: 1) the construct of spatial literacy in the form of operational definitions, six indicators, 17 sub indicators and 34 questions in the form of multiple choices has shown a form of spatial concept integration with literacy, 2) spatial literacy test instruments are feasible because they meet index validity requirements V Aiken between 0.67 - 0.89. The test kit also states fit for 34 items, because it is in the acceptance limit range of >0.77 to <1.30. In addition, the level of difficulty on the test using a logit scale that produces 13 categorized items is very easy, 6 items are easy, and 15 items are difficult. In the study, the value of reliability was 0.704 (> 0.5). While the Standard Error of Measurement (SEM) which is a value that measures how precise the value obtained is equal to 1.287. Henceforth, this test kit can be used by the academic community at universities or other agencies concerned to measure the level of spatial literacy of prospective mathematics teachers.

1. Introduction
In the early development, literacy was defined as the ability to use language and images in various forms to read, write, listen, speak, see, present and think critically about ideas [1]. Furthermore, mathematical literacy is considered as important as reading literacy and writing literacy is considered dominant. If literacy is the basis for all learning, mathematics literacy is also important if someone wants to understand the information that exists in society [2].

Based on De Lange's theory, mathematical literacy abilities are not only limited to aspects of numeracy. He revealed that mathematical literacy includes spatial literacy, numerical and quantitative literacy [3]. Of the three aspects, research on spatial literacy considered as not yet done. This is one of them because the instrument for measuring spatial literacy is not yet available. Some mathematical literacy research more often leads to quantitative literacy. One of them was done by Setiani and Rafianti, they conducted a study to determine the effect of the level of visual-spatial intelligence on the quantitative literacy of prospective mathematics teacher students [4]. They use the notion that quantitative literacy is similar to mathematical literacy, where the equation between quantitative literacy and mathematical literacy is not only focused on minimal knowledge in mathematics but also includes "doing mathematics" that is using mathematical concepts in other fields and in aspects of...
daily life [5]. The instrument of quantitative literacy questions he developed was in the form of a test in the form of a description so that researchers could easily see the process of answering the test questions. In addition, Firmanda et al. has also conducted research to identify the quantitative literacy abilities of students studied from the aspect of content change and relationship in algebra in junior high school [6]. In his research, he only made a written test amounting to 2 questions, which then the results of student work were analyzed specifically examined from the four aspects of quantitative literacy, that is interpretation, representation, calculation, and communication. Similar to the study, Oktaviani et al. also conducted student quantitative literacy analysis on statistical material but in aspects of content uncertainty and data [7]. Hence, the instruments he developed were two questions that were adopted and adapted from the PISA questions in 2009 and 2012 related to the content uncertainty and data aspects.

Related to spatial, there is a test that has been developed and is often used by several studies. However, this measuring instrument known as the TOSA (Test of Spatial Assembly) was developed to measure spatial abilities for children aged three years [8]. Thus, the usefulness of this test is only valid for spatial growth and development in three-year-olds. The research related to spatial literacy has been done by Maharani and Maryani. They conducted experiments using media maps to improve the spatial literacy of fourth grade students in elementary school. The instruments used were in the form of spatial literacy tests consisting of pre-test (initial test) and post-test (final test) [9].

If the context is observed, the study is more focused on the geographic subjects of elementary school students. Maps are considered as media that are able to help students understand spatial knowledge. Meanwhile, in mathematical literacy, building space and space become a whole aspect that can support understanding of geometry. This correct understanding of geometry can be built by mastering spatial literacy. Thus, spatial literacy is considered important to be held by prospective mathematics teacher students. Bernarz also mentioned that the United States National Academy of Sciences found that spatial thinking is a key component in spatial literacy, where spatial literacy has been considered to be at the heart of several major discoveries in the world of science and has become a fundamental component of several professions and career [10]. However, so far, the spatial literacy test is less available because the development of spatial literacy constructs is considered still small.

De Lange's definition of spatial literacy has actually been revealed, where spatial literacy is the ability to use spatial thinking skills to visualize ideas, situations, and problems in everyday life and the world around us [11]. This definition is used as a conceptual definition in this study. Meanwhile, in this case, the researcher seeks to establish operational definitions and constructs of spatial literacy from the results of observations on some conceptual definitions of literacy and spatial ability. There are three definitions of literacy and twelve definitions of spatial ability from twelve experts. Some of these definitions have mentioned the dimensions or indicators contained therein, but there are also definitions that have not mentioned the indicators contained therein. Thus, that researchers estimate the indicator points of the definition of spatial ability.

Mizzi also observed a number of definitions found in spatial red threads that focus on spatial ability like navigating and manipulating space. Spatial tasks also require students to develop ways to solve spatial problems [12]. There are no definitions and dimensions/indicators that have been stated by spatial experts previously that are integrated with the concept of literacy where several items of tests become contextual and the problems presented occur in everyday life. Thus, based on the observations of researchers, an operational definition of spatial literacy is formed where spatial literacy is the ability of a person to use spatial thinking to build, visualize, understand, create, change the space well in the mind, and communicate it to solve problems in life, which is shown in the results of spatial literacy tests. After estimating the indicator points from the twelve definitions of spatial ability, the researcher takes the slices of these indicators. The result is that there are 6 (six) main indicators that are considered capable of forming spatial literacy skills in a person. The six indicators include: 1) Spatial Perception, 2) Spatial Visualization, 3) Mental Rotation, 4) Spatial Relations, 5) Spatial Orientation, and 6) Spatial Communication. Furthermore, these six indicators produce 34 items in the form of
multiple choices. Multiple choice which has five A, B, C, D, and E answer options, it is necessary to conduct a feasibility test before it is used to measure.

In several studies, it was said that a good test instrument is an instrument whose points are well designed and empirically evaluated to ensure accuracy and user information. Miller, Linn, & Gronlund stated that good tests must fulfill three characteristics, which are validity, reliability, and reusability [13]. Validity is if the instrument actually measures what should be measured. The empirical validity test consists of three groups of validation procedures; content validation, construct validation and validation based on criteria [14].

Besides that, the reliability of the test also needs to know. Reliability is one of the criteria in the development of both test and non-test instruments. If the reliability of the instrument is high, then an instrument is very good for use in measurement. Instruments are considered consistent if the instrument is carried out from time to time but has the same value. In this internal consistency approach, the reliability estimation procedure is applied through an analysis of the distribution of grain scores or the score distribution of the item groups, not an analysis of the test scores. The several ways of estimating reliability with internal consistency include: 1) test division, 2) brown spearman formula, 3) alpha formula, 4) rulon formula, 5) several formulas for Richardson brothers, 6) halves with different lengths, 7) formula Kristof for split three, fund tau 8) hoyt formula [14]. Thus, the validity and reliability test needs to be done to determine the feasibility level of the spatial literacy test instrument for prospective mathematics teacher students.

2. Methods
This study involved 150 students majoring in mathematics education for empirical trials, which were devoted to those who were studying in the first year. The researcher considered that mathematics education majors who were in their first year had taken geometry subjects, especially building space, during junior high and high school, and had not gained much geometry during the lecture. Those who study in mathematics education are also considered to have an interest in mathematics and a good initial spatial ability capital than other majors.

The feasibility test of the construct of the spatial literacy test instrument used in this study is the test of content validity and reliability. Content validity is the extent to which the elements of a measuring instrument are truly relevant and represent representations of constructs that are in accordance with the objectives of measurement [15]. One of the statistics that shows the validity of item content is by using V Aiken's analysis [16] [17]. Validation involving 3 (three) experts in the field of mathematical geometry and measurement with 4 (four) scale validation instructions, which are very appropriate, appropriate, quite appropriate, and not appropriate. The data from the evaluation of the three validators were analyzed by calculating the content validity coefficient using the following V Aiken formula:

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

Where V is the rater agreement index regarding item validity, S is the score set for each rater minus the lowest score in the category used (s = r - lo, r = score of rater pickup category, lo lowest score in the scoring category), n is the number of rater and c is the number of categories the validator can choose. An item or device can be categorized as validity based on its index. If the index is less than or equal to 0.4 it is said that the validity is lacking; 0.4 - 0.8 said validity is moderate; and if greater than 0.8 is said to be valid [18].

The reliability test used in this study is to use the Alpha formula which will produce the Cronbach's Alpha coefficient. The procedure for estimating reliability with Cronbach's Alpha computational coefficients can be directly processed with SPSS from item score distribution data without dividing or dividing the items into groups. In addition, in this study also tested the suitability of items with the Rasch model using Quest software to determine the level of difficulty of the item. In this case, the
researcher determined the difficulty level category according to Sumintono and Widhiarso with the provisions presented in table 1 below [19].

| Index of Difficulty | Category         |
|---------------------|------------------|
| x > 1               | Very Difficult   |
| 0 ≤ x ≤ 1           | Difficult        |
| -1 ≤ x ≤ 0          | Easy             |
| x < -1              | Very Easy        |

### 3. Result and Discussion

#### 3.1. Construct of Spatial Literacy

Based on the operational definition of spatial literacy that is formed, that is the ability of a person to use spatial thinking to build, understand, create, change, and visualize the building of space well in the mind, and communicate it to solve problems in daily life; developed constructs of spatial literacy instruments consisting of 6 (six) indicators, 17 sub-indicators, and 34 questions. Thus, the grid of spatial literacy test instruments is presented in the following Table 2.

| Theory                        | Indicator                        | Sub Indicator                                                                 | Item Number |
|-------------------------------|----------------------------------|-------------------------------------------------------------------------------|-------------|
| Spatial Literacy of Candidates for Mathematics Teachers | A. Spatial Perception            | A.1 Determine the position or quantity of depth of a building space (in the context of personality, education, work, public, or scientific) | 9           |
|                               | A.2 Determine the number of compilers to build space that forms a building space |                                                                              | 15          |
|                               | A.3 Determine the position and content of a building space against vertical / horizontal references (in the context of personality, education, work, public, or scientific) |                                                                              | 1, 17, 22   |
|                               | B. Spatial Visualization        | B.1 Determine an irregular shape building if the nets are known               | 25          |
|                               | B.2 Determine an irregular shape space if the nets are known                   |                                                                              | 2, 24       |
|                               | B.3 Determine the shape of the net if a regular spatial structure is known     |                                                                              | 23          |
|                               | B.4 Determine the shape of the net if an irregularly shaped facet is known    |                                                                              | 5, 14       |
|                               | B.5 Mention some of the building spaces that make up another building         |                                                                              | 11          |
| Spatial Literacy of Students  | C. Mental Rotation               | C.1 Determine the shape of the building if the wake is rotated                | 7, 12, 30, 33|
|                               | D. Spatial Relation              | D.1 Connecting the visual parts on the side of the building in a regular aspect space if it is transformed into two dimensions | 3, 29       |
|                               |                                  | D.2 Connecting the visual parts to the side of the building in an irregular aspect space if it is transformed into two dimensions | 10, 18, 32  |
E. Spatial Orientation
E.1 Determine the surface area of the building 6, 28
E.2 Determine the shape of the space formed by the intersection/intersection of two fields in a building space 34
E.3 Determine a visual object that is contextual when viewed from various perspectives 19, 27
E.4 Determine irregular visual objects in building space when viewed from various points of view 21, 26

F. Spatial Communication
F.1 Determine the position of objects against other objects in open or closed spaces (in the context of personality, education, work, public, or scientific) 4, 13, 20
F.2 Describe the route of an object on a map/floor plan with the help of wind direction and clockwise (in the context of personality, education, work, public, or scientific) 8, 16, 31

3.2. Content Validity
Data from the assessment of three predefined validators were analyzed by calculating the content validity coefficient using the V Aiken formula. The following is a graph of the distribution of V Aiken values for 34 items.

![Graph of V Aiken’ Items](image)

Figure 1. Graph of V Aiken’ Items

Based on Figure 1 above, it can be seen that the V Aiken value for 34 items in the spatial literacy test is in the range 0.67 - 0.89. There are 16 items that have a validity index of 0.67 and 0.78 included in the medium valid category. While the remaining 18 items have a validity index of 0.89, which means that it belongs to the high validity category. When referring to the Aiken’s V table, the minimum value of Aiken’s V resulting from the evaluation of three validators on a scale of four is between 0 and 1.00 [16]. On the other hand, Azwar said that the number 0.67 obtained from the calculation of the V Aiken formula can be interpreted as an adequate coefficient for the item, and is considered to have good content validity and supports the value of the validity of the overall test contest [14].

3.3. Item Fit Analysis
The next step is to test the compatibility of the items with the model (fit test). The item is fit if MNSQ’s INFIT value is in the range ≥0.77 to ≤1.30 [20] [21]. The following are the fit test results for 34 items on the spatial literacy ability test.

![Figure 2](image2.png)

**Figure 2.** Result of Item Fit Analysis on Spatial Literacy Test Instrument

Based on the picture above, it appears that 34 multiple choice questions on the spatial literacy ability test instrument for mathematics teacher candidate students are declared fit or suitable with Rasch models with acceptance limits of ≥0.77 to ≤1.30. Hence, all items have been declared valid.

![Figure 3](image3.png)  
**Figure 3.** Graph of ICC for Item Number 1

![Figure 4](image4.png)  
**Figure 4.** Graph of Test Information Function (TIF) for Spatial Literacy Test Instrument

Figure 3 shows an analysis of grain compatibility using Winstep also provides illustrations in curve graph form. The graph illustrates the answer patterns of prospective mathematics teacher students. For example, the graph is the answer pattern of prospective mathematics teacher students in answering item number 1 on the spatial literal ability test. The answer pattern is in the infit reception and outfit space. The graph of item suitability analysis with the Rasch model above shows that the
items developed provide a good answer pattern. While, the graph in figure 4 shows that the curve is increasingly pointing towards the center. Sumintono and Widhiarso explained that the more curves pointing towards the center, indicating that the instrument was considered to be good for measuring the level of spatial literacy abilities of the average student candidate for mathematics [19]. Based on this explanation, test instruments provide optimal information when given to prospective mathematics teacher students with an average level of spatial literacy ability.

3.4. Level of Difficulty Item

The level of difficulty in the spatial literacy ability test instrument consists of 2 (two) discussions, that is the level of difficulty of each item and the level of difficulty of the test based on indicators of spatial literacy ability. Because the items in the spatial literacy ability test match the Rasch model, the grain characteristics that appear are the difficulty level of each item. The level of item difficulty in the Rasch model is the same as the level of difficulty of classical test theory, that is the comparison between the correct answer and the number of questions tested (odd-ratio). The difference is that this opportunity value is scaled by entering a logarithmic function. The logit estimation result of the odd-ratio is called logit or W Score or Measure value. Thus, information covering the level of difficulty of the items on the spatial literacy test instrument is summarized in Figure 5 below.

![Distribution of the Difficulty Level of Question Items on Spatial Literacy Test Instruments](image1)

**Figure 5.** Distribution of the Difficulty Level of Question Items on Spatial Literacy Test Instruments

If observed in Figure 5 above, then there are 13 categorized items very easily, 6 items are easy, 15 items are categorized as difficult and no items categorized are very difficult in this test. For more detailed information, the index of the difficulty of the test items is presented in Figure 6 below. While on Figure 6, it can be seen that the items in the test instrument for spatial literacy ability have difficulty levels which are in the range -1.465 up to 0.886. It means that the level of difficulty of the items in the test of spatial literacy abilities is different. In addition to each item, the average score for the difficulty level of spatial literacy items if viewed from the indicators can be seen in Figure 7 below.

![Index of Difficulty for All Item](image2)

**Figure 6.** Index of Difficulty for All Item
Figure 7. Index of Difficulty for All Indicators of Spatial Literacy

Figure 7 above shows a comparison of the level of difficulty of the items from each indicator of spatial literacy. From the picture, it can be observed that the items on the mental rotation indicator are considered the easiest among the items on the other indicators. According to the results of interviews with two test participants, in general, mental rotation indicators are indeed easy because they only imagine the rotation of the objects listed in the problem. Even though the objects contained in the question are irregular spaces, to choose the answer to the option is not difficult.

3.5. Reliability
The technique used to calculate the estimated reliability coefficient in this study is to use the Cronbach's Alpha coefficient. The following results of the reliability analysis of the instrument test spatial literacy abilities.

Table 3. Estimated Reliability of Instruments for Spatial Literacy Test

| Reliability Statistics | Cronbach's Alpha | Based on | Standardized | Cronbach's Alpha | Items | N of Items |
|------------------------|------------------|----------|--------------|------------------|-------|------------|
|                        | .704             | .710     | 34           |

Based on the above calculation results, it is known that the spatial literacy test instrument has a reliability index of 0.704. According to Allen and Yen, using Cronbach's Alpha, the reliability can be said to be high if more than 0.7 [22]. Thus, the spatial literacy test instrument in this study has a high degree of permanence and can be used to collect data. If the reliability index has been obtained, the next step is to find the value of the Standard Error of Measurement (SEM). From the SEM value, it can be concluded whether the test that measures the spatial literacy of students can be reused or not. SEM calculations use the following formula:

\[ SEM = SD\sqrt{1 - \alpha} \]

The SD value is the standard deviation test. In this case, the standard deviation value has been obtained from SPSS output which is the result of analysis of 34 items that have been fit, where the standard deviation of the spatial literacy test instrument is 4.34937. The following is a statistical scale output, which contains the standard deviation value.

Table 4. Statistic Scale

| Mean       | Variance | Std. Deviation | N of Items |
|------------|----------|----------------|------------|
| 23,6800    | 18.917   | 4.34937        | 34         |
Thus, the calculation of the Standard Error of Measurement (SEM) value for test questions that measure the spatial literacy of mathematics education students is as follows.

\[
SEM = SD \sqrt{1 - r_{ij}} \\
= (4.34937) \sqrt{1 - 0.704} \\
= 1.28741352 \approx 1.287
\]

Based on the SEM values above, it can be said that if the test questions that measure spatial literacy are used again, then the score that will be obtained by the respondent that is the student lies in the interval up to \(X_r - 1.287\) and up to \(X_r + 1.287\).

4. Conclusion
This study produced a spatial literacy construct in the form of operational definitions, six indicators, 17 sub-indicators and 34 multiple choice questions. This spatial literacy test device has been tested theoretically and empirically, so it is feasible to use it to measure spatial literacy abilities. Spatial literacy includes six indicators, namely spatial perception, spaisal visualization, mental rotation, spatial relations, spatial orientation, and spatial communication. The construction of a spatial literacy construct is the result of a study of some of the theories of previous spatial experts. McGee emphasized that spatial ability has two main factors, that is spatial visualization and spatial orientation [23]. While Guay divides spatial abilities only into three dimensions, which are development, view, and rotation [24]. The instruments that he has developed are 36 items in the form of multiple choices and all of them have no context. Maier argues that spatial literacy includes four major aspects that intersect, mentally dynamic, mentally static, mental position and mental processes. Of the four aspects, it includes five indicators as compiled by researchers, except for spatial communication indicators [25]. Unfortunately, there are no dimensions/indicators that have been suggested by previous spatial experts that are integrated with the concept of literacy where some of the measuring test items are contextual. So the preparation of this structure has shown a form of integrating spatial concepts with literacy.

Based on the content validity test with V Aiken from 3 (three) validators, the validation value was 0.67 to 0.89. The test kit also states fit for 34 items, because it is in the acceptance limit range of >0.77 to <1.30. In addition, the level of difficulty on the test using a logit scale that produces 13 categorized items is very easy, 6 items are easy, and 15 items are difficult. In the study, the value of reliability was 0.704 (> 0.5). Meanwhile, the Standard Error of Measurement (SEM) which is a value that measures how precise the value obtained is equal to 1.287. Based on the description, it can be said that the spatial literacy construct is feasible because it meets the requirements of validity and reliability. For further research, it is expected to be able to test the feasibility of spatial literacy test instruments in a larger population, so that the value of validity and consistency of the test is getting better. Then, this test tool can be used by the academic community at universities or other agencies with an interest to know how the level of spatial literacy skills of a person, especially mathematics education students, who in fact are prospective mathematics teachers.

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