Student mathematical imagination instruments: construction, cultural adaptation and validity

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Abstract. Imagination has an important role as the center of sensorimotor activity of the students. The purpose of this research is to construct the instrument of students' mathematical imagination in understanding concept of algebraic expression. The researcher performs validity using questionnaire and test technique and data analysis using descriptive method. Stages performed include: 1) the construction of the embodiment of the imagination; 2) determine the learning style questionnaire; 3) construct instruments; 4) translate to Indonesian as well as adaptation of learning style questionnaire content to student culture; 5) perform content validation. The results stated that the constructed instrument is valid by content validation and empirical validation so that it can be used with revisions. Content validation involves Indonesian linguists, English linguists and mathematics material experts. Empirical validation is done through a legibility test (10 students) and shows that in general the language used can be understood. In addition, a questionnaire test (86 students) was analyzed using a biserial point correlation technique resulting in 16 valid items with a reliability test using KR 20 with medium reliability criteria. While the test instrument test (32 students) to find all items are valid and reliability test using KR 21 with reliability is 0.62.

1. Introduction
Imagination has contributed to the innovation and development of human civilization from the past to the present day. This richness of the imagination has a valuable role in the education process for humans [1]. Albert Einstein even says that “imagination is more important than knowledge.” An imaginative and creative thinking process becomes the opening way for the learning process. Education itself comes from a learner that is defined as a process to nurture and give practice about morals and intelligence of the mind. Meanwhile, the intelligence of thinking is not a standard form of thinking and rigid.

In the intelligence of thinking, it takes abilities beyond the normal limits of thought. That ability can happen by giving wide space to the imagination. With the development of imagination in the world of education, there is a continuous and always new education process [2]. In 2008, a conference was attended by 140 delegates from 20 countries. This conference became a marker that the form of imaginative education has become an international concern. They realize that the importance of imagination is necessary to meet the need to provide quality education for learners [3]. Many things can affect the kind of imagination that comes from a student’s self. Caligaris, Rodríguez & Laugero [4]
who argue that student habits can influence the ability to build relationships between different ideas and concepts, developing a greater capacity for abstraction through imagination. The habits that are often used by students in learning are referred to as learning styles. Learning styles are defined as a preferred way of doing activities thinking, processing and understanding of information [5]. Preliminary research has been done to see the conceptual understanding of Algebra expression.

As we all know that imagination is a mental process whose measurement requires an embodiment. But so far, the existing research has not touched on the embodiment of the imagination. Abroad, many studies have examined gestures and utterance as a manifestation of the students' imagination in solving a separate mathematical problem. This study combines the two embodiments in one study. Imagination is closely related to geometric objects in the formation of mental images, while algebraic objects are not much associated with imagination. For that, the novelty of this study examines the gesture and utterance as Embodied cognition from the mathematical imagination in understanding the concept of algebraic expression.

Based on the description, more in-depth study of how students' imagination in understanding the concept of algebraic expression is needed. The first stage of doing so is "how instrument binding to explore embodied cognition of mathematical imagination in conceptual understanding of algebraic expression and how to develop a learning style questionnaire to characterize the subject?".

2. Methods
2.1 Participants
Participants in this study were involved in the instrument of validity test. Content validation involves an Indonesian expert, an English linguist, a mathematical content expert and a psychologist to know the imaginative sizes in test instruments and interview guides. While empirical validation involves ten students in the test of legibility, 32 students in the test instrument of mathematical imagination test in understanding the concept of algebraic expression and 86 students in learning style questionnaire test. All students are junior high school students spread in class VII and class VIII with the age range of 12 years up to 15 years.

2.2 Techniques of Data Collection and Analysis
Data collection and analysis techniques adjust to research objectives. As already mentioned for the purpose of this study, the techniques of collecting and analyzing the data are as follows: (1) construction of data instrument of students' mathematical imagination in conceptual understanding of algebra expression and cultural adaptation data in the development of learning style questionnaire was obtained through the method of documentation of relevant theories then are analyzed descriptively [6]; (2) content validation data is obtained through using validation questionnaire given to Indonesian linguist, an English linguist, a mathematics content expert and psychologist. Expert validation results are analyzed descriptively [6]; and (3) empirical validation data was obtained through using questionnaires and test techniques. Questionnaires were used to obtain legibility test data and try non-test instruments, while test techniques were used to obtain the data of test instrument. The results of the legibility test were analyzed descriptively. The results of the learning style questionnaire were analyzed using statistics, i.e., for validity test using biserial point correlation technique [7] and reliability of KR-20 method [6]. While the test instrument test was analyzed using statistical test of validity, reliability, difficulty level and the differentiating problem.

2.3 Research Procedures
The steps undertaken in research procedures are: (1) The instrument construction procedure of mathematical imagination in concept comprehension; and (2) Learning style questionnaire development procedure.

3. Results and Discussion
3.1 Construction of the instrument of mathematical imagination in conceptual understanding.
3.1.1 Theoretical review. The results of the theoretical study define imagination as mental activity to form the visualization/image necessary to combine, alter, and create new experiences/knowledge based on old experience/knowledge as the basis of mathematical knowledge [8]. Embodied cognition is the manifestation of conceptual knowledge in the form of sensorimotor experience obtained through our body interaction with the environment [9, 10, 11]. While the conceptual understanding is defined as the process that the students do in explaining the concepts, using concepts in different situations or solving problems correctly using their knowledge [12].

3.1.2 Construction of indicators of the embodied cognition of mathematical imagination. The embodied cognitive of the mathematical imaginations used in this study include Gestures consisting of representative gestures, pointing gestures and gestures writing [13] and utterance from facial expressions, gaze and eye motion, production and intonation of sounds and body poise [14].

3.1.3 Construction of indicators of mathematical imagination in understanding the concept of algebraic expression. Indicators of the embodied cognition of mathematical imagination are substituted in the seven stages of understanding the concept proposed by Bloom [15].

3.1.4 Construction test instruments. The test question consists of 7 items that represent each stage of concept comprehension. Although each item represents each indicator, in fact, in some points, the question of exploring the students' concepts is supported by interviews to explore students' written answers.

3.1.5 Construction of no test instruments
The non-test instrument is made with the open form. The result of instrument construction can be seen in Table 1.

Table 1. A Result of result of instrument construction

| items based on the stage of understanding the concept | interview guidelines |
|------------------------------------------------------|----------------------|
| Reni has 2 boxes of chocolate, where one box is still full while one other box has been reduced 4 pieces of chocolate (interpreting) x + 2y + 2; 2 + 7; uv + u – v; and 2y + 4 = 8 (exemplifying) | a. Can you make a mathematical form of the image?  
b. Describe the mathematical form you wrote.  
Consider the examples of algebraic expressions and not the following algebraic expression.  
a. Give examples of other algebraic expressions.  
b. Can you change one of these algebraic expressions into a real situation as well as about number 1?  
c. Describe the algebraic expression you wrote. |
| 2p-3; 3+6; x²y-xy²+xy; and (x-2)(y+4) = 7 (classifying) (summarizing) | Classify the problem based on the algebraic expression and not the algebraic expression, then give the reason.  
From the previous question, indicate the characteristics of the algebra. |
| (inferring) | What is the definition of algebraic expression? |
| (comparing) | What is the difference between the algebraic expression and not the algebraic expression? |
| x² + xy + 4x + 5y – 5 (explaining) | a. If the algebraic expression is changed into the form: x² + xy + 4x + 5y = 5, is it still an algebraic expression? Why?  
b. If the form is added or subtracted by 5a, is it still an algebraic expression? Why? |
3.1.6 **Validity Instrument of mathematical imagination in conceptual understanding.** Content validation involves an Indonesian linguist, an English linguist, an expert in mathematical content and a psychologist. Validation results show that the resulting instrument is feasible to use with revision because it can measure the embodied cognition of the students' mathematical imagination in concept understanding of algebra expression. While the empirical validation is a test of legibility involving ten students and shows that, in general, they can understand the language used. In addition, empirical validation was also done through test instrument tests involving 32 students was analyzed using a biserial point correlation technique and showing all items are valid and reliability test using KR 21 with reability is 0.62 (Table 2).

| Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|------|---|---|---|---|---|---|---|
| \( r_{xy} \) | 0.66 | 0.70 | 0.54 | 0.58 | 0.40 | 0.37 | 0.66 |
| \( r_{table} \) | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| criteria | Valid | Valid | Valid | Valid | Valid | Valid | Valid |

3.1.7 **The feasibility of a mathematical imagination instrument in conceptual understanding.** Based on the stages that have been passed, it can be concluded that the instrument has been constructed and is capable of measuring mathematical imagination in conceptual understanding and feasible to use.

3.2 **Learning Style Questionnaire Development**

3.2.1 **Review existing learning style questionnaires.** Researchers reviewed the existing kinesthetic, audio, and visual learning style questionnaire. From several questionnaires, the researchers' attention refers to a questionnaire developed by DePoter & Hernacki [16] and a learning style questionnaire compiled by psychology majors at Swinburn University Technology, Melbourne, Australia.

3.2.2 **Questionnaire to be developed.** Based on the consideration of learning style measurement, the researcher chose a questionnaire which is a learning style questionnaire compiled in the psychology department of Swinburner University of Technology, Melbourne, Australia to be developed. This is because, in each item, it allows students to show their learning style.

3.2.3 **Translation.** The researcher took over the Indonesian language and then perform the construct validation by an Indonesian linguist. Validation results show that the Indonesian language used is the Indonesian language which is good and correct and by the age of students of grade VII Junior High School. Validation results are then translated back into English by a different translator. Then, the researcher performs the construct validation by comparing the first English questionnaire (original) with the result of the second English translation and the validation results show that the two documents have the same meaning so it can be concluded that the questionnaire resulted from the Indonesian language is valid based on the of the content validation.

3.2.4 **Adaptation of questionnaire content with students' culture in Indonesian class of grade VII in Junior High School.** A questionnaire consisting of 30 items is reduced into 23 items as a result of cultural adaptation. Some items (language content as well as material content ) which are not appropriate to the culture of grade VII students of Junior High School are omitted. The contents of the language in question such as "operating new equipment," and "I tend to say" are considered less specific so it can result in a variety of answers. The material content that is considered less appropriate to the culture of the seventh-grade students of junior high school with an age range of 12 years up to 14 years is "if I buy a new car." Another content is "if choosing food from the menu," and the option given to the question "when I meet new people, I will?". For example arranging meetings with others or eating together.

3.2.5 **Empirical Validation.** Questionnaire trials were conducted on 86 students and was analyzed using a biserial point correlation technique resulting in 16 valid items with a reliability test using KR 20 with medium reliability criteria.
3.2.6 Eligibility of questionnaire learning style. Based on the stages that have been passed, it can be concluded that the questionnaire learning style developed can measure the tendency of learning styles of students as well as its feasibility.

3.3 Discussion Construction of students mathematical imagination

Imagination is a mental activity that needs to be pervaded as an embodied cognition. Embodied cognition of the mathematical imaginations can be seen from the actions of our bodies [17]. The embodied cognitive of the mathematical imaginations used in this study include gestures and utterance. Utterance that includes multimodal aspects such as: facial expression, gesture, tone of voice, sound production, eye motion, body poise, gaze, and so forth [14]. It is clear that gestures are part of utterance, but researchers want to see gestures in more specific forms of representational gestures and pointing gestures [13] and gestures writing [18]. Cognitive stages in mathematical conceptual understanding used in the study are: (1) interpreting; (2) exemplifying; (3) classifying; (4) summarizing; (5) inferring; (6) comparing; And (7) explaining. This is considered to be more detailed than the stages put forward by other experts (Table 3).

Table 3. A opinions of experts about the cognitive stages in conceptual understanding

| Bloom [15] | Kilpatrick, Swafford & Findell [19] | Duffin & Simpson [20] |
|------------|----------------------------------|----------------------|
| Interpreting | Interpreting | Interpreting |
| Exemplifying | Classifying | Applying |
| Classifying | Applying | Developing |
| Summarizing | Mathematics Representations | |
| Inferring | Comparing | |
| Comparing | | |
| Explaining | | |

The research method chosen is qualitative research because the purpose of the research is to build, confirm, or validate relationships and to develop generalizations that contribute to the theory [21]. This study conducted experiments and surveys to produce statistical data that will support the results of the analysis in descriptions. This is in line with an opinion from [22] which states that quantitative research uses investigation strategies such as experiments and surveys in data collection using a predetermined instrument to generate statistical data. Non-test instruments consist of interview guides and observation guides that are constructed in the form of open guidelines. This is so that the data can be explorative exploration so that the data obtained is the natural data of the subject. This is in line with [22] view of qualitative research images as an evolving model occurring in a natural environment that allows researchers to develop the level of detail of high involvement in experience. One of the qualitative research identifiers is the social phenomenon observed from the participants. For that reason, the construction of non-test instruments uses open form. The use of the open form is also used by Nugroho and Dwijayanti [23] in a study that analyzes thinking processes regarding metacognitive abilities.

3.4 Discussion Development of a learning style questionnaire through cultural adaptation of 7th-grade students of Junior High School students in Indonesia

The language content that is perceived to be inconsistent with the culture of grade VII of Junior High School students in Indonesia is "to operate new equipment," "I tend to say" it is less specific to produce various answers. In communication, attitudes and feelings of a person can be known by others. For that reason, communication will only be effective if the message conveyed is interpreted the same by the recipient of the message [24]. Therefore, the selection of language that does not result in multi-interpretation is very important in both written and oral communication to create effective communication [25]. This supports research using communication as one of the strategies to build thinking skills [26, 27]. Content in a learning style questionnaire seems to be inconsistent with the
culture of seventh-grade students of junior high school student with a range age of 12 years to 14 years old is "if I buy a new car." In Indonesia, age limit to drive a motor vehicle is at least 17 years, as the rules contained in Law No. 22 of 2009 [28]. Another content is "if choosing food from the menu," this is because most mothers in Indonesia choose cooking food alone for the family so that most of the students from lower middle class will be unfamiliar with this. The last content that I think is less appropriate is the option given to the question "when I meet new people, I will!" This is because the activities tend to be done by an adult. For example arranging meetings with others or eating together.

3.5 Discussion Validity and reliability of the instrument of mathematical imagination in understanding the concept and questionnaire of student learning style

Validation results show that the instrument can measure mathematical imagination in understanding the concept and learning styles of students. This indicates that the instrument fulfills good validity because validity is the degree of accuracy / feasibility of the instrument used to measure what will be measured and the extent to which the instrument performs its measurement function [29, 30, 31]. The researcher performs the validity of the Content through the validation of the linguist to ensure that the measuring instrument used contains a precise operational definition of a theoretical concept that can be observed and measured. Content validity is done through the validation of mathematical concept experts and psychologists to ensure the instrument has a content suitability that can measure mathematical imagination in understanding the concept of algebraic expressions and learning styles of students. Researchers also do empirical validity to compare between the criteria that exist in the instrument with empirical facts that occur in the field. The validity of content are attempts by the researcher to ensure the internal validity of the mathematical imagination instrument constructed and the learning style questionnaire developed. Researchers involved 86 students in one of the trials, this is done to improve external validity [32]. The results of the calculation of test instrument reliability are in the high category, meaning that the instrument has the excellent consistency of results, although it is done on the data retrieval. The results of non-test instrument reliability calculation are in the medium category, meaning that the instrument has a consistency of good results although it was done on the data retrieval. The instrument reliability meter is performed by the researcher for the reliability or consistency of the results obtained from the use of the instrument even though it is repeated [29, 33].

4. Conclusion

The conclusion of this study is that the construction of the mathematical imagination test in understanding the concept of algebraic expression instrument is proven to be valid by the content validity and the empirical validity. The development of a learning style questionnaire has been adapted to the Indonesian culture and has proven to be valid by the content validity and the empirical validity.

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