Development of the complexity measurement instruments of the mathematical contextual problem of trigonometry topic

by Madha Melissa Margaretha

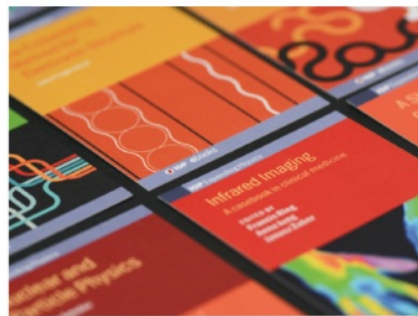**PAPER · OPEN ACCESS**

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Abstract. The complexity of mathematical contextual problems was used to estimate the time to solve the problem and know whether students achieve the competence or not. This aim of this study was to produce the instrument for measuring the complexity of mathematical contextual problem of trigonometry topic. This research and development model used the combination of Plomp and Cennamo & Kalk. The phase were: (1) preliminary study, (2) development, and (3) presentation. The subjects of this study were 1 mathematics teacher, 4 prospective mathematics teachers, and 2 mathematics lecturers. Data collection techniques used questionnaire, test, and interview. Questionnaire validation was used to determine the validation of the developed instrument. The complexity measurement instrument filled by the test subjects to determine the reliability of the developed instrument. Trigonometric test was used to classify students into groups according to their level of ability. Interview was used to determine the practicality of the instruments developed. The results of the study showed that the complexity measurement instrument of mathematical contextual problem that being developed had good quality, it was valid, practice, and reliable. The instrument has been declared valid by the expert and eligible to be tested with minor revisions. This instrument also reached practical criteria based on the results of interviews with respondents. This instrument had fulfilled the reliable criteria based on the calculation of the reliability coefficient which was obtained that each component had fulfilled a minimum "sufficient category" of reliability. There were 4 high reliability components and 2 sufficient reliability components.

1. Introduction

The purpose of learning mathematics could be achieved if learning takes place effectively. National Council Teacher of Mathematics (NCTM) stated that effective mathematics learning will be able to foster understanding of what learners learn [1]. One of the factors to know the effectiveness of the mathematics learning process in schools comprehensively, teachers must be able to do and took advantage of evaluations, assessments, and learning outcomes of students. In addition, Minister of National Education Regulation Number 16 of 2007 concerning Academic Qualifications and Competency Standards Subject teachers (including senior high school) stated that subject teacher competencies include developing assessment instruments [2].

Assessments can provide constructive feedback for teachers and students. The results of the assessment can also motivate students to perform better. Therefore, to achieve this goal, mathematics learning in schools must be meaningful and useful for students in their daily lives. One way for learning to be meaningful and useful for students is to provide mathematical contextual questions. According to Lailatul Istiqomah [3] contextual is linking between learning material with the real world

situation of students, and encouraging students to make a connection between the knowledge they have and their application in their daily lives.

Based on the results of an interview with one of the mathematics teachers at Pangudi Luhur Santo Yusup Senior High School in Yogyakarta, it was found that the teacher conducted an evaluation of mathematics learning by giving questions, assignments, Daily Deuteronomy, Mid Semester Deuteronomy, Semester Deuteronomy, and School Deuteronomy. The type of question the teacher always uses is a matter of description. Teachers usually give 10 items for easy problem categories or 5 items for moderate problem categories or 2 items for difficult questions. The way the teacher classifies the questions given includes difficult, moderate, or easy questions that are based on teaching experience in the classroom. This is done because there is no instrument to measure the difficulty level of the question. Teachers rarely provide contextual questions because many students find it difficult to turn a sentence into a mathematical sentence. Mathematical contextual questions are mathematical questions that use various contexts so as to present situations that have been experienced in real terms for students. In the question, the context must be in accordance with the mathematical concepts being studied.

One of the difficult material in high school according to the teacher is trigonometry. Trigonometry is one branch of mathematics that studies the relationship of angles and sides in a triangle. Trigonometry material used in research is the material learned by 10th grade students about comparisons, functions, equations, and trigonometric identities. Because material trigonometry is difficult for students, it would be better if in learning the teacher provides contextual and real questions in life so that it is easier for students to imagine.

One reason for the lack of effectiveness of contextual learning usually occurs because of giving mathematical questions that are not in accordance with the competencies or material being studied. The scope of the questions that are too broad make it difficult for students to solve the problem. This has an impact on the time allocation given. In other words, the math problem given is too complex. Complex can be defined as some complicated, complicated and difficult elements. According to William and Clarke [4] in Towards Construct Measuring the Complexity of Application Tasks propose to pay attention to six important components that are believed to be able to measure the complexity of a mathematical contextual problem namely: 1) Conceptual Complexity, 2) Complexity of Mathematics, 3) Complexity of Linguistics, 4) Intellectual Complexity, 5) Representational Complexity, and 6) Contextual Complexity.

According to Colton and Covert [5] and Purwanto [6] instruments are tools used to measure phenomena, record information intended for assessment and make decisions. The complexity of a contextual question needs to be measured so that it can be more precise in its use, such as the time needed to work on the problem and the achievement of competence. The instrument is said to be of high quality if it meets the criteria: validity, practicality, and reliability [7].

4 Research Methodology

This research is a development research. The development research model used in this study is combining the development model proposed by Plomp [8], and Cennamo & Kalk [9], with adjustments and simplifications. The development procedure includes the following activities: 1) preliminary investigation, 2) define and design, 3) construction, 4) test and revision, 5) delivery.

After the problem complexity assessment instrument was developed, field trials were carried out. Instrument testing activities in the field (field testing) are carried out in two stages, namely: expert judgment and limited trials. The aim is to be carried out by expert judgment to determine the quality of the product developed from the aspect of validity. Expert review is done by validating the draft instrument for measuring the complexity of contextual questions that have been developed by mathematicians using a validation sheet. The aim of this trial is to apply the instrument for measuring the complexity of the mathematical contextual problems developed. This trial is intended to test the practicality and reliability of the instrument.

The subjects of the trial group were limited to this study, namely 1 mathematics teacher of class X Pangudi Luhur Santo Yusup High School Yogyakarta, 8th semester mathematics teacher candidates at Sanata Dharma University, and 2 mathematics lecturers in the Mathematics Education study program at Sanata Dharma University. Data collection techniques use questionnaires, written tests and interviews. The instruments of data collection are questionnaire validation sheets and questionnaires measuring the complexity of contextual issues, contextual math problems, and interview guidelines. The validity analysis technique that is the product developed is said to fulfill the validity aspect if each component in the instrument developed is said to be valid and the minimum validator states that the product developed is worthy of being tested in the field with revisions. For practicality analysis, the product developed is said to be practical if the results of the interview show that the questionnaire is practically used. Reliability analysis is calculated using SPSS and the product developed is said to be reliable if at least it meets sufficient reliability categories. The reliability category were in the table.

Table 1. The reliability category

Coefficient of reliability	Category
$0{,}80 < rxy \leq 1{,}00$	Very high category
$0{,}60 < rxy \leq 0{,}80$	High category
$0{,}40 < rxy \leq 0{,}60$	Medium category
$0{,}20 < rxy \leq 0{,}40$	Low category
$rxy \leq 0{,}20$	Very low category

The complexity criteria as follow.

Table 2. The complexity criteria

| Interval score	Category
$43{,}45 < \bar{x} \leq 53$	Very high complexity
$37{,}15 < \bar{x} \leq 43{,}45$	High complexity
$30{,}85 < \bar{x} \leq 37{,}15$	Medium complexity
$24{,}55 < \bar{x} \leq 30{,}85$	Low complexity
$15 < \bar{x} \leq 24{,}55$	Very low complexity

3. Result and Discussion

In this section, we would discuss about the complexity measurement instrument, how it used to predict students' answer, validity, practicality, and reliability of the instrument. The aspect of complexity measurement instrument are as follows:

1) Contextual complexity: (a) The number of topic of the question, and (b) development of the mindsets.
2) Complexity of mathematics: (a) The number of steps to solve the problem, (b) The length of the solution, (c) The type of the problem.
3) Complexity of linguistic: (a) The kind of language that used, (b) The language of the problem, (c) Sentence of the problem.
4) Intellectual complexity: (a) Solution need analysis and (b) The level of problem challenge.
5) Representational complexity: (a) Solution can be represent by diagram, graphic, or picture and (b) The complexity to draw diagram, graphic, or picture.
6) Contextual complexity: (a) Type of the problem, (c) Contextual level of the problem, (c) The reality of the problem.

From the results of the measurement of the complexity of contextual questions for question number 1 which has been filled in by teachers, prospective teachers, and mathematics lecturers based on

existing instruments, researchers perform calculations and based on existing criteria obtained that number one has a **moderate complexity** because it has an average of 30. It predicted that students will not have so much difficulty in solving the problem because the topics related to the problem are low. They also predict that students will be able to represent the image and solve the problem in various ways. The contextual matter measurement instrument that has been filled in by the teacher, the prospective teacher and the mathematics lecturer will be compared with the results of the student's work.
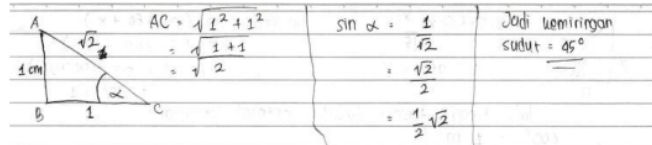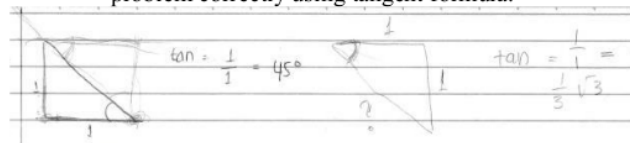

Figure 1. The answer of student 1 for question number 1. Student draw the sketch, but not appropriate with the problem. Student solve the problem use sine formula. The answer was correct.
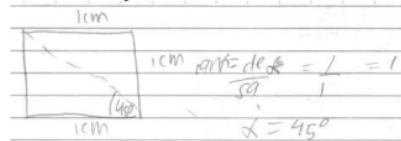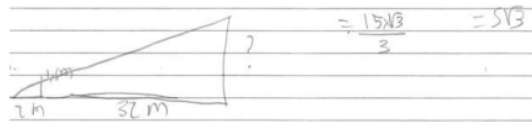
Figure 2. The answer of student 2 for question number 1. Student draw the sketch and answer the problem correctly using tangent formula.
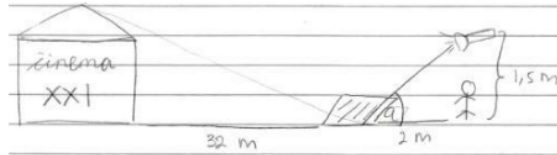
Figure 3. The answer of student 3 for question number 1. Student draw the sketch and answer the problem correctly using tangent formula.

From the three results of student work, it can be seen that it is true that the three students can represent solutions in the form of drawings or sketches, even though the images they make are not in accordance with what is known from the problem. This is possible because of the lack of analytical skills of students in working on question number 1. But they answered correctly for mathematical calculations. From the results of student work it can also be seen that students various ways of answering questions. Student 1 answers the question using the Pythagorean formula, then uses the sine rule to solve it. Students 2 and 3 can directly answer questions using tangent rules. This is in accordance with the predictions of teachers, prospective teachers and mathematics lecturers that students will use various steps/ways to solve this problem. This shows that the complexity of the problem is moderate.

From the results of calculations and based on the existing criteria it is found that the question number 2 has a **high level of complexity** because it has an average of 39,257. Teachers, prospective teachers, and mathematics lecturers predict that high school students in class X given the problem will experience difficulties. They predict that students will solve the problem in various ways and use a long enough step. In addition, analysis is needed in solving these questions, this is seen from the level of challenge of the questions that are quite high and the types of questions given are about mathematical applications because it requires a lot of information processing in modelling mathematical forms. Student 1 didn't answer the question.
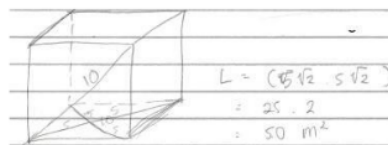
Figure 4. The answer of student 2 for question number 2. Student tried to draw a sketch, but it didn't mean anything. The answer was incorrect.
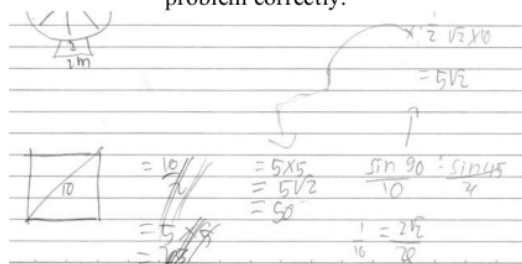

Figure 5. The answer of student 3 for question number 2. Student made the correct sketch, but didn't solve the problem.

From the results of the answers the students found it very difficult to work on question number 2. This can be seen from many students who did not work on the problem. Student 1 doesn't work at all. Student 2 tries to answer by making a sketch, but the picture they made does not mean anything at all. They only make triangles and lines, along with a little information. Student 3 is correct in sketching, but does not do mathematical calculations. This shows the complexity of the problem number 3 including in high complexity.

From the results of measurement number 3, it was found that the average was 25.71 so that it was included in the category of **low complexity**. Teachers, prospective teachers, and mathematics lecturers predict if high school students in class X are given the problem students will not have difficulty in doing the work.

Figure 6. The answer of student 1 for question number 3. Student draw the sketch and answer the problem correctly.

Figure 7. The answer of student 2 for question number 3. The student answer the question correctly, but the sketch was not clear.

Figure 8. The answer of student 3 for question number 3. Student draw the sketch and answer the problem correctly.

From the student's answers, it can be seen that most students answer question number 3 correctly. All students begin the settlement by sketching first, then doing mathematical calculations. The method used by each student is different, this affects the number of steps students take. After sketching, student 1 immediately calculates, so that only one step is needed. Students 2 and 3 solve this problem by looking for the build side first, then find a solution, so they need 2-3 steps of work. Based on this, the level of complexity of question number 3 falls into the category of low complexity.

The results of the validation show that the instrument for measuring the complexity of contextual mathematical problems needs to be improved. After repairs are made, each item of the instrument is declared valid by the validator and the product developed is ready to be tested in the field.

The practicality test is obtained based on the results of interviews of researchers with the subject of the trial. There were four respondents who the researchers took from the four prospective mathematics teachers. They said that the instrument for measuring the complexity of the mathematical contextual problems developed was quite good. It can be concluded that this instrument is quite easy to use, so that this instrument meets the practical category. Based on the results of the interview, it was concluded that the measurement instrument for contestants' complexity is easy to use because it does not require a lot of equipment, easy to check, equipped with clear instructions so that it is easy to use by others, making instruments is also economical, does not require a lot of energy, and time which is used to fill this instrument is relatively short. Therefore, the instrument that has been developed can be said to be practical in its use.

Tests for reliability obtained from the results of the Cronbach's Alpha calculation obtained results:
1) Reliability of conceptual complexity is 0,75 in a high category
2) Reliability of complexity of mathematics is 0,62 in a high category
3) Reliability of complexity of linguistic is 0,68 in a high category
4) Reliability of intellectual complexity is 0,72 in a high category
5) Reliability of representational complexity is 0,5 in a medium category
6) Reliability of contextual complexity is 0,57 in a medium category

It can be seen that each component meets the reliability criteria, that is, at least the reliability criteria are sufficient. So it can be concluded that the instrument for measuring the complexity of mathematical contextual questions that have been developed meets criteria that are reliable and feasible to use.

Based on the description of the study above, it can be concluded that the product of the mathematics contextual problem measurement instrument has proven its validity, practicality and reliability. Thus, the product of the complexity contextual mathematical problem measurement instrument is feasible.

4. Conclusion

The results of the study showed that the complexity measurement instrument of mathematical contextual problem that being developed had good quality, it is fulfilling valid, practical, and reliable criteria. The instrument has been declared valid by the expert and eligible to be tested with minor revisions. This instrument also reaches practical criteria based on the results of interviews with respondents. This instrument has fulfilled the reliable criteria based on the calculation of the reliability coefficient which is obtained that each component has fulfilled a minimum "sufficient category" of

reliability. There are 4 components that have high reliability and 2 components have sufficient reliability.

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