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Development of CORE model-based student worksheet on trigonometric ratios to facilitate students' mathematical conceptual understanding

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Abstract

This research was motivated by the low ability of students to understand mathematical concepts, particularly in the topic of trigonometric ratios. The CORE model was chosen because it encourages active student participation in constructing concepts through systematic stages. The purpose of this study is to develop a valid and practical CORE-based worksheet on trigonometric ratios to support students' conceptual understanding. The development process followed the 4-D model (define, design, development, disseminate). Research data consisted of qualitative input from validators and students, as well as quantitative data from questionnaire scores. Data collection was conducted through interviews and questionnaires using validation sheets and student response instruments. The sample was selected through purposive sampling: 6 students from class XE.1 (Small Group) and 30 students from class XE.3 (Field Test). A worksheet is considered valid and practical if it achieves its values. The results showed that the developed worksheet was very valid (94.31%) based on appearance, content, and construction aspects. It was also very practical, with scores of 97.36% for Small Group and 90.13% for Field Test, assessed based on presentation, ease of use, readability, and time. CORE based worksheets encourage students to actively construct concepts actively actively, thereby facilitating their ability to conceptual understand trigonometric ratios.

Keywords: mathematical conceptual understanding; worksheet; core learning; trigonometric ratios

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I. Introduction

Conceptual understanding is a fundamental aspect of mathematics learning (Syaiful, Aprillya & Anggraeni, 2020). This ability includes the skills of remembering, explaining, applying, and connecting various concepts to achieve meaningful and applicable understanding (Meidianti, Kholifah & Sari, 2022). Mathematical conceptual understanding reflects students' ability to absorb, understand, and convey mathematical ideas (Rani, Zulkarnain & Kusumawati, 2021; Styoningtyas & Hariastuti, 2020). This ability enables students to remember concepts well, explain them in their own words, and relate them to other concepts in problem-solving (Apriani, Novaliyosi & Jaenudin, 2021; Tampubolon, Sihombing & Sinaga, 2023). Therefore, strengthening conceptual understanding must be a priority in learning strategies to create a deeper and more meaningful learning experience.

The topic of trigonometric ratios is an abstract learning topic that is difficult for students to understand (Armiati & Budi, 2021). On the topic of trigonometric ratios, many students still have difficulty naming the sides of right triangles. Furthermore, students tend to memorize formulas without understanding the underlying concepts, which impacts their understanding of other trigonometric concepts (Cholid, Ahmadi & Oktaviani, 2022). Therefore, mathematics learning regarding trigonometric ratios needs to be designed as well as possible to achieve a successful understanding of the topic.

In fact, the ability to understand mathematical concepts is still relatively low. The results of the *Programme for International Student Assessment* (PISA) 2022 showed that Indonesia ranked 66th out of 81 countries, with an average score of 366, still far below the international average of 427 (OECD, 2024). PISA questions not only require the ability to apply concepts but also emphasize how understood concepts can be applied in various situations (Afifah, Tamrin, Salsabila, Hasanah & Herman, 2024). Empirical data also support this low ability. Research Desmi, Hryono & Melia (2023) shows that students have not been able to meet the indicators for restating and applying concepts. Furthermore, Rahim, Kurniati & Rahmi (2022) concluded that students' overall ability is in the very low category, with the indicator linking various concepts being the weakest, only achieving an average score of 0.14 out of a maximum score of 4 (around 10.25%).

One solution to addressing low mathematical concept comprehension is to utilize student-centered teaching materials, namely student worksheets (Tahir & Marniati, 2022). Worksheets contain learning activities that help students maximize understanding and achieve learning objectives (Retta & Fitriasari, 2022). Worksheets are printed teaching materials that contain material, summaries, and assignment instructions, serving as guides and support tools for student learning, investigation, and problem-solving.

Mathematics generally focuses on students' knowledge of mathematical topics (knowing) and their ability to find appropriate solutions to problems using prior knowledge (doing). To support these two aspects, a learning model that fosters deep conceptual understanding is needed. One relevant model is CORE (Connecting, Organizing, Reflecting, and Extending) (Dolapcioglu & Doğanay, 2020). The CORE learning model combines four important constructivist elements: connecting students' prior knowledge, organizing new knowledge, providing opportunities for reflection, and enabling students to extend their understanding (Saregar, Cahyanti, Susilowati & Anugrah, 2021). This model was chosen based on its ability to train students' memory of a concept, provide meaningful learning experiences, and encourage active student involvement in connecting various concepts, organizing knowledge, reflecting on understanding, and broadening horizons (Yusuf & Juleha, 2020). These four stages are crucial components in developing a deep conceptual understanding, particularly in mathematics learning. This finding aligns with research conducted by (Ditasari, Ulya & Wanabuliandari, 2022; Yusuf & Juleha, 2020), which demonstrates that the CORE model is effective in enhancing students' understanding of concepts related to learning topics.

Several studies relevant to this research include those by (Yudela, Putra & Laswadi, 2020). The study aimed to develop YouTube learning resources to support conceptual understanding skills. This study, however, developed a CORE-based learning worksheet that emphasizes students' direct activities in the learning process. Furthermore, research by Wahyuni, Efuansyah & Sukasno (2020) aimed to develop a CORE-based worksheet to improve mathematical connection skills, whereas this study focuses more on developing a CORE-based worksheet to facilitate mathematical concept understanding skills.

Based on the description above, this paper has developed a CORE learning-based worksheet on the topic of trigonometric comparisons to facilitate the mathematical concept understanding ability of Phase E students, meeting valid and practical criteria.

II. Research Method

The type of research used is R&D research *(Research and Development)*, the aim is to produce a product in the form of a CORE learning-based worksheet on the topic of trigonometric comparisons. This research applies the 4-D development model (*Four D*) presented by (Thiagarajan, 1974), which consists of four stages: define, *design, development* and *disseminate*. The level of *define*, preliminary-final analysis was conducted through interviews with mathematics teachers to identify research problems, student analysis to identify target characteristics, task analysis to identify tasks in accordance with learning outcomes, concept analysis to conduct interviews with mathematics teachers to determine the material that must be taught in accordance with learning outcomes, as well as the specification of learning objectives to formulate TP to address research deviations from initial objectives.

At this stage of *design*, the activities carried out include compiling criteria tests, namely creating validation questionnaire sheets and student responses to measure the validity and practicality of the product being developed, selecting media and formats, namely selecting supporting applications to develop worksheets and creating worksheet formats according to the model used, as well as the initial design of the product. Next, at the stage of *development,* the designed worksheets are evaluated formatively, following the procedures outlined by (Wedman & Tessmer, 1993), which include *self-evaluation, expert review* to measure validity, *one-to-one* testing to assess readability, as well as *small-group* and *field tests* to evaluate the practicality of the worksheets. Finally, the stages are disseminated, and the worksheets that have been declared valid and practical are then distributed to high school-level schools.

The subjects in the trial to develop a worksheet based on CORE learning to facilitate understanding of mathematical concepts were 6 students of class XE.1 of SMAN 1 Guguak for the trial*. Small Group*. This student selection was carried out based on suggestions from the mathematics teacher who teaches in the class to ensure that various levels of student ability can be represented. As well as 30 students from class XE.3 for the trial *Field Test*. This class selection was conducted to assess the practicality of the worksheet on a large scale. During the trial, *Small Group* and *Field Test* Students were given a student response questionnaire to assess the practicality of the worksheets developed. Data collection techniques for identifying the problem or initial analysis were conducted through interviews. This interview was conducted with one of the 10th-grade mathematics teachers to determine how the learning process was taking place. Furthermore, this study also used a questionnaire as a data collection instrument.

The instrument used to collect data was an expert validation instrument in the form of a validity questionnaire to measure the validity of the worksheet developed with the criteria of very valid, valid, quite valid, less valid and not valid, with three validators, namely two lecturers and one practitioner. The practicality instrument was in the form of a student response questionnaire, measuring the practicality of the worksheet using the following criteria: "very practical," "practical," "quite practical," "less practical," and "not practical." The determination of the assessment scale in both questionnaires was based on the Likert scale. The Likert scale is used to measure a person's attitudes, opinions and perceptions with answer choices, namely, 5 (Strongly Agree), 4 (Agree), 3 (Undecided), 2 (Disagree), and 1 (Strongly Disagree) (Sugiyono, 2016).

Table 1. Validation instrument grid

Evaluation Aspects	Assessment Indicators
Appearance Aspect	• There are learning topic titles • There is space for student identity • Worksheet design
Content Aspect	• Compliance of worksheet contents with CP and TP • The topics are presented systematically • Correctness of worksheet presentation • The worksheet contains tasks that train the ability to understand mathematical concepts.
Constructive Aspect	• Conformity of worksheet presentation with the four syntaxes in the CORE model • Suitability of worksheet presentation with indicators of mathematical concept understanding ability

Source: Adopted from Margayu et al., 2020

Table 2. Practicality instrument grid

Evaluation Aspects	Assessment Indicators
Presentation	• Display design • Clarity of instructions • Use of font type and size
Ease of Use	• Clarity of the problem • Ease of implementation in the learning process • Clarity of questions
Readability	• Readability of font type and size • Clarity of language
Time	• Timeliness

Source: Adopted from Ariani, 2022

Validity data was obtained from the validity questionnaire completed by the validator. With the following steps: 1) Giving a score to the validity questionnaire with indicators based on a Likert scale by the validator. 2) Determining the highest total score. The highest score is obtained by multiplying the number of indicators by the maximum score for each indicator. 3) Determining the total score obtained from each validator. 4) Determining the validity value using the formula adopted by (Novita, Lufri, Ardi & Selaras, 2023) as follows.

$$V_a = \frac{T_{se}}{T_{sh}} \times 100\%$$

Information:
V_a is the percentage of validity
T_{se} is the total score obtained from validator
T_{sh} is the maximum total score that expected

The practicality analysis technique also uses the formula adopted according to (Novita et al., 2023) as follows.

$$V_p = \frac{T_{se}}{T_{sh}} \times 100\%$$

Information:
V_p is the percentage of practicality
T_{se} is the total empirical score of the observer
T_{sh} is the maximum total score expected

The results of these values are then analyzed based on the validity and practicality categories in the following table to determine the extent to which the developed worksheet is valid and practical.

Table 3. Validity and practicality categories

Interval	Validity Category	Practicality Category
$V < 21\%$	Invalid	Impractical
$21\% \leq V < 40\%$	Less Valid	Less practical
$40\% \leq V < 60\%$	Quite Valid	Quite Practical
$60\% \leq V < 80\%$	Valid	Practical
$80\% \leq V \leq 100\%$	Very Valid	Very Practical

Source: Adopted from Marlini et al., 2022

Based on table 3, the CORE learning-based worksheet is considered valid and practical if it obtains validity and practicality values $\geq 60\%$, and is not valid and practical if it obtains validity and practicality values $< 60\%$.

III. Results and Discussion

This research is an R&D research (*Research and Development*). The development model used is a 4-D model, which includes *define, design, development* and *disseminate*. The activities carried out by researchers at each 4-D stage to produce valid and practical worksheets are explained as follows.

The first stage is defined, which includes five activities: pre-post analysis, student analysis, task analysis, concept analysis, and specification of learning objectives. The pre-post analysis aims to identify the main problems in the research. The results of interviews with mathematics teachers at SMAN 1 Guguak revealed that there are no worksheets available that can facilitate indicators of students' mathematical concept understanding abilities on the topic of trigonometric ratios. Additionally, the worksheets currently used are not independently created by teachers. Therefore, teachers strongly support the development of CORE learning-based worksheets that can help students develop their understanding of mathematical concepts. This finding aligns with research (Ditasari et al., 2022; Yusuf & Julaeha, 2020), which demonstrates that the CORE model is effective in enhancing students' conceptual understanding of the studied topics. Through the stages of the CORE model, students not only learn concepts but also link concepts, organize information, strengthen existing concepts, and expand their knowledge.

The student analysis activity aims to determine the characteristics of Phase E students in following the learning process, which is used as a reference in designing the developed worksheet. Based on a literature review, it is known that students in phase E are between 15-16 years old, and according to (Ibda, 2015), at this age, children have entered the formal operational stage of cognitive development. At this stage, children no longer require the assistance of concrete objects or events in their thinking, but are already capable of abstract thinking (Ibda, 2015), Based on interviews with mathematics teachers at SMAN 1 Guguak, it was revealed that students often make several errors, such as difficulty linking concepts and applying them when solving problems. This is in line with the findings (Desmi et al, 2023; Rahim et al, 2022), which state that students' low understanding of mathematical concepts is caused by their inability to link various mathematical concepts, restate a concept and apply concepts or algorithms in problem solving.

Task analysis activities were conducted to analyze the Learning Outcomes (CP) contained in Kemendikbudristek Number 032/H/KR/2024 to produce a Learning Objective Flow (ATP). The ATP results are presented in the following table.

Table 4. Results of learning objective flow analysis (ATP)

Learning Outcomes (CP) Phase E	At the end of phase E, students can solve right triangle problems involving trigonometric ratios and their applications.
Learning Objective Flow	TP 1. Determining comparison trigonometry in triangles right angles and their applications in everyday life TP 2. Determining the value trigonometric ratios at special angles and its application in daily life TP 3. Determining the value trigonometric ratios each quadrant and its application in daily life
Elements	Geometry
Topic	Trigonometric Ratios
Total JP	6 JP (6 × 45 minute)
Pancasila Student Profile	Critical thinking, independent, creative, collaborative

Concept analysis activities are conducted to identify the primary concepts being taught and examine the details of the concepts that require instruction. This activity creates a concept map for the topic of trigonometric ratios, as shown in the following figure.

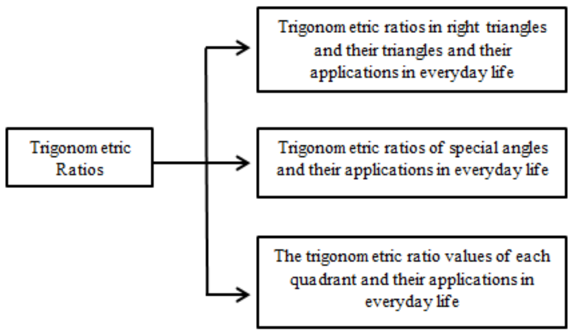

Figure 1. Concept map of the topic of trigonometric ratios

The learning objective specification activity is conducted to formulate the learning objectives that students are expected to achieve. The following are the results of the analysis of learning objectives on the topic of trigonometric ratios.

Table 5. Learning objective specification results

Meeting	Learning objectives	JP
1	Students can determine trigonometric ratios in right triangles and their applications in everyday life.	2
2	Students can determine the value of trigonometric ratios at special angles and their applications in everyday life.	2
3	Students can determine the trigonometric ratio values of each quadrant and their applications in everyday life.	2

The second stage is design, where three activities are carried out: compiling criteria tests, selecting media and formats, and creating an initial product design (*Prototype-1*) worksheet based on CORE learning. At the stage of preparing the criteria test, what is done is to compile a validation questionnaire sheet to measure the validity of the product being developed, consisting of appearance aspects, content aspects, and construct aspects with criteria of very valid, valid, quite valid, less valid and not valid, with three validators, namely two lecturers and one practitioner, as well as compiling a student response questionnaire sheet to measure the practicality of the product being developed, consisting of presentation aspects, ease of use aspects, readability aspects, and time aspects with criteria of very practical, practical, quite practical, less practical, and not practical. Next, the media selection and format selection activities. The chosen media is print media, assisted by the application *Canva,* and the worksheet format is determined, consisting of an introduction page, worksheet contents, and practice questions, which are in the fourth stage of the CORE model, namely *Extending*. Based on the selection of media and format, an initial worksheet design is made (*Prototype-1*). In this design, students' conceptual understanding is built gradually through each CORE syntax, designed to meet the indicators of conceptual understanding ability. Stage *Connecting* help students relate prior knowledge to new concepts, stages *Organizing* guides students to organize the ideas they get, stage *Reflecting* encourages students to reflect on the learning process and results, while the next stage *Extending* expands the application of concepts through practice problems. Thus, each stage of CORE contributes directly to the development of students' conceptual understanding, so that the worksheets developed serve not only as worksheets but also as learning tools that guide students in constructing concepts independently, in a structured and meaningful manner.

The third stage is development, at this stage, the initial design of the worksheet or *prototype-1* formative evaluation is carried out. *Prototype-1* was given to three validators (*expert review*) to assess the suitability of the worksheet based on aspects of appearance, content, and construction by obtaining feedback, comments, and suggestions for improvement, which form the basis for revising the worksheet. The results of the worksheet validity are presented in the following table.

Table 6. Validity worksheet results data

Rated Products	Average of Assessment Aspects of 3 Validators			Average
	Aspect Appearance	Content Aspect	Constructive Aspect	
Worksheet-1	94,29%	95,33%	94,45%	94,69%
Worksheet-2	93,33%	94,67%	94,45%	94,15%
Worksheet-3	94,29%	94,67%	93,33%	94,10%
Average	93,97%	94,89%	94,08%	94,31%
Average Validity of worksheet 1-3				94,31%
Category				Very Valid

Based on Table 6, the average score of the three validators for CORE-based worksheets 1-3 in facilitating mathematical concept understanding reached 94.31%, categorized as very valid. This result indicates that the developed worksheets have met the development criteria according to (Trianto, 2009), namely didactic, constructional, and technical requirements. This finding aligns with research (Amalia, 2011) that confirms learning with valid worksheets is more effective than without their use. Furthermore, Amalia's research also shows that valid CORE based worksheets can facilitate in-depth conceptual understanding. Thus, the results of this study support previous findings while providing a new contribution in the form of an emphasis on the CORE strategy in improving worksheet quality. Therefore, the developed worksheets are worthy of being tested after revision in accordance with input from the validators.

Table 7. Validator suggestions and revision results

Validator Suggestions	Follow-up
In terms of appearance, the validator suggested that the use of EYD be improved, the symbols used to be made consistent, and the size of the blank space in students' answers be adjusted.	Improve the use of EYD, ensure consistency in the symbols used, and enhance the student answer space on the worksheet.
In terms of content, the validator suggested that the activity instructions and questions on the worksheet be clarified further.	Revise the sentences in the activity instructions and questions on the worksheet to make them easier for students to understand.
In terms of construction, in the Organising section, the validator suggested giving students the opportunity to construct their own knowledge. Meanwhile, in the Extending section, the validator suggested increasing the number of practice questions to achieve the Extending objective.	Improve activities at the organizing stage so that students can build their own knowledge, and add practice questions at the extending stage.

Along with the validation process, researchers also conducted *one-on-one* trials with three students. This trial aimed to determine readability and identify deficiencies in the worksheet. The trial results showed errors in Worksheet-1 and Worksheet-2. Based on input from the *expert review* and *one-on-one* trials, the worksheet is then revised to *prototype-2.*

The next stage of product testing involves a *small group* of six students from class XE.1 of SMAN 1 Guguak, with varying levels of ability. This trial aimed to assess the practicality of the worksheet developed on a small scale. The results of the student response questionnaire in the *trial small group* are presented in the following table.

Table 8. Student response questionnaire results for small group test

Aspect	Average (%)
Presentation Aspects	93,89%
Ease of Use Aspects	95,56%
Readability Aspect	100%
Time Aspect	100%
Average Practicality of worksheet 1-3	97,36%
Category	Very Practical

Based on Table 8, the average practicality score for worksheets 1-3 is 97.36%, categorized as very practical. According to Riduwan (2015), this score indicates that the developed worksheets are practical, as their practicality score is above 60%.

The final trial was conducted through a large-scale group trial (*Field Test*) involving thirty students from class XE.3 of SMAN 1 Guguak, with varying academic abilities. This trial aims to evaluate the practicality of worksheets in learning on a broader scale. The results of the student response questionnaire in the large group trial are presented in the following table.

Table 9. Student response questionnaire results for large group test

Aspect	Average (%)
Presentation Aspects	89,48%
Ease of Use Aspects	89,71%
Readability Aspect	90,44%
Time Aspect	90,89%
Average Practicality of worksheet 1-3	90,13%
Category	Very Practical

Based on the trial, students were able to work on the worksheet according to the CORE syntax, thereby facilitating the indicators of understanding mathematical concepts. At the *Reflecting* stage, students can restate concepts well, in line with the findings (Cholid et al., 2022). Stage *Connecting and Organizing* students can connect old knowledge with new knowledge and manage information, even though some answers are still imperfect. At this stage, *Extending* appears that students can use procedures and algorithms correctly, as shown by the results (Roza & Yuanita, 2021). Overall, CORE-based worksheets predominantly facilitate understanding of mathematical concepts, with most students demonstrating good mastery, as supported by previous research (Ditasari et al., 2022; Yusuf & Julaeha, 2020). Based on the validity and practicality analyses, the CORE-based worksheet on trigonometric ratios meets the requirements for validity and practicality, allowing it to proceed to the final development stage.

The last stage is disseminate, namely, packaging by printing worksheets and distributing them by handing them over to contributing schools. The following is a cover design for the CORE-based worksheet packaging on the topic of trigonometric comparisons, designed to facilitate students' mathematical conceptual understanding of phase E.

Figure 2. Worksheet cover design

IV. Conclusion

This research produces a CORE learning-based worksheet on the topic of trigonometric comparisons to facilitate the mathematical concept understanding ability of phase E students. The development procedure follows a 4-D model that includes the following stages: *define, design, development,* and *disseminate.* Based on the results of the validity and practicality tests, the worksheet developed meets the requirements for validity and practicality, making it suitable for use in teaching the topic of trigonometric comparisons to Phase E students.

This research was only conducted up to the validity and practicality testing stage; therefore, it is recommended that further researchers continue to the effectiveness testing stage. Additionally, it is recommended that CORE learning-based worksheets be developed on different topics and at various levels of education.

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