



Enhancing students' relational understanding through the development of higher order thinking skills (HOTS)-based student worksheet

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Abstract

Relational comprehension represents a critical skill that students should acquire to correctly associate concepts. This investigation aims to cultivate a High Order Thinking Skills (HOTS)-based Student Worksheet that is both valid and practical, as well as effective, with the potential to significantly influence the relational comprehension of senior high school students. The 'design research' method, incorporating a 'formative research' development model, is used in this research, which is broken down into two stages: initial assessment and self-review. This study was carried out at Muhammadiyah 1 High School in Palembang, focusing on tenth-grade students. Data was evaluated qualitatively in a descriptive manner, founded on observations, interviews, and tests. The study's findings highlight that the developed HOTS-based student worksheet is valid, practical, and efficient in boosting students' relational comprehension once implemented in the classroom. The test outcomes indicate that students possess a reasonably good ability to comprehend HOTS category C4 problems, but are lacking in understanding HOTS category C5 problems. Therefore, additional research is deemed necessary to enhance students' understanding of HOTS category C5 problems.

INTRODUCTION

In the 21st century era, it is crucial for students to develop high-level thinking abilities, or High Order Thinking Skills (HOTS), which enable them to solve new problems and connect concepts in innovative ways (Khaesarani & Ananda, 2022). This approach equips students with the capacity to respond to and adapt to new challenges (Irwandi & Bahriah, 2020). HOTS align with the cognitive process dimension in Bloom's Taxonomy, which has been updated by Anderson & Krathwohl (Khaesarani & Ananda, 2022) to include analysis (C4), evaluation (C5), and creation (C6) (Masitoh & Aedi, 2020). However, these skills are often inadequately mastered by students, as shown by Indonesia's ranking in the Program for International Student Assessment (PISA), placing 71st out of 79 participating countries in mathematical and scientific skills assessment (OECD, 2016).

In addition to high-level thinking skills, relational understanding is also highly crucial for students, particularly in mathematics learning. Relational understanding allows students to connect mathematical concepts and comprehend them more deeply (Blanton et al., 2018; Saparida et al., 2013). However, many students struggle to connect these concepts, often because teachers do not fully implement this understanding in the learning process (Mulyono & Hapizah., 2018). Further observations and studies corroborate these findings, showing that many students are still unable to use relational understanding in comprehending and applying mathematical formulas or concepts (Rahmah & Rahardi, 2021). Given these challenges,

developing more effective teaching materials in schools becomes of paramount importance, and this is the primary focus of this research.

To overcome challenges in understanding mathematical concepts relationally identified earlier, Student Worksheet (LKPD) can potentially be a useful tool. Developed by teachers as teaching materials, LKPD provides prearranged working steps and integrated assessment techniques, which may assist students in understanding mathematical concepts more profoundly (Noprinda & Soleh, 2019; Purwasi & Fitriyana, 2020). Besides its primary role in individual learning processes, LKPD also promotes cooperation among students. Through this collaboration, students can share ideas and seek solutions together, which may ultimately facilitate their relational understanding development (Agustarina et al., 2020). In other words, LKPD might offer one possible solution to challenges in relational understanding-focused mathematical instruction.

Previous research has revealed the importance of LKPD use in enhancing students' relational understanding. For instance, Novitasari et al. (2021) demonstrated that LKPD could help students uncover mathematical concepts more effectively. Meanwhile, Jaelani (2013) found that LKPD promotes cooperation among students, potentially facilitating relational understanding. Research by Umbaryati (2016) showed that teachers often fail to apply concepts in ways that facilitate relational understanding, an issue potentially mitigated by LKPD. Nasir's study (2018) found that students often struggle to comprehend concepts using relational understanding, pointing to the need for teaching materials like LKPD. Finally, research by Mulyono & Hapizah (2018) indicated that students often face difficulties in using mathematical concepts that relate to prior knowledge, a problem potentially addressed by LKPD. While previous research has demonstrated the benefits of LKPD in enhancing relational understanding, there remains limited research specifically focusing on the development of HOTS-based LKPD. Therefore, this research has the potential to provide a significant contribution to the literature surrounding LKPD and relational understanding.

METHODS

The researcher employed a design research type of development study with a formative research type of development model. This study was conducted in two stages: preliminary (preparation) and formative evaluation stage which consists of self-evaluation, expert reviews, one-to-one, small group, and field test (Flagg, 2013; Tesmer, 1993). The subjects of the study were grade X students at Muhammadiyah 1 High School in Palembang, totaling 37 students (11 males and 26 females). The focus of this study is the relational abilities of the students concerning the development of a HOTS-based Student Worksheet (LKPD). The flow of the formative evaluation stage design is shown in Figure 1.

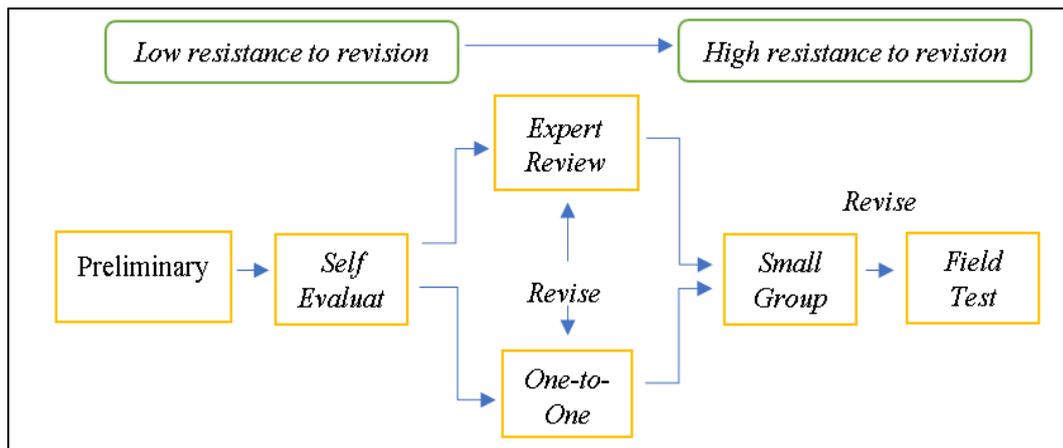


Figure 1. Flow Design of Formative Evaluation Stage (Flagg, 2013; Tesmer, 1993)

The data analysis technique in this study is descriptively qualitative based on walkthroughs, interviews, observations, and tests. Walkthroughs are used to obtain the validity of the developed Student Worksheet (LKPD) based on comments and suggestions during the expert review stage. Interviews are employed to support the validity and practicality of the developed LKPD during the one-to-one and small group stages. Observations are utilized in the one-to-one stage to identify difficulties students encounter while working on the LKPD, and during the small group stage to assess the practicality of the LKPD. Observations are also performed to observe the potential effects on the students' relational understanding after implementing the developed HOTS-based LKPD for the System of Linear Equations in Two Variables (SPLTV) material during the field test stage. Tests are carried out to observe the potential effect of the HOTS-based LKPD on the students' relational understanding of SPLTV material. The indicators of relational understanding used in this study are presented in Table 1.

Table 1. Indicators of Relational Understanding and Descriptors

No.	Indicators of Relational Understanding	Descriptors
1	Identifying data contained in the provided information.	Writing down the provided information.
2	Presenting concepts in the form of mathematical representation.	Formulating variable reasoning and mathematical models.
3	Applying concepts algorithmically.	Solving problems using the chosen strategy.
4	Providing logical arguments when carrying out procedures.	Drawing conclusions.
5	Recognizing new types of problems that can be solved using procedures.	Solving new problems using procedures.

RESULTS AND DISCUSSION

Preliminary Phase

In this phase, the researcher analyzes the subjects of the study, who are the students of class X.1 at SMA Muhammadiyah 1 Palembang, consisting of 37 individuals (11 males and 26 females). Subsequently, the curriculum used at SMA Muhammadiyah 1 Palembang is analyzed, which is the "independent learning" curriculum. In analyzing the material, the researcher selected the SPLTV topic that is included in the independent curriculum, under the phase E in

the algebra element. In addition, the researcher also designed a student worksheet (LKPD) which includes student activities, contextual problems, and is equipped with an answer column containing indicators of relational understanding. After the preliminary stage, the next phase is prototyping.

Formative Evaluation Phase

In the self-evaluation phase, the researcher self-evaluates the problems in the designed LKPD and identifies the errors. The result of this analysis is referred to as Prototype I. Prototype I will then be tested in the subsequent phases, which are the Expert review and one to one phases. In the Expert review phase, the LKPD is validated by three experts to determine its validity in terms of content, construct, and language. Validation is conducted directly (face-to-face). The characteristics considered in terms of construct are the suitability of the LKPD which includes HOTS questions. The characteristics considered in terms of content are the compatibility of the material with the independent learning curriculum. In terms of language, it is checked whether it uses standard language in accordance with the Enhanced Spelling (EYD), whether the sentences used are easy to understand, and whether they do not cause double interpretation errors.

Concurrent with the expert review phase, the one to one phase is conducted with three students selected based on their high, medium, and low abilities. The one to one phase aims to ascertain the validity of the LKPD in terms of readability, clarity of problems and questions contained in the LKPD. Then, the researcher provides a comment sheet and interviews the students to identify difficulties they encountered during the LKPD completion process in terms of language, sentences, readability, and clarity. After the Expert review and one to one phases, a revision decision is made based on comments, suggestions, and interviews as shown in Table 2.

Table 2. Expert Review Phase and One to One Trial Phase

No	Revision Decision
LKPD 1	<ul style="list-style-type: none"> The sentence in the information does not need to be rewritten. In question no.6, revise the phrase "not less than," which students less understood, to "minimum."
LKPD 2	<ul style="list-style-type: none"> The sentence in the problem, "The number of vehicles at the Rp 20,500 tariff is eight more than the number of vehicles with the Rp 31,000 and Rp 41,500 tariffs," is revised to "The number of vehicles at the Rp 20,500 tariff is eight more than the total number of vehicles with the Rp 31,000 and Rp 41,500 tariffs."
Test Questions	<ul style="list-style-type: none"> Provide sources and images in the test questions. There is no need for an answer column in the question.

Based on the findings from the expert review and one-to-one stages, problems were identified in terms of content and construct. The validity criterion based on content is the alignment of the material with its learning objectives, while the construct involves the clarity and readability of the concepts contained within. From a language perspective, the criterion is the use of language based on the Enhanced Spelling System (EYD) and the avoidance of double interpretations (Asmara & Sari, 2021). After the student worksheet (LKPD) and test questions in prototype I were revised following the suggestions and comments from the validators and students in the expert review and one-to-one stages, LKPD prototype II was obtained. The research then proceeds to the small group testing stage.

In the small group stage, six students with high, medium, and low abilities were tested, divided into three small groups. The purpose of the small group testing stage is to assess the practicality of the developed LKPD. The characteristics of practicality can be seen in terms of effectiveness, efficiency, and ease of use (Tesmer, 1993). This is consistent with previous research where practicality can be assessed based on the one-to-one stage and the field test stage (Kamid et al., 2021; Susanti & Hartatik, 2022). After the students completed the LKPD, the researcher provided a comment sheet, suggestions, and interviewed the students. The decisions made based on the revision results from the small group testing stage are presented in Table 3.

Table 3. Small Group Stage

No	Revision Decision
LKPD 1	The sentence in the problem, "the number of visitors on workdays is twice as many as on Saturdays and Sundays," is revised to "the number of visitors on workdays is twice the total number of visitors on Saturdays and Sundays."
LKPD 2	The sentence in the problem, "is it true that the number of vehicles with a fare of IDR 41,500 is more than the vehicles with fares of IDR 20,500 and IDR 31,000," is revised to "is it true that the number of vehicles with a fare of IDR 41,500 is more than the total number of vehicles with fares of IDR 20,500 and IDR 31,000."

Based on the revisions obtained in the small group stage, prototype III is produced, which will be tested in the field test stage. In the field test stage, the results of the LKPD prototype III are trialed in class X.1 at SMA Muhammadiyah 1 Palembang over three sessions. The learning process in the classroom is conducted by the learning model teacher, with the researcher acting as an observer. The first and second meetings involve learning using HOTS-based LKPD, while in the third meeting, a test is conducted to observe the students' relational understanding of SPLTV material.

In the first meeting, the teacher provides the LKPD that includes C4 level questions. In the second meeting, the teacher provides the LKPD that includes C5 level questions. In the third meeting, the teacher provides a test that includes both C4 and C5 level questions. The LKPD containing C4 level questions from the first meeting is shown in Figure 2.

AKTIVITAS 1

Masalah 1

TRIBUNSUMSEL.COM, PALEMBANG- Menyambut libur sekolah, taman air OPI Water FUN Jakabaring sudah memberlakukan aktivitas normal seperti sebelum pandemi. Humas OPI Water Fun Jakabaring Lena Adi Pratiwi mengatakan pemerintah sudah memberikan kelonggaran beraktivitas termasuk mengizinkan wahana permainan ini beroperasi full 100 persen menerima pengunjung. Harga tiket dibandrol Rp 40.000/orang untuk hari senin-jumat (hari kerja), Sabtu dibandrol dengan harga Rp 50.000/orang, dan minggu dibandrol dengan harga Rp 60.000/orang.

Sumber: <https://sumsel.tribunnews.com/2022/06/16/harga-tiket-masuk-opi-water-fun-2022-lengkap-jam-operasional-dan-fasilitasnya>.

Jumlah pengunjung pada hari kerja adalah dua kali total pengunjung pada hari sabtu dan minggu Sedangkan total pengunjung pada hari minggu adalah 75 orang. Jika jumlah pengunjung pada hari Kerja, Sabtu dan Minggu adalah 450 orang. Setujukah anda, Jika banyaknya jumlah pengunjung pada hari Kerja dua kali lebih banyak dari hari Sabtu dan Minggu? berikan alasanmu!.

Figure 2. The problems in LKPD 1

The problems in LKPD 1 include steps to their solution, which includes indicators of relational understanding. An example answer from a student in Group 7 is shown in Figure 3.

Figure 3. Group 7 Response Result

Based on the answers from Group 7, the students have written 5 relational understanding indicators. However, the information is incomplete, they didn't mention the chosen strategy, and the argument in the conclusion is also not fully formed. In the second meeting, problems were given that involve C5 level questions, as shown in Figure 4.

SOAL TES SPLTV

Ayo Kita Berlatih!

1.



Sumber: <https://www.cgvi.id/en/schedule/cinema/027>

Social Market Palembang adalah salah satu tempat pilihan yang menarik bagi yang ingin menonton film. Jika penonton banyak memilih tiket regular dengan rincian harga berdasarkan hari di atas. Maka jumlah penonton pada hari biasa, Jumat dan akhir pekan adalah 600 orang. Jika total penonton pada akhir pekan adalah 120 orang, sedangkan jumlah penonton pada hari biasa adalah dua kali total penonton pada hari Jumat dan akhir pekan.

- Setujukah anda, jika banyaknya penonton pada hari biasa lebih sedikit dari jumlah penonton pada hari jumat dan akhir pekan? Berikan alasanmu!
- Berapa total pemasukan keseluruhan yang diperoleh pada hari biasa, Jumat dan akhir pekan?

2.



Sumber: <https://lamanqu.id/wp-content/uploads/2021/07/Tarif-Parkir-di-Bandara-Sultan-Mahmud-Badaruddin-II-Palembang>.

Bandar Udara Sultan Mahmud Badaruddin II di Palembang memiliki tarif parkir yang berbeda masing-masing kendaraan. Harga tarif parkir */jam pertama* untuk mobil, motor dan bus yang tertera di atas. Jumlah kendaraan ketiganya parkir */jam pertama* sebanyak 87 kendaraan. Jika bus 25 lebih banyak dari mobil sedangkan motor dua kurangnya dari bus.

- Benarkah banyaknya jumlah mobil dan motor yang terparkir */jam pertama* lebih banyak dari jumlah bus? Berikan alasanmu!
- Hitunglah pendapatan yang diperoleh */jam pertama* untuk mobil dan bus?

Figure 6. Test Questions

In the context of the results of the C4 level test questions, this research found significant variation in the emergence of relational understanding indicators among students: the first indicator appeared in 22 individuals, the second in 33, the third in 27, the fourth in 33, and the fifth in 32. However, only 16 people included all indicators, affirming the findings of Hanifah et al. (2019) regarding the difficulties students have in applying relational understanding in a comprehensive manner. To overcome this challenge, this research supports the previous approach by Alfiana & Dewi (2021) and Putra et al. (2018) that suggested the use of LKPD to enhance the understanding of mathematical concepts.

The C5 level test questions, the analysis results show that the emergence of relational understanding indicators also varies among students: the first indicator appeared in 14 individuals, the second in 33, the third in 14, the fourth in 13, and the fifth in 10. However, only 6 people included all indicators, which is lower compared to the C4 level test. This indicates that students face greater challenges in understanding and applying more complex concepts covered in C5 level questions. These results are consistent with previous research indicating that students' higher-order thinking abilities are often limited (OECD, 2016). Therefore, the

increased use of HOTS-based LKPD may be very important to improve relational understanding and students' higher-order thinking abilities. Nevertheless, further research is still needed to ensure the effectiveness and relevance of HOTS-based LKPD in various learning contexts.

Based on the results of the C4 and C5 level test questions with the appearance of the satisfactory relational understanding indicators above, the researcher selected some of the answers and interview results from the research subjects on the test questions containing C5. An example answer is shown in Figure 7.

2. Dik: - Harga tarif parkir jam pertama untuk mobil = Rp. 5.000
 - Harga tarif parkir jam pertama untuk motor = Rp. 3.000
 - Harga tarif parkir jam pertama untuk bus = Rp. 15.000
 - Jumlah kendaraan ketiganya parkir jam pertama = 87 kendaraan
 - Jika bus 25 lebih banyak dari mobil, sedangkan motor dua kurangnya dari bus.

Model & Bentuk Matematikanya = - Jumlah mobil = x
 - Jumlah motor = y
 - Jumlah bus = z

$x + y + z = 87$
 $z = y + 25$
 $y = z - 25$

$x + y + z = 87$ (i)
 $x + z = 25$ (ii)
 $y - z = -25$ (iii)

$x + y + z = 87$
 $x + 0 + z = 25$

$y + z = -2$
 $-3z = -114$
 $z = \frac{-114}{-3} = z = 38$

The research subject was able to write down the information correctly.

The research subject accurately presented the concept in the form of mathematical representations.

The research subject applied the concept algorithmically, however, they did not complete it to the final result.

Figure 7. Research Subject 1 Response Result

During the interview, the research subject encountered difficulties when modeling mathematics from the given problem, so the student could not complete until the final step and only included a few indicators. The results of the research subject 2 are shown in Figure 8.

2. Jumlah mobil = x
 Jumlah motor = y
 Jumlah bus = z

$x + y + z = 87 \dots (1)$
 $z = 25 + x - 2y$
 $x + 2y + z = 25 \dots (2)$

~~$x + y + z = 87$
 $x + y + 25x - 50y = 87$
 $26x - 49y = 87 \dots (2)$~~

~~$x + y + z = 87$
 $x + y + z = 87$
 $-x + 2y + z = 25$
 $2x - y = 62 \dots (3)$~~

$x + y + z = 87$
 $2x - y = 62$
 $3x + z = 149 \dots (4)$

The research subject could present the concept in the form of mathematical representations, but erred in modeling the mathematics.

The research subject made mistakes in applying concepts algorithmically, thereby affecting the results obtained.

Figure 8. Research Subject 2 Response Result

Based on the interview results with research subject 2, it was noted that the student forgot to write the information contained in the problem given because they were accustomed to directly formulating variables, made errors in constructing their mathematical model, and did not complete the task as the given time had run out. The answer from research subject 3 is shown in Figure 9.

2. **Diketahui:**
 x = Jumlah kendaraan mobil
 y = Jumlah kendaraan bus
 z = jumlah kendaraan motor

Bentuk matematika:
 $x + y + z = 87 \dots (1)$
 $4x - 25 + x \dots (2)$
 $z = 2 - y \dots (3)$

SUBS. y & z ke persamaan (1)
 $x + y + z = 87$
 $x + (25 + x) + (2 - y) = 87$
 $x + x - y + 25 + 2 = 87$
 $2x - y + 27 = 87$
 $2x - y = 87 - 27$
 $2x - y = 60 \dots (4)$

Eliminasi y dipersamakan 2×2
 $2x - y = 60$
 $-x + y = 25 \quad +$
 $\hline x = 75$

SUBS x ke persamaan 4
 $2x - y = 60$
 $2(75) - y = 60$
 $150 - y = 60$
 $-y = 60 - 150$
 $-y = -90$
 $\hline y = 90$

SUB x & y ke persamaan 1
 $x + y + z = 87$
 $75 + 90 + z = 87$
 $165 + z = 87$
 $z = 87 - 165$
 $z = -78$

maka $x + y + z = 75 + 90 + (-78) = 87$

Salah, karena jumlah mobil & motor yang terdapat / jam pertama lebih banyak dari jumlah bus. Pembuktian: x (jumlah mobil) = 75 & z (jumlah motor) = -78 Sedangkan (y) jumlah bus = 90. $y > x + z$

The research subjects were imprecise in presenting concepts in the form of mathematical representations.

The research subjects made errors in applying concepts algorithmically.

The research subjects were not accurate in providing logical arguments when carrying out procedures.

Figure 9. Research Subject 3 Response Result

According to the interview results with the research subject, the student forgot to write the information from the given problem because they were used to the learning method at school that involves direct variable reasoning, made mistakes in their mathematical modelling which affected the outcome, and could not complete the task due to time constraints.

From the answers and interviews with several research subjects, it is evident that students face significant challenges when working on C5 level questions. This is apparent from their difficulty in documenting what is known from the given information. In previous research, Nurhayati & Pust (2018) identified similar issues, emphasizing the importance of the ability to extract and articulate key information from mathematical problems.

Additionally, research subjects also had difficulty in modelling mathematics from the given problems, which impacted the results they obtained. This aligns with the findings of Mulyono & Hapizah (2018), reporting that students often struggle to connect mathematical

concepts and use them to solve problems. Finally, several students also battled time constraints, which prevented them from solving problems comprehensively. This factor suggests that in addition to conceptual understanding and modelling abilities, time management may also be a critical factor in a student's ability to successfully work on HOTS questions. Based on these findings, further research on the use of HOTS-based LKPD and other strategies to support students in overcoming these challenges may be very crucial.

These findings reinforce the importance of developing and implementing strategies and tools designed by teachers to facilitate conceptual understanding and mathematical modelling, such as HOTS-based LKPD. Moreover, teaching students how to extract and write down essential information from questions could be an integral component of this strategy. The teacher's role in providing guidance and support during this process also cannot be overlooked. These results underscore the need to support teachers in implementing this approach. This may involve providing time, resources, and relevant professional training. Additionally, schools should consider how best to integrate such techniques into existing curricular and time structures. Lastly, for future researchers, it is hoped that research will focus more on effective strategies and tools to help students overcome the challenges identified in this study. Further research may also need to consider how factors such as student backgrounds, learning contexts, and school resources affect the effectiveness of these strategies and tools. In this way, future research can contribute further to improving conceptual understanding and mathematical modelling among students.

CONCLUSIONS

Based on the findings of this research, it can be concluded that the High Order Thinking Skills (HOTS) based Student Worksheet (SW) on the topic of Three-Variable Linear Equation System (TVLES) for high school students is a valid and practical tool. This tool potentially impacts strengthening students' relational understanding, as indicated by the test results. Particularly for HOTS questions of category C4, students demonstrated improved skills in noting down and processing information until they produced correct final answers. However, for HOTS questions of category C5, students still faced challenges, especially in writing down the given information and in presenting concepts in the form of mathematical representations. The time constraint factor in the tests also seemed to affect student performance. Therefore, there needs to be adjustments and improvements in teaching and assessment strategies to facilitate enhancements in this area.

This study highlights the importance of introducing and implementing HOTS-based SW by teachers, as a means to enhance students' relational understanding. In addition, teachers should focus more on their teaching to assist students in writing down the provided information and representing mathematical concepts accurately. This underscores the importance of training and professional support for teachers in this regard. For students, the HOTS-based SW could be a tool that helps them understand and apply mathematical concepts more effectively and efficiently.

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AUTHOR CONTRIBUTIONS STATEMENT

DK acted as the primary researcher, contributing to generating ideas and designing the HOTS-based SW. NA and H acted as supervising lecturers assisting the researcher in completing the research.

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