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The Effectiveness of an ICON-Based Worksheet to Support Students' Conceptual Understanding of Matrix Material

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Abstrak
Penelitian ini bertujuan untuk mengembangkan lembar kerja peserta didik (LKPD) berbasis ICON pada materi matriks serta mengkaji validitas, kepraktisan, dan efektivitasnya. ICON merujuk pada model desain Interpretation–Construction, yang menekankan proses peserta didik dalam menginterpretasikan permasalahan kontekstual dan mengonstruksi konsep matematika. Penelitian ini menggunakan model pengembangan Plomp yang meliputi tahap pendahuluan, perancangan, dan penilaian, dengan evaluasi formatif melalui validasi ahli, uji coba satu-satu, uji coba kelompok kecil, dan uji lapangan. Hasil penelitian menunjukkan bahwa LKPD mencapai tingkat cukup valid berdasarkan penilaian ahli terhadap aspek isi, konstruk, dan bahasa serta direvisi sesuai hasil validasi awal. LKPD juga menunjukkan kepraktisan karena mudah dipahami oleh peserta didik. Efektivitas ditunjukkan oleh 22 dari 34 peserta didik yang mencapai Kriteria Ketercapaian Tujuan Pembelajaran (KKTP). Temuan ini menunjukkan bahwa LKPD berbasis ICON layak digunakan dengan revisi untuk mendukung pemahaman konseptual peserta didik pada materi matriks.
***Kata kunci**: Efektivitas pembelajaran; Interpretasi konstruksi; Konsep matriks; Lembar kerja; Pendidikan matematika.*

Abstract
This study aims to develop an ICON-based student worksheet (LKPD) on matrix material for high school students and to examine its validity, practicality, and effectiveness. ICON refers to the Interpretation–Construction design model, which emphasizes students' processes of interpreting contextual problems and constructing mathematical concepts. The research employed the Plomp development model consisting of the preliminary, prototyping, and assessment phases, supported by formative evaluation through expert review, one-to-one trials, small-group trials, and field test. The results indicate that the LKPD achieved a fairly valid level based on expert evaluations of content, construct, and language and was revised accordingly. The worksheet also demonstrated practicality, as students found the instructions and activities easy to understand. Effectiveness was indicated by 22 out of 34 students achieving the Learning Objective Achievement Criteria (KKTP). These findings suggest that the ICON-based worksheet is feasible for use with revisions to support students' conceptual understanding of matrix concepts.
Keywords: Interpretation construction; Learning effectiveness; Matrix concepts; Mathematics education; Worksheet.

I. INTRODUCTION

Mathematics education plays an important role in supporting students' ability to understand and apply mathematical concepts in real-life situations (Ismail et al., 2020; Üredi & Doğanay, 2023). Given the objectives of mathematics learning, schools are expected to improve students' mathematical abilities, particularly their conceptual understanding. However, several studies have reported that Indonesian students' understanding of mathematical concepts remains low. Ningrum et al. (2022) found that students' conceptual understanding is still categorized as low, indicating the need for further investigation. This condition is supported by large-scale international assessments such as TIMSS and PISA, in which Indonesia consistently performs below the international average and ranks among the lowest participating countries (Sudirman et al., 2020). At the classroom level, students continue to experience difficulties in understanding mathematical concepts (Widyastuti et al., 2020; Saepuloh, Luritawaty, & Afriansyah, 2024).

Students' limited conceptual understanding is partly influenced by the complexity of certain mathematical topics. One topic that is considered difficult in mathematics is matrices. Many students show low interest and perceive learning mathematics, particularly matrices, as boring (Haezer et al., 2023). This difficulty is further exacerbated by the fact that matrices are a new topic introduced at the high school level, causing many students to be unfamiliar with its basic concepts (Somakim et al., 2023).

To avoid mathematics learning becoming stuck in memorizing formulas and procedural steps, students need to be guided to interpret information, relate situations to relevant concepts, and build understanding gradually. The ICON model (Interpretation–construction design model) is one alternative that can address these needs because its syntax emphasizes the processes of interpretation, meaning construction, and linking concepts to students' real-life contexts (Black & McClintock, 1995). Through this interpretation process, students not only understand concepts formally, but are also able to read problem situations and explain the relationships between the information provided (Zulkarnaen, 2018; Hasanudin & Maryati, 2023). In addition, the ICON model is oriented towards student-centered learning, while teachers act as facilitators who help guide the interpretation of concepts in authentic contexts (Zulkarnaen & Kusumah, 2019).

Classroom observations and interviews with mathematics teachers at a public senior high school in Karawang Regency revealed that the worksheets currently used tend to emphasize procedural tasks and offer limited opportunities for students to develop contextual understanding of mathematical concepts, especially in matrix topics. Most of the worksheets distributed in schools were general in nature and mainly contained summaries of the material (Kosasih et al., 2023; Somakim et al., 2023). This condition indicates that existing LKPD have not optimally supported the development of students' conceptual understanding. Although student worksheets are widely used as learning tools to facilitate both individual and group learning and to encourage student engagement (Pasani & Kamaliyah, 2017; Nuraeni et al., 2023), their effectiveness largely depends on how learning activities are designed. Therefore, there is a need for the development of LKPD that emphasize conceptual understanding and meaningful learning, such as worksheets designed based on the ICON (Interpretation–Construction) design model.

Several studies have reported the development of student worksheets (LKPD), including those focusing on matrix topics (Somakim et al., 2023), RME-based worksheet (Nufus et al., 2023), and PBL-based worksheet (Panekenan et al., 2024). The development of ICON-based worksheets for matrix topics at the high school level has not yet been widely explored. Therefore, this study aims to design and evaluate an ICON-based worksheet in terms of its validity, practicality, and effectiveness in supporting grade XI students' understanding of matrix concepts.

II. METHOD

This research adopted the development framework proposed by Plomp (2013), which is organized into three main phases: preliminary, prototyping, and assessment. The preliminary phase involved a series of analytical activities, namely needs analysis, curriculum analysis, and student analysis. The needs analysis aimed to identify problems in existing student worksheets (LKPD), particularly those related to students' conceptual understanding of matrix material. Curriculum analysis was conducted to ensure alignment with the applicable curriculum, while student analysis focused on students' characteristics and learning needs.

During the prototyping stage, the study applied Tessmer's formative evaluation framework (Zulkardi & Kohar, 2018), comprising self-evaluation, expert validation, one-to-one evaluation, small-group evaluation, and field testing. Expert validation was conducted by two mathematics education lecturers and two mathematics teachers to assess the validity of the developed LKPD. The one-to-one evaluation involved three students and has been published in the Proceedings of the National Seminar on Mathematics Education at Universitas Singaperbangsa Karawang (SESIOMADIKA) 2025. The small-group evaluation was conducted with 12 students (Kohar et al., 2014), while the field test involved 34 students. During the assessment phase, the study focused on evaluating the LKPD by analyzing students' learning outcomes and responses obtained from the field test.

Although the effectiveness measurement did not employ a pre-test, the observed learning outcomes can be associated with the learning activities embedded in the ICON-based worksheet. The LKPD guided students through interpretation and construction stages, enabling them to analyze contextual problems and construct matrix representations. Students' ability to complete matrix-related tasks and achieving the Learning Objective Achievement Criteria (KKTP) suggests that the worksheet supported their conceptual understanding during the learning process. However, the absence of a pre-test limits causal interpretation, and future studies are recommended to employ pre-test–post-test designs or control groups.

Data for this study were collected using multiple instruments. Questionnaires were employed to gather expert and student responses related to the validity and practicality of the LKPD. To complement the quantitative data, interviews and classroom observations were conducted to obtain qualitative information concerning students' learning processes and the practical use of the worksheet. Student learning outcomes from the field test were used to evaluate the LKPD's effectiveness. Data analysis involved both qualitative and quantitative approaches. Qualitative analysis focused on interpreting expert feedback, interview findings, and observation records to examine the validity and practicality of the LKPD, while quantitative analysis was applied to summarize questionnaire and test results.

An adapted percentage scoring method proposed by Sari et al. (2023) was employed to assess the validity and practicality of the developed LKPD. The percentage score was calculated using the following formula:

$$P = \frac{\sum x}{\sum x_i} \times 100\%$$

Note:

P : the percentage of validity or practicality

$\sum x$: the total score obtained from validators or respondents

$\sum x_i$: the maximum possible score

The level of LKPD validity was determined by comparing the expert validation scores with the validity criteria presented in Table 1, while the level of practicality was determined based on student response scores using the practicality criteria shown in Table 2. In addition to quantitative analysis, qualitative data from expert comments and student feedback were analyzed descriptively to support the interpretation of validity and practicality results.

Table 1.
Validity Criteria of LKPD

Percentage	Category
81–100%	Very Valid
61–80%	Valid
41–60%	Fairly Valid
21–40%	Less Valid

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Percentage	Category
0–20%	Invalid

Table 2.
Practicality Criteria of LKPD

Percentage	Category
81–100%	Very Practical
61–80%	Practical
41–60%	Fairly Practical
21–40%	Less Practical
0–20%	Impractical

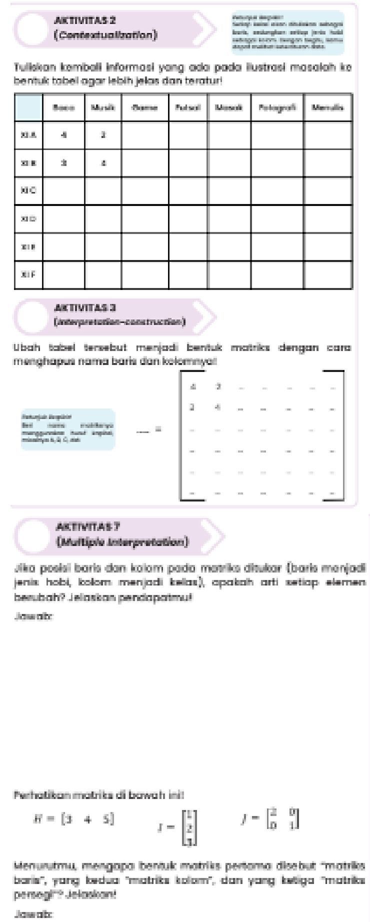
III. RESULT AND DISCUSSION

The expert validation results represent the initial validation stage, indicating that the LKPD achieved a fairly valid level, with content, construct, and language scores of 54%, 46%, and 56%, respectively. Based on experts' comments and suggestions, revisions were conducted, particularly to improve the construct aspect, including task sequencing, clarity of instructions, and alignment between learning objectives and activities. The revised version of the LKPD was then used in the small-group and field testing phases. Although a second round of quantitative expert validation was not conducted, the revisions addressed the main issues identified during the initial validation. In addition, the results of the student response questionnaire in the one-to-one evaluation show that the clarity and readability aspects obtained percentage scores of 65% and 67%, respectively, both of which are categorized as good. These findings indicate that the instructions and content of the worksheet are generally clear and readable for students.

The quantitative findings were followed up by incorporating validators' feedback and recommendations into the revision of the worksheet. An overview of the validators' input and the corresponding revisions is provided in Table 3.

Table 3.
Validator Comments, Suggestions, and Follow-up Actions

Validator	Comments and Suggestions	Follow-up Actions
Mathematics Education Lecturer	The context must be "close" to the students but still relevant to the material.	Change the context from "school cafeteria sales data" to "personal context: students' hobbies."  Berikut merupakan hasil pengumpulan data dari siswa yang memiliki hobi membaca buku, bermain musik, bermain *game*, futsal, memasak, fotografi, dan menulis. *Catatan!* *Setiap angka menunjukkan jumlah siswa di tiap kelas yang memiliki hobi tertentu.* • Kelas XI A: Membaca (4), Musik (2), *Game* (5), Futsal (6), Memasak (2), Fotografi (1), Menulis (3) • Kelas XI B: Membaca (3), Musik (4), *Game* (2), Futsal (5), Memasak (1), Fotografi (3), Menulis (2) • Kelas XI C: Membaca (2), Musik (3), *Game* (4), Futsal (3), Memasak (2), Fotografi (2), Menulis (1) • Kelas XI D: Membaca (1), Musik (5), *Game* (3), Futsal (4), Memasak (3), Fotografi (2), Menulis (2) • Kelas XI E: Membaca (5), Musik (2), *Game* (6), Futsal (3), Memasak (1), Fotografi (4), Menulis (3) • Kelas XI F: Membaca (3), Musik (3), *Game* (4), Futsal (6), Memasak (2), Fotografi (1), Menulis (4)

Validator	Comments and Suggestions	Follow-up Actions
	Organize the material systematically while paying attention to time allocation, for example, use the basic concepts of matrices first, then continue to the types of matric.	Change the material used, initially "basic concepts of matrices and matrix addition" to "basic concepts of matrices and types of matrices.". 
	Provide clear instructions for the activities presented in the worksheet.	Provide instructions on how to correctly convert table information into matrix form.

AKTIVITAS 2
(Contextualization)

Tuliskan kembali informasi yang ada pada ilustrasi masalah ke bentuk tabel agar lebih jelas dan teratur!

	Baca	Musik	Game	Futsal	Masak	Fotografi	Menulis
XI A	4	2					
XI B	3	4					
XI C							
XI D							
XI E							
XI F							

AKTIVITAS 3
(Interpretation–construction)

Ubah tabel tersebut menjadi bentuk matriks dengan cara menghapus nama baris dan kolomnya!

AKTIVITAS 7
(Multiple Interpretation)

Jika posisi baris dan kolom pada matriks ditukar (baris menjadi jenis hobi, kolom menjadi kelas), apakah arti setiap elemen berubah? Jelaskan pendapatmu!

Jawab:

Perhatikan matriks di bawah ini!

Menurutmu, mengapa bentuk matriks pertama disebut "matriks baris", yang kedua "matriks kolom", dan yang ketiga "matriks persegi"? Jelaskan!

Jawab:

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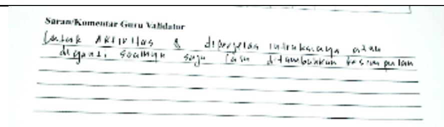
<table>
<tr><th>Validator</th><th>Comments and Suggestions</th><th>Follow-up Actions</th></tr>
<tr><td></td><td></td><td>
AKTIVITAS 2
(Contextualization)
Tuliskan kembali informasi yang ada pada ilustrasi masalah ke bentuk tabel agar lebih jelas dan teratur!<table><tr><th></th><th>Baca</th><th>Musik</th><th>Game</th><th>Futsal</th><th>Masak</th><th>Fotografi</th><th>Menulis</th></tr><tr><td>XI A</td><td>4</td><td>2</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>XI B</td><td>3</td><td>4</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>XI C</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>XI D</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>XI E</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>XI F</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>AKTIVITAS 3
Ubah tabel tersebut menjadi bentuk matriks dengan cara menghapus nama baris dan kolomnya!</td></tr>
<tr><td>High School Math Teacher</td><td>
Saran/Komentar Guru Validator
Untuk Aktivitas 8 diperjelas instruksinya atau diganti soalnya saja lalu ditambahkan kesimpulan</td><td>Add a conclusion section and modify activity 8 to provide a clearer transition between the previous and subsequent activities.</td></tr>
</table>

During the expert validation stage, researchers also conducted one-to-one tests with three students representing high, medium, and low ability levels. These tests were conducted to assess whether the developed product met the feasibility standards, especially in terms of readability and clarity of the worksheet questions (Effendi et al., 2019). In this study, the one-to-one test focused on the ICON-based worksheet for matrix material at the high school level. The readability test showed that the language was easy to understand, so students did not have difficulty understanding the worksheet's content, while the clarity test showed that each instruction on the worksheet was easy for students to understand.

The discrepancy between the expert validation results and the field test outcomes may indicate differences in perspective between experts and students. While experts emphasized theoretical alignment and construct precision, students responded positively to the worksheet’s scaffolding structure and contextual tasks, which supported their learning processes. This suggests that although the LKPD requires further refinement in terms of construct validity, it is practically functional and responsive to students’ learning needs. Such findings highlight the importance of balancing theoretical rigor and classroom applicability in instructional material development.

Practicality at the small-group stage was demonstrated through student interest, ease of use, and comfort in following the steps of the activities in the

ICON-based worksheet (Effendi et al., 2019). The practicality of the ICON-based worksheet at the small-group stage was evaluated using a student response questionnaire. The results show that the attractiveness, usefulness, and ease-of-use aspects obtained percentage scores of 73%, 78%, and 66%, respectively, all of which fall into the practical category. These results indicate that the worksheet is practically usable and supports students in following the learning activities in a logical and structured manner. Students also reported that the instructions were clear and that the examples and contexts provided helped them understand matrix concepts more easily.

Field testing was conducted as the final phase of the worksheet development process to examine students' learning outcomes following the use of the worksheet. This stage was implemented after the third prototype had been revised and deemed valid and practical by experts. The field test involved 32 eleventh-grade students from a public senior high school in Karawang. The students completed several activities on the worksheet, including reading illustrations in the form of short stories related to their hobbies, then solving the problems based on the illustrations, and then continuing with activities to understand and answer questions related to types of matrices, accompanied by individual evaluation tasks.

After completing all activities in the worksheet, students were given an individual evaluation task to assess the achievement of the learning objectives, including presenting contextual data in matrix form and correctly identifying matrix types based on their characteristics. The results show that 22 out of 34 students (64.7%) achieved scores above the school's achievement standard of 78. Referring to Regulation of the Minister of Education, Culture, Research, and Technology No. 12 of 2022, student assessment is intended to evaluate the achievement of learning objectives, in which the KKTP is applied as the minimum standard for learning mastery. These results indicate that the ICON-based worksheet supports students in achieving the expected learning outcomes. However, the effectiveness in this study was evaluated based on the achievement of learning objectives without a pre-test comparison, which may be addressed in future studies.

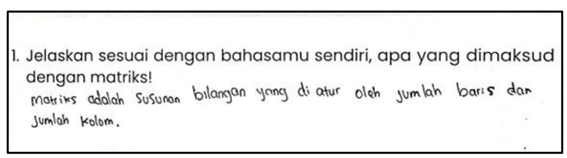
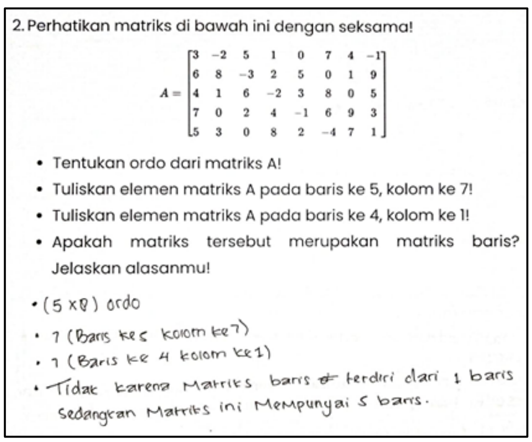

1. Jelaskan sesuai dengan bahasamu sendiri, apa yang dimaksud dengan matriks!
Matriks adalah susunan bilangan yang di atur oleh jumlah baris dan jumlah kolom.

Figure 1. Student field test answers

Based on the students' answers in Figure 1, it appears they have correctly explained the basic concept of matrices. Students mentioned that a matrix is "a set of numbers arranged by the number of rows and columns." This statement is consistent with the mathematical definition that describes a matrix as a rectangular array of numbers organized into rows and columns. This answer shows that students understand two important elements of a matrix: its constituent structure (the numbers) and its characteristic form (the number of rows and columns). Students can identify that a matrix is not just a collection of numbers but has certain arrangement rules. On average, students provided definitions, as shown in Figure 1. This indicates that the learning objectives at the stage of introducing the concept of matrices have been achieved.


2. Perhatikan matriks di bawah ini dengan seksama!

$$A = \begin{bmatrix} 3 & -2 & 5 & 1 & 0 & 7 & 4 & -1 \\ 6 & 8 & -3 & 2 & 5 & 0 & 1 & 9 \\ 4 & 1 & 6 & -2 & 3 & 8 & 0 & 5 \\ 7 & 0 & 2 & 4 & -1 & 6 & 9 & 3 \\ 5 & 3 & 0 & 8 & 2 & -4 & 7 & 1 \end{bmatrix}$$

- Tentukan ordo dari matriks A!
- Tuliskan elemen matriks A pada baris ke 5, kolom ke 7!
- Tuliskan elemen matriks A pada baris ke 4, kolom ke 1!
- Apakah matriks tersebut merupakan matriks baris? Jelaskan alasanmu!

- (5 x 8) ordo
- 7 (Baris ke 5 kolom ke 7)
- 7 (Baris ke 4 kolom ke 1)
- Tidak karena Matriks baris terdiri dari 1 baris sedangkan Matriks ini Mempunyai 5 baris.

Figure 2. Students' field test answers

The results suggest that the feasibility and practicality of the ICON-based worksheet are influenced by the way learning activities are organized within the ICON (Interpretation–Construction) design framework. In particular, the interpretation stage guides students to connect contextual situations with matrix representations, while the construction stage supports students in gradually developing conceptual understanding through guided questions and step-by-step tasks. This structure helps students follow the learning flow and answer questions aligned with the learning objectives.

The use of scaffolding in the worksheet is not implemented in a general manner, but is specifically embedded within the syntax of the ICON model. Guided questions and sequential instructions function as cognitive scaffolds that resemble the principles of cognitive apprenticeship, where support is gradually reduced as students gain understanding. The findings of this study are in line with earlier research highlighting the role of constructivist scaffolding in promoting students' problem-solving activities and conceptual learning (Arifin et al., 2020).

Despite these strengths, some students still experienced difficulty in explaining their reasoning, particularly when answering questions that required them to articulate their thought processes. Thiss difficulty may indicate a limitation in the worksheet design, especially in providing opportunities for multiple interpretations or multiple representations of matrix concepts. In addition, students' initial abilities in mathematical reasoning may also have influenced their performance. These findings suggest that future revisions of the worksheet should include more activities that encourage students to express and justify their reasoning explicitly, particularly at the interpretation stage of the ICON model.

IV. Conclusion

This study developed an ICON-based student worksheet (LKPD) for matrix material at the high school level. Based on the findings, the LKPD is feasible for use with revisions, as it demonstrated good readability, practicality, and initial effectiveness in field implementation. This study contributes to the development of ICON-based worksheet in mathematics education and highlights the importance of aligning expert validation with classroom applicability, particularly in supporting students' conceptual learning processes. Future research is recommended to conduct further validation and employ pre-test–post-test designs to strengthen effectiveness claims.

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