

DEVELOPMENT OF STUDENT WORKSHEETS BASED ON HOTS AND REALWORLD PROBLEMS ON THE TOPIC OF GRAPHS

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Abstract

This study aims to develop student worksheets based on Higher Order Thinking Skills and real-world problems on graph topics. The type of research used is development research to produce valid and practical products in the form of HOTS-Based Student Worksheets and real-world problems. The development model used is the 4D model (define, design, develop, dissemination) by Thiagarajan. The research subjects were 40 Mathematics Education students of UIN North Sumatra, semester VII of the 2024/2025 academic year, the object of the research was the graph topic in the Advanced Discrete Mathematics course. The product quality test from Nieveen is the Validity Test and Practicality Test. The resulting product is a HOTS-Based Student Worksheet and real-world problems on graph topics consisting of 9 essay questions, with details of 4 questions for the cognitive analysis level, 2 questions for the evaluation level, and 3 questions for the creation level. The development product is declared very valid and very practical, so it can be used in Discrete Mathematics lectures on graph topics.

Keywords: Student Worksheets, HOTS, Real World Problems



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1. INTRODUCTION

HOTS-based student worksheets and real-life graph problems offer a relevant alternative for connecting abstract concepts to real-world applications. As a compulsory course in the Mathematics Education study program, discrete mathematics examines several important and broad topics, often containing abstract concepts and definitions, such as graph theory. Law No. 12 of 2012 concerning higher education mandates higher education to develop the potential of capable, creative, skilled, and competent students. This means that students must be able to apply their knowledge to solve problems, including those in complex real-world situations. 21st-century learning also requires students to master essential skills such as critical thinking, problem-solving, and communication to achieve success (Partnership for 21st Century Learning, 2015). Higher Order Thinking Skills (HOTS) enable students to go beyond simply memorizing or understanding, but also develop the ability to analyze, evaluate, and create creative and applicable solutions. To achieve this goal, HOTS-based student worksheets are needed in the mathematics learning process, especially on graph topics. For example, the concept of the shortest path can be applied in transportation route planning.

Based on observations and interviews with a number of students, it was found that many students admitted to having difficulty understanding the application of graphs in real life, especially if the problem domain requires analysis, evaluation and creation. For example, how to use the concept of the shortest path to design a transportation route. As a solution to this problem, students must be accustomed to solving problems that involve real-world situations and require critical thinking, evaluation, and creation. The preparation of student worksheets that accommodate HOTS and real-life problems is the right solution to be implemented.

Managing learning resources is crucial in learning. For example, learning resources related to real life can be used as context for real-world problems that students must solve. (Slameto, 2003) suggests that in the mathematics learning process, mathematical problem solving is an important basic intellectual process and skill that teachers must pay attention to. Real-world problems are contextual questions that clearly describe real-life situations or phenomena (Sugara et al., 2017). Real-world problems are one solution to understanding concepts (Kua et al., 2015). Providing real-world problems stimulates students to associate the problem with graph concepts. Real-world problems should be designed using operational verbs for HOTS (Hotness-Skilled Skills) so that students become accustomed to using HOTS. The cognitive aspect of HOTS, according to the revised Bloom's Taxonomy, is the ability to analyze, evaluate, and create (Wilson, 2016). The characteristics of HOTS questions are: 1) non-algorithmic, unlike routine questions; 2) complex; 3) generating multiple solutions; 4) involving differences of opinion or interpretation; 5) involving connections between multiple disciplines; 6) involving uncertainty; 7) demanding independence in the thinking process; 8) involving meaning; 9) requiring hard work (Partnership for 21st Century Learning, 2015). In this regard, educators must be able to formulate problems so that students can engage HOTS in solving them. If the questions given do not have a clear question, students must learn to formulate one.

Many studies have been conducted examining the context of HOTS and real-world problems. Among them are (Putri et al., 2019); using real-world problems as the context in the questions; (Sugiati et al., 2024) who studied the form of scaffolding for students using real-world problems; (Aldiyah Mellawati, 2024) who used problem posing based on real-world context; (Aviyanti & Setianingsih, 2021) who used contextual problems about the real world in geometry material; (Verschaffel et al., 2020) studied word problems in mathematics; (Loc, 2015) also studied word problems; (Dewantara et al., 2024) who studied the difficulties of prospective teachers in solving context-based problems in mathematics; (Rosidin et al., 2019) using HOTS-based assessments on school students to improve thinking skills; (Pratini & Widyaningsih, 2018) who studied how to stimulate students' HOTS; (Suratno, 2020) which seeks to improve HOTS by using a problem based learning model; and (Eliyasni et al., 2019) which improves HOTS with blended learning; (Tanujaya et al., 2017) which examines the relationship between HOTS and academic performance.

The study materials for HOTS and real-world problems that have been studied previously are quite varied. These range from the use of real-world problems and HOTS in presenting problems or questions to students as research subjects, to how to improve HOTS skills. However, among these various relevant studies, there has been no specific study on how to develop HOTS-based questions and real-world problems, especially in graph theory. This gap can be used as a new and different research opportunity from previous research. How can student worksheets based on HOTS and real-world problems in graph theory be developed?

This question is interesting to study and contains elements of novelty. Therefore, researchers are interested in conducting this study.

2. METHODOLOGY

This development research was conducted using Thiagarajan's 4D (Four D) model, consisting of the stages of Define, Design, Develop, and Dissemination (Kreano, 2012). Development research produces a product. The quality of the developed product is assessed based on Nieveen (Akker, 1999). The research was conducted in the Mathematics Education Study Program, with the subjects being seventh-semester students in the 2024/2025 academic year. The research instruments consisted of a validation questionnaire by subject matter experts and a response questionnaire to assess student practicality. The questionnaire for subject matter experts and the questionnaire for students were analyzed using the formula (Damayanti, 2018):

$$\sum P = \frac{\sum x}{\sum x_1} \cdot 100\%$$

Dimana:

P = percentage of validity value

$\sum x$ = total score obtained

$\sum x_1$ = maximum score

3. RESULT

The define stage is filled with the process of studying the fundamental problems faced by students related to mathematics learning, especially on the topic of graphs in discrete mathematics courses. Then, identifying what can be done to solve these problems. At this stage, it was found that the learning of discrete mathematics so far still does not emphasize the aspect of applying discrete mathematics concepts in life. Based on this, a solution was found, namely by providing students with more real-world-based problems related to the concepts discussed. The design stage is filled with designing an assignment containing questions related to real-world problems. As a consideration for determining the design of these questions is the Semester Learning Plan of the discrete mathematics course on the subject of graphs. The focus is on designing questions that cover the Course Learning Outcomes (CLO) in the Semester Learning Plan. The CLO Advanced Discrete Mathematics which includes graph theory consists of 9 Sub-CLO, namely as follows:

1. Sub-CLO1-1: Able to define graphs, types of graphs, graph applications, graph terminology such as adjacent vertices, adjacent paths, isolated vertices, empty graphs, and trivial graphs.

2. Sub-CLO1-2: Able to apply the concepts of vertex degree, graph degree, anting-anting vertices, and handsaking lemma in solving problems.
3. Sub-CLO1-3: Able to apply the concepts of paths, circuits, connected vertices, and connected graphs in solving problems.
4. Sub-CLO1-4: Able to apply the concepts of subgraphs, complements of subgraphs, spanning subgraphs, bridges (cut sets), and weighted graphs.
5. Sub-CLO1-5: Able to apply specific simple graph concepts in solving problems.
6. Sub-CLO1-6: Able to represent graphs in other forms.
7. Sub-CLO1-7: Able to apply the concepts of isomorphic graphs, planar graphs, and plane graphs in solving problems.
8. Sub-CLO1-8: Able to apply the concepts of Eulerian and Hamiltonian graphs to solve problems.
9. Sub-CLO1-9: Able to apply the concepts of graph coloring and Dijkstra's algorithm to solve problems.

The assignment was then developed into a worksheet. In the development stage, a worksheet containing several questions related to the CLO was prepared. After being prepared, the worksheet was validated constructively by colleagues so that it could be revised and produce a worksheet that was construct-valid. The expert validator who assessed this worksheet was Nur Ainun Lubis, M.Pd, a lecturer at the Mathematics Education Study Program at UIN North Sumatra. With this expert assessment, it is hoped that this worksheet will be more precise, effective, tested, and have accuracy between the intended CLO and the questions developed. The revision notes from the expert validator are:

1. Adapt operational verbs appropriately to the HOTS cognitive level.
2. Revise the question wording to make it simpler and more engaging.
3. Revise the real-world problem context for each question item to better reflect real-world situations.

The validity of the worksheet is determined using the criteria in Table 1.

Table 1. Validity Criteria for Student Worksheets

Achievement Level (in Percent)	Qualification	Description
81 s/d 100	Very Good	Very Valid
61 s/d 80	Good	Valid
41 s/d 60	Fair	Good
21 s/d 40	Fair	Fair Valid
0 s/d 20	Poor Not Good	Not Valid

The expert assessment of the validity of the Student Worksheet is VERY VALID.

Then, the expert-validated worksheets were given to students who had previously taken Discrete Mathematics courses, specifically those focused on graphs, for assessment. These students then completed a questionnaire to measure the practicality of the worksheets. The practicality of the student worksheets was determined using the criteria shown in Table 2:

Table 2. Practicality Criteria for Student Worksheets

Achievement Level (in Percent)	Qualification	Description
81 s/d 100	Very Good	Very Practical
61 s/d 80	Good	Practical
41 s/d 60	Fair	Quite Practical
21 s/d 40	Fair	Not Practical
0 s/d 20	Poor Not Good	Not Practical

The results of the practicality validation sheet are VERY PRACTICAL.

In the dissemination stage, the validated and practical worksheets were distributed to various parties, such as students and lecturers. There are three qualities of the development product: VALID, PRACTICAL, and EFFECTIVE (Akker, 1999). However, in this study, an effectiveness test was not conducted, considering that the study was not intended to measure improvements in mathematical ability.

4. DISCUSSION

A. Level HOTS

Table 3 displays the results of the review of the questions developed, their relationship to CLO, cognitive level, and the concepts asked in the questions.

Table 3. Review of Student Worksheets Based on HOTS Level

No.	CLO	Cognitive Level HOTS	Questioned Concept In Problem
1	Able to state the definition of graphs, types of graphs, applications of graphs, graph terminology in the form of adjacent vertices, vertex-adjacent paths, isolated vertices, empty graphs and trivial graphs	Analyze	Detailing the nodes and detailing the paths that exist in the context of the problem

2	Able to apply the concepts of vertex degree, graph degree, pendant vertex, and handsaking lemma in solving problems.	Evaluate	Check whether the context given in the question is in accordance with the handshake lemma.
3	ble to apply the concepts of paths, circuits, connected nodes, and connected graphs in solving problems.	Evaluate	Agree or refute the context presented in the question whether it does not contain isolated nodes.
4	Able to apply the concepts of subgraphs, complements of subgraphs, spanning subgraphs, bridges (cut sets), and weighted graphs.	Analyze	Check what happened when the communication network was cut off
5	Able to apply special simple graph concepts in solving problems	Analyze	Identify whether this is an example of a special simple graph problem
6	Able to represent graphs in other forms.	Analyze	Checking whether If the graph does not exist then can its adjacency matrix be created?
7	Able to apply the concepts of isomorphic graphs, planar graphs and plane graphs in solving problem	Create	Create family relationships whose graph is isomorphic to the family relationship graph which are given
8	Able to apply the concepts of Eulerian and Hamiltonian graphs in solving problems.	Create	Forming a travel itinerary from the context presented
9	concept of graph coloring and Dijikstra's algorithm in depth solve the problem	Create	Forming scheduling proposals using the concept of graph coloring

B. Student Worksheets Based on HOTS Realworld Problems on The Topic of Graphs

The following are the questions on the student worksheet that was developed.

1. In a party invitation, there is a location map distributed as in the picture. Suppose each location shown is a node and the paths between them are edges. Create a graph representing this journey. Identify which nodes are neighbors and describe the paths you can take to reach one location from another.

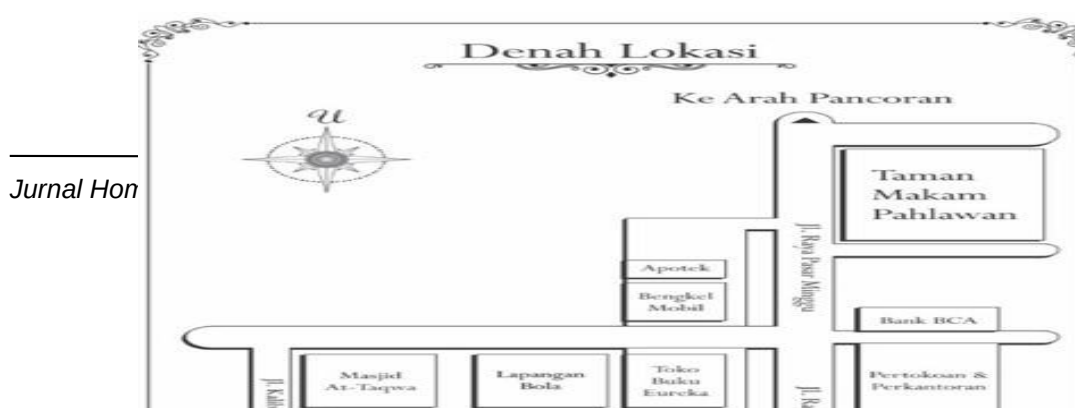


Figure source: <https://pbs.twimg.com/media/B2czRrSCAApDtt>.

This question is a HOTS question with an analysis level, marked by the operational verbs detailing and describing.

2. A meeting is attended by ten people who are about to conclude a trade agreement. Each person shakes hands with everyone else once. This situation can be modeled with a graph. Considering the number of handshakes that occur, does this graph conform to the handshake lemma? Explain.

This question is a HOTS question with an evaluation level, marked by the operational verb to examine or check the truth of the statement.

3. In a large family, there are 10 members living together, each named Amir, Budi, Chika, Dian, Ema, Feri, Gita, Hendra, Indra, and Jaka. It is known that Amir, Budi, and Chika are siblings, and they are cousins of Dian and Ema from the mother's side. Meanwhile, Feri and Gita are siblings, and cousins of Hendra and Indra from the father's side. In addition, Indra and Chika are also known to have a relationship as cousins, as are Ema and Feri. A student stated that this problem does not contain a remote node? Do you agree? Explain.

This question is a HOTS question with an evaluation level, marked by the operational verb of refuting or agreeing with the truth of a statement.

4. A telecommunications company manages a cable network connecting five cities: City A, B, C, D, and E. This cable network is designed as follows:

City A is connected to City B and City C; City B is connected to City D; City C is connected to City D and City E; and City D is connected to City E. If all telecommunications networks in City C are disconnected, what will happen to the communication networks in the five cities?

This question is a HOTS question with an analysis level, marked by the operational verb of examining what happens if the communication network in city C is cut off.

5. A strategy game competition is contested by two teams: the Superior team and the Champion team. The Superior team has two members, and the Champion team has three members. Each member of the Superior team must compete against each member of the Champion team. Identify whether this is an example of a special simple graph problem. Why? How many game sessions should the committee prepare?

This question is a HOTS question with an analysis level, marked by the verb identification.

6. Sarah's house is located in a complex. The complex contains several blocks: the Anggrek block, which has two branches, the Carnation block, which has three branches, the Melati block, which has three branches, the Mawar block, which has four branches, and the Kenanga block, which has four branches.

a. Can this problem be modeled as a graph? If the graph can be modeled, create an adjacency matrix.

b. If the graph cannot be modeled, can an adjacency matrix be created? Explain.

This question is a HOTS question with an analysis level, marked by the verb to check whether the problem can be modeled or not.

7. The Setiawan and Furqon families consist of family members who are connected by mutually ISOMORPHIC familial relationships. Setiawan's familial relationships are as follows:

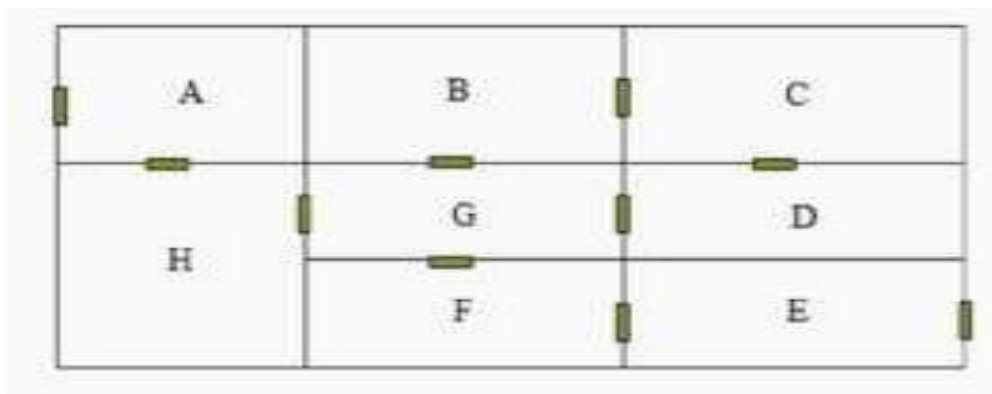
Setiawan's Family Relationships

- Member A has a direct relationship with B, C, and D.
- Member B has a relationship with A and E.
- Member C has a relationship with A and F.
- Member D has a relationship with A and E.
- Member E has a relationship with B and D.
- Member F has a relationship with C.

a. Model the graph of Setiawan's family relationship.

b. Construct Furqan's family relationship so that it is isomorphic to Setiawan's family relationship. Explain.

8. The following figure shows the floor plan of a house. A person entering through the front door in room A intends to pass through each room exactly once and exit the house through the back door in room E.



Construct the person's travel path if it exists. If it doesn't, explain why.

This question is a HOTS question at the creation level, characterized by the operational verb "construct."

9. In a hospital, five specialist doctors (A, B, C, D, and E) work in five different clinics. Some doctors must visit more than one clinic because their expertise is needed there. To avoid scheduling conflicts, hospital management wants to create a schedule that allows each doctor to work in different clinics on the same day. The relationship between clinics based on the doctors assigned to several clinics is as follows:

Doctor A works in clinics 1 and 2; Doctor B works in clinics 2 and 3; Doctor C works in clinics 3 and 4; Doctor D works in clinics 4 and 5; Doctor E works in clinics 5 and 1.

Propose a doctor's work schedule based on graph coloring.

This question is a HOTS question with a creative level, marked by operational verbs to form a proposed doctor's work schedule based on graph coloring.

To solve this HOTS analysis-level problem, students must detail the nodes and paths in the graph, then describe the connections between those nodes. To solve HOTS evaluation-level problems, students must validate whether the problem aligns with a specific simple graph concept, namely a complete graph. To solve HOTS creation-level problems, students are not asked to directly compare two graphs to determine whether they are isomorphic or not, but rather to design another family relationship graph that is isomorphic to the first. These three problems represent HOTS-based problems and real-world problems. The analysis shows that these three problems meet the characteristics of HOTS problems, including being contextual (having a situation, in this case a real-world situation), being complex and not amenable to conventional procedures, and most importantly, using appropriate operational verbs, namely, analyzing, evaluating, and creating, at the HOTS level.

It is actually not difficult to construct a HOTS-based problem based on real-world problems. The real-world context of the problem is used as the problem context. To construct

a HOTS problem, it is important to consider operational verbs (KKO) that align with the intended cognitive aspect. The HOTS KKO referred to is presented in Table 4 (Retno Utari, 2020).

Table 4. HOTS Operational Verbs for Cognitive Aspects

HOTS Cognitive Level	Description	Operational Verb
Analyze	The ability to separate a concept into its components and relate them to each other to gain a complete understanding of the concept.	Differentiate, compare, contrast, separate, connect, show relationships between variables, break into parts, isolate, speculate, consider, contrast, rearrange, characterize, restructure, test, integrate, organize, and frame.
Evaluate	The ability to determine the degree of something based on certain norms, criteria, or benchmarks.	Defend, select, defend, evaluate, support, assess, justify, check, criticize, predict, justify, and condemn.
Create	The ability to combine elements into a new, whole and coherent form, or create something original.	Assemble, design, discover, create, obtain, develop, formulate, build, form, complete, make, perfect, innovate, design, produce work.

Ordinary questions (not HOTS questions) can be reconstructed by adjusting the appropriate KKO, then changing the question sentence so that it is in accordance with the selected KKO, including the context (situation) in it, and also by adding relevant images if necessary (Widana, 2017).

4. CONCLUSION

The development of HOTS-based student worksheets and real-world problems is essential to address students' difficulties in solving real-world problems, particularly those related to graphs. These HOTS-based student worksheets can be used to familiarize students with solving these types of problems, thereby developing critical thinking, creativity, and problem-solving skills.

These HOTS-based student worksheets consist of nine questions within a real-world context and cover the HOTS cognitive levels: four levels of analysis, two levels of evaluation, and three levels of creation. These student worksheets are considered highly valid and practical, making them suitable for use in discrete mathematics lectures on graphs. These HOTS-based student worksheets are expected to provide a practical solution to overcome students' difficulties in solving graph problems in discrete mathematics.

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