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# Enhancing Direct Instruction on Introductory Physics for Supporting Students' Mental-Modeling Ability

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**Abstract**

This paper describes an instructional design for introductory physics that integrates previous research results of physics problem-solving and the use of external representation into direct instruction (DI). The research is a part of research in obtaining an established instructional design to support mental-modeling ability. By integrating with the previous research results of problem-solving and external representation with the characteristics of DI, we obtained stages of a hypothetical design. The hypothetical design has been developed by implementing phases of formative research to obtain a final model of enhanced direct instruction (EDI). Results of experimental phase showed that EDI can support the students' mental-modeling ability.

**Keywords:** direct instruction, enhanced direct instruction, external representation, mental-modeling ability, problem-solving

## 1. Introduction

Many lecturers who have taught introductory physics for many years recall some salient experiences: a reasonably successful student who can produce a graph but cannot explain its meaning; many students of a cohort of cross-section abilities who remember physics formula without understanding despite they have involved in well-designed lectures (Redish, 1994). Although it was stated more than twenty years ago, a question should be answered: how are introductory physics lectures in 2015? We can find different answers for the question and they depend on our perspective and progress of physics education research (PER) in our country. The contribution of PER in reforming a traditional lecture to a reformed lecture is an important aspect for resulting successful learners.

Five years after the Redish's statement, Thornton (1999) proposed a question: "Are most students in physics courses obtaining a conceptual understanding of fundamental physics principles?" Based on his review of some studies, he stated that studies of students' fundamental conceptual knowledge in high schools and colleges have showed some in the larger community of physics teachers that there is less basic understanding than they have believed. The results of these studies show that the students can solve some traditional problems involving the solution of algebraic or calculus equations, but they failed to answer the simple conceptual questions.

One of the most widely used teaching models in introductory physics is a traditional instruction (at least at Tadulako University, Indonesia). In general, the instruction for introductory physics has been conducted predominantly in very simple steps, i.e., instructor gives an explanation, problem example (solved by the instructor), and problem(s) exercise (solved by students). The condition also generally happens at junior and senior high schools in Indonesia. Effects of the condition are physics perceived by students as difficult and boring, and the teaching could result in misconception(s), and other difficulties or constraints in learning physics. This is a part of stereotypes and in part to the courses taught (Thornton, 1999).

The impact of lecture instruction on students' conceptual understanding of physics has been investigated for several decades. Most studies have reported disappointingly small improvements in the students' performance on conceptual questions despite of direct instruction on the relevant topics. These results have supported some efforts to improve the quality of learning in physics courses through new curricula and instructional design (Heron, 2015). Efforts to create a meaningful teaching are a challenge for researchers in physics education. Research-based curricula designed to improve students' conceptual learning can result in substantial gains over traditional lecture (Redish, 2004).

One of the famous teaching models is Direct Instruction (DI). DI, also known as Active Teaching or Whole Class Teaching, refers to a teaching style in which the teachers are actively engaged in bringing a learning material to students by teaching the whole class directly (Reynolds & Muijs, 2011). DI refers to the instruction led by the teacher, as in "the teacher provides direct instruction in solving problems". The term has appeared in a variety of meanings (general, specific, positive, and negative). This problem occurs because DI, and terms such as direct teaching and explicit instruction has both a general meaning and a specific meaning. The general meaning refers to any instruction led by the teacher regardless of quality (Rosenshine, 2008).

Efforts for becoming DI as an effective learning has been carried out by researchers. Beginning around 1968, researchers used DI as a summary term for the instructional procedures used to teach higher level cognitive tasks. For example, Dykstra (1968) concluded that DI in comprehension is essential. Since that time, the term DI has been implemented for some objectives, i.e.: strategies for reading comprehension, predicting, clarifying, question-generating, summarizing, combining sentences, developing process skill, test-taking strategies and engaging in reflective thinking (Rosenshine, 2008). Beside the research results that showed the advantages of DI in certain aspects, some writers believe (as summarized by Rosenshine, 2008) that DI represents undesirable teaching, authoritarian, regimented, fact accumulation at the expense of thinking skill development, and focusing on tests. Some writers portrayed DI as a passive mode of teaching, pouring information from one container (the teacher's head) to another container (the students' head). All of these critics are proposing that teachers need to use different forms of student-centered or activity-based instruction in place of direct instruction.

Among the advantages and disadvantages of DI as described above, there is a challenge for researchers to make this learning model effective in certain aspects by minimizing the possible shortcomings. We can enrich DI by considering the results of previous studies.

This paper presents enhanced DI model from the results of previous studies by Rosengrant et al. (2006), Cock (2012), Sabia et al. (2013), Ningsih et al. (2013), Ibrahim and Rebello (2013), Rahmilia et al. (2014), and Mansyur (2015). This research aimed to obtain an instructional design that is a research-based instruction by making DI as a basis. The research results of the physics problem-solving and the use of an external representational system can enrich the instructional design. The orientation of the enhanced DI model (from now on, it is called as Enhanced Direct Instruction, EDI) is a mental-modeling ability (MMA) according to the potential aspects after the enhancement.

### *1.1 Focus of the study*

We used hypothetical model of Darsikin and Mansyur (2015) as a basis of this research. We conducted evaluation to the model to produce a more robust design model. To do this, we followed Chen and Teh's (2013) work that it was necessary to identify methods that are part of the model. Therefore, the specific objective of this study is to enhance DI model for the research-based model using the formative research methodology. The research question of this study is: Is there an influence of the EDI towards MMA?

## 2. Theoretical Framework

Reynolds and Muijs (2011) stated that there are several reasons why DI has been found to be effective. One of the reasons is that studies have found that DI allows teachers to make more contacts with each student than individual work, and interaction between students and teacher is a crucial aspect of successful teaching and learning. Students have also been found to be more likely to be on task during the whole class sessions than during individualized instruction. This is a main factor because it is easier for the teacher to monitor the whole class while teaching than to monitor individual students. DI also allows the teacher to change and vary activities and to react quickly to sign that students are switching off, either through lack of understanding of the content or boredom.

Based on across some studies, Rosenshine (2008) concluded that when effective teachers taught well-structured topics, they used the following pattern:

- Begin a lesson with a short review of previous learning.
- Begin a lesson with a short statement of goals.
- Present new material in small steps, providing students with practice after each step.
- Give clear and detailed instructions and explanations.
- Provide a high level of active practice for all students.

- Ask a lot of questions, check students' understanding, and obtain responses from the students. Guide students during initial practice.
- Provide systematic feedback and corrections.
- Provide explicit instruction and practice for seatwork exercises and monitor the students during seatwork.

Rosenshine and Stevens (1986) and Rosenshine (2008) further grouped these instructional procedures as teaching functions, as shown in Table 1.

Table 1. Results from the effective teacher research

| Function | Action |
|---|---|
| Reduce the difficulty of the task during initial practice. | State lesson goals. |
| | Divide the task into smaller components. |
| Use scaffolds and guidance to support students during initial practice. | Model a strategy or a procedure. |
| | Think aloud the selected strategies. |
| | Anticipate student's errors. |
| | Check student's understanding. |
| | Obtain responses from all students. |
| | Combine gradually the components into a whole. |
| Provide supportive feedback. | Provide systematic corrections and feedback. |
| | Provide checklists. |
| | Provide models of the completed task. |
| | Provide students with fix-up strategies. |
| Provide extensive practice for student (independent practice). | |

According to Merrill (2007), there are two main principles of an instructional design, namely:

1) The instructional goal is to encourage the development of cognitive structure that is more consistent with the performance of the expected learning outcomes.
2) The instructional goal is to encourage active cognitive processing that enables learners to use cognitive structure in a manner consistent with the performance of the expected learning outcomes.

We follow the principles of macro-strategy on instructional design as summarized by Chen and Teh (2013) in Table 2.

Table 2. Principles of the macro-strategy

| Principles | Description |
|---|---|
| Objectives | Identifying the types of learning (labels, verbal information, intellectual skills and/or cognitive strategies) and the respective learning objectives. |
| Integrative goals | Determining the integrative goals by combining several interrelated objectives that are to be integrated into a comprehensive purposeful activity, which is called an enterprise. |
| Enterprise scenario/problem | Identifying the enterprise scenario that must be played out in conducting the enterprise. It is similar to the problem posed in a constructivist learning environment. This problem comprises three integrated components: problem context, problem representation, and problem manipulation space. |

| | |
|---|---|
| Support tools | Providing various interpretative and intellectual systems to support constructivist learning through the problem posed. These may include related cases, information resources, and various cognitive tools. |
| Instructional activities | Providing instructional activities to support constructivist learning, which includes modeling, coaching, and scaffolding. |

To assess students' MMA, we used a rubric of Wang (2007), and it has been modified by Mansyur (2010) as presented in Table 3.

Tabel 3. Protocol of MMA (Wang, 2006; Mansyur, 2010)

| Characteristics of MMA | | Score | MMA score (maximum) |
|---|---|---|---|
| 1a | Generate a mental model w/ and w/o a 2D representation (diagram) or other relevant representations | 2 | 2 |
| 1b | Generate a mental model based on a 2D representation (diagram) or other relevant representations | 1 | |
| 2a | Manipulate the mental model based on propositions | 4 | 4 |
| 2b | Possess a rigid mental model and conclude that the shape of mental model would not change when a new proposition is added to the model; sometimes need to rely on a concrete model | 2 | |
| *3 | Metacognitively monitor processes of mental modeling | 2 | 2 |
| *4 | Self-check using an alternative approach for testing or inspecting the mental model to identify errors from the mental model | 2 | 2 |
| Total (maximum) | | | 12 |

* Not included in this article.

Component 1a (or 1b) and 2a (or 2b) are the main orientation of this research. We focus on the improvement of the students' ability in transforming an external representation to other representations.

### *2.1 Formative Research*

This article focuses on enhancing the instructional design using formative research. The work entails what many have referred to design and development research (Chen & Teh, 2013). Reigeluth and Frick (1999) stated that formative research is a kind of developmental research intended to improve design theory for designing instructional practices or processes. Using it as the basis for a developmental or "action" research methodology for improving instructional-design theories is a natural evolution from its use to improve particular instructional systems. It is also useful to develop and test design theory on other aspects of education, including curriculum development, counseling, administration, finance, and governance. Formative research has been used to improve the existing instructional design theories and models, such as elaboration theory, a theory to facilitate understanding, a theory for the design of computer-based simulations and theory for designing instructions for teams (Chen & Teh, 2013).

We adapted the work of Reigeluth and Frick (1999) for conducting the formative research in this study. Chen and Teh (2013) have implemented the process as in the following:

a) Selecting a design theory (or model).

b) Designing an instance of the model, which is a specific application of the design model. This study involved an expert of the model to ensure that the design instance was as pure an instance of the design model as possible to avoid two types of weaknesses; omission and commission.

c) Conducting a pilot study.

d) Collecting and analyzing formative data on the instance. The purpose is to identify and remove problems in the instance, explore consequences of adding new elements or remove existing elements from the design instance as well as to reconfirm the appropriateness of methods prescribed by the model.

e) Repeating data collection and analysis cycles to confirm earlier findings.

f) Offering tentative revision of the model.

Most of these stages are used to finalize the instructional design by integrating the principles of macro-strategy by adopting Chen and Teh's (2013) work with the patterns of DI implementation according to Rosenshine (2008). Results and recommendations of previous studies are further integrated into the existing structure as elements of micro-strategy.

## 3. Method

### *3.1 Expert Validation for the Initial Model*

Expert validation was carried out to provide the suitability of the theoretical models with learning targets from the viewpoint of experts. Aspects and indicators of the assessment are:

a. Macro strategy: scope, clarity, integration and rationality.

b. Micro strategy: scope, clarity, integration, rationality and supporting to macro strategy.

c. Potential aspect: supporting to MMA, supporting effective problem-solving and flexibility in implementation.

d. Accommodation: integration with previous the research results and conformity with levels of thinking (high school student to the second year university student).

### *3.2 Pilot Study*

We conducted a pilot study on Introductory Physics II (Academic year 2014/2015). Focuses of the pilot study were on the implementation aspects and flexibility of general stages of the design. The study was dominantly as a reflective study.

### *3.3 Sampling*

Research population was 115 students of Physics Education Study Program (Academic year 2015/2016). They were in three classes, excluding the students who have backgrounds in senior vocational high schools. The research sample was determined by using purposive random sampling (cluster) where there was one class (Class A, n = 34) as an experimental group and one class (Class B, n = 30) as a control group.

### *3.4 Intervention*

Experimentation of EDI as a hypothetical model was implemented by using quasi-experimental design. In the experimental group, we implemented EDI, while in the control group, we implemented DI model. Both the experimental and control group, the learning took place six lessons excluding introductory meeting/lecture contract, pretest, and posttest session.

### *3.5 Data Collection*

Data collection included pretest, posttest, and interview. The pretest and the posttest were intended to emphasize the data relating to the aspects of MMA about the transformation of the representation based on the propositions of each problem. In this case, construction of a diagram is the main aspect of MMA. The interview focused on the students' response to the learning structure of the experimental group.

#### 3.5.1 Instrument

#### 3.5.1.1 Test

The test for pretest and posttest includes concept mastery of fundamental mechanics in Introductory Physics I, namely Kinematics, Dynamics and Work-Energy. The test consisted of five items essay test. Although the test was a test of concept mastery, the test can be used to assess the aspects of MMA by using a rubric. All the problems included in the test contained elements as a stimulus for students to use a diagram in problem-solving activity. If each student made up diagram more than one in every problem, we counted them as one diagram so that there are five diagrams (as maximum) for each student.

#### 3.5.1.2 Rubric

MMA rubric was predominantly used to assess Component 1a (or 1b) and 2a (or 2b) of Table 1 as the main focus of this study.

#### 3.5.1.3 Interview Protocol

Interview protocol included questions about the responses of students to the learning structure.

### *3.6 Data Analysis*

Although this study used a quasi-experimental design, data analysis focused on the qualitative-descriptive aspects of the learning model. The data analysis was carried out on the aspects of MMA that appeared on the answer sheet of the experimental and control group. In this case, we calculated the proportion of students in both classes that constructed a diagram for each problem in the pretest and posttest. Also, we calculated the total number of diagrams constructed by the students. The data were also as an initial benchmark for assessing the condition of the real MMA. The increasing of the students proportion that constructed the diagram is determined by using a formula (Hake, 2007):

$$\langle g_p \rangle = \frac{P_{post} - P_{pre}}{100 - P_{pre}} \times 100\% \qquad (1)$$

where:

$<g_p>$ : the average normalized gain for students proportion

$P_{pre}$ : the students' proportion that constructed the diagram in pretest

$P_{post}$ : the students' proportion that constructed the diagram in posttest

The increasing of the number of diagrams is determined by using a formula (Hake, 2007):

$$\langle g_d \rangle = \frac{D_{post} - D_{pre}}{D_{max} - D_{pre}} \times 100\% \qquad (2)$$

where:

$<g_p>$ : the average normalized gain for number of diagrams

$D_{pre}$ : the total number of diagrams in pretest

$D_{post}$ : the total number of diagrams in posttest

$D_{max}$ : the total maximum number of diagrams

The increasing of the number of diagrams using formula (Hake, 2007):

$$\langle g_{mma} \rangle = \frac{M_{post} - M_{pre}}{M_{max} - M_{pre}} \times 100\% \qquad (3)$$

where:

$<g_{mma}>$: average normalized gain for MMA

$M_{pre}$ : MMA score in pretest

$M_{post}$ : MMA score in posttest

$M_{max}$ : total maximum score of MMA

The analysis of the interview results emphasizes on the comfort and convenience of the students to involve their self in the learning structure. The interview results are also used to determine the implementation aspects of the model to accommodate the needs of students.

## 4. Results and Discussion

### *4.1 Description of Hypothetical Model*

Hypothetical model of the instructional design as integration results contains macro- and micro-strategy, presented in Appendix A (Darsikin & Mansyur, 2015). The process for obtaining EDI followed the pattern made by Chen and Teh (2013) in developing an instructional design of virtual reality-based learning. The process starts from the center of the circular shape of the macro-strategy (innermost ring) and gradually moves outward to the outmost ring. The hypothetical model is 'injected' with micro-strategy by considering the previous research results.

From the integration of the micro-strategy elements into the macro-strategy through DI pattern (Rosenshine, 2008; Hunter, 1982), we obtained hypothetical stages of EDI (Darsikin & Mansyur, 2015) as presented in Table 4.

Table 4. DI pattern and hypothetical stages of EDI

| Direct instruction pattern (Rosenshine, 2008) | Hyphotetical stages of EDI (Darsikin & Mansyur, 2015) |
|---|---|
| • Begin a lesson with a short review of the previous learning.<br>• Begin a lesson with a short statement of goals<br>• Present new material in small steps, provide practice for student after each step.<br>• Give clear and detailed instructions and explanations.<br>• Provide a high level of active practice for all students.<br>• Ask a lot of questions, check students' understanding, and obtain responses from all students.<br>• Guide students during initial practice.<br>• Provide systematic feedback and corrections<br>• Provide explicit instruction and practice on seatwork exercises and monitor the students during seatwork. | Elicit initial knowledge<br>Inform learning goal<br>Give instruction and explanation (explain mode of students' involvement in the learning)<br>Gradually, present learning material. There is exercise(s) in each step. In the problem exercise, the lecturer model the problem-solving steps by thinking-aloud; give time for problem understanding step with its proportion is more than the other steps; emphasize the proportion in presenting the problem example; emphasize the use of a diagram, emphasize the simultaneous use of diagram and identification of the given and required variables.<br>Provide reciprocal teaching approach (in small scale). One or more students perform problem-solving process by thinking-aloud.<br>Guide the students during initial practice.<br>Ask a lot of questions, check student's understanding, and obtain responses from all students (insert the use of multiple representations).<br>Form groups.<br>Provide practice for the students (insert information of external representation and its transformation).<br>Use reciprocal teaching approach in groups (there is a student as a guide for his/her group; he/she performs problem-solving by thinking-aloud).<br>Provide explicit instruction and practice for seatwork exercises and monitor the students during seatwork.<br>Provide systematic feedback and corrections.<br>Provide independent task. |

Based on the pattern of DI by Rosenshine (2008) in Table 4, we conducted modification and rationalization to the aspects (based on the findings of the previous research) and Hunter's (1982) research. Table 4 shows the integration of the principles of macro-strategy into DI pattern with micro-strategy forming EDI structure that is more specific but more complex.

The stages of EDI as a hypothetical design should be operated through the preparation of lesson plans as part of the development stage. The hypothetical design that has been formulated follow the development procedure by applying formative research. The hypothetical design was also validated by an expert of learning structure to obtain its feasibility. Table 5 presents the result of the expert validation. Table 5 shows the proposed theoretical model having potential characteristics.

Table 5. Result of the expert validation about hypothetical model

| Aspects | Indicators | Score (max. = 4) |
|---|---|---|
| Macro strategy | Scope | 4 |
| | Clarity | 3 |
| | Integration | 4 |
| | Rationality | 4 |
| Micro strategy | Scope | 4 |
| | Clarity | 4 |
| | Supporting macro strategy | 4 |
| | Rationality | 3 |
| Potential aspect | Supporting mental-modeling ability | 3 |
| | Supporting effective problem-solving | 4 |
| | Flexibility in implementation | 3 |
| Accommodation | Integration with the previous research results | 3 |
| | Conformity with the levels of thinking (high school student to the second year university student) | 4 |

### *4.2 Results of Experimentation*

#### 4.2.1 Results of Pretest and Posttest

Table 6 presents description of the pretest and posttest results for both groups. Table 6 contains the proportion and the increase of the proportion (after normalized) of the students that constructed a diagram on each item. The table does not show the correctness of the diagram. However, the data can reflect the proportion of the students trying to construct a diagram as a main component of MMA.

Table 6. The proportion of the students constructing diagram for each item and N-gain

| | Experimental group (n = 34) | | | | Control group (n = 30) | | | |
|---|---|---|---|---|---|---|---|---|
| Item number | Pretest (%) | Posttest (%) | N-gain | | Pretest (%) | Posttest (%) | N-gain | |
| | | | % | Category | | | % | Category |
| 1 | 38 | 68 | 48 | Moderate | 10 | 30 | 22 | low |
| 2 | 62 | 85 | 62 | Moderate | 37 | 67 | 47 | moderate |
| 3 | 71 | 88 | 60 | Moderate | 60 | 87 | 67 | moderate |
| 4 | 9 | 71 | 68 | Moderate | 3 | 13 | 10 | low |
| 5 | 6 | 88 | 88 | High | 10 | 27 | 19 | low |
| Average | 37 | 80 | 65 | Moderate | 24 | 45 | 33 | moderate |

Table 7. The number of diagrams constructed by the students of both groups

| Exp. group (n = 34, max. number = 170) | | | | Cont. group (n = 30, max. number = 150) | | | |
|---|---|---|---|---|---|---|---|
| Pretest | Posttest | N-gain | | Pretest | Posttest | N-gain | |
| | | % | Category | | | % | Category |
| 62 | 136 | 69 | Moderate | 35 | 66 | 27 | Low |

Table 6 shows the increase of the students' proportion constructed diagram in the pretest and the posttest of both groups. However, the largest proportion occurred in the experimental group. The data illustrate that learning with EDI structure can encourage the students' attention to a role of the diagram as a representation that is essential in problem-solving. The students' proportion has a relation with the number of diagrams constructed by the students. Table 7 shows the increase of the number of diagram constructed from the pretest to the posttest of both groups.

The correctness and feasibility of the constructed diagrams are further reviewed by using the MMA rubric (Wang, 2007; Mansyur, 2010). Table 8 presents the students' MMA score of both groups.

Table 8. Score and N-gain of MMA of both groups

| Exp. group (n = 34, max. score = 1020) | | | | Cont. group (n = 30, max. score = 900) | | | |
|---|---|---|---|---|---|---|---|
| Pretest | Posttest | N-gain | | Pretest | Posttest | N-gain (%) | |
| | | (%) | Category | | | % | Category |
| 121 | 248 | 14 | Low | 103 | 177 | 9 | Low |

* Maximum score for each item is 6, the total score for the overall items is 30.

Table 8 shows that there is an increase of MMA score of both groups, but N-gain ($<g_{mma}>$) is a low category. Qualitatively, there is a difference of $<g_{mma}>$ between the experimental and the control group. The value of $<g_{mma}>$ of the experimental group is higher than the value of $<g_{mma}>$ of the control group. The value shows that teaching with EDI (in the experimental group), qualitatively outperforms teaching with DI (in the the control group). Although $<g_{mma}>$ is in the low category, explicit instruction in the experimental group took place on the importance of the diagram, contributing to the 'embryo' of a productive problem-solving.

### 4.2.2 Interview

In this part, we present results of the interview with two students. The interviews focused on the students' response on the learning structure and the role of a diagram in problem-solving activity. The two students were Zahra and Dian (assumed).

When Zahra was asked about the learning structure, she said (translated):

> *By teaching, gradually through the diagram, it allows us to analyze cases (phenomena) that exist. In high school, we were taught directly into a formula, known, required variable. However, we cannot analyze and might forget the concept. With such a systematic way, we can understand in detail, starting from the root (basic). We are not easy to make a mistake. We can do it with a good understanding. Presentation of the concept is interesting, and it can make us pull out our arguments and our opinions about what we think about the concept and be able to know that it is understandable and wrong. About the presentation of the problem examples, we see from simple to more complicated, gradually...*

Dian said (translated):

> *It is very good teaching structure. We were taught as...need to know how to solve problems, how to find their solution. We do not understand the concepts associated with the phenomena. Your lesson was started from the concept, for example, we can think logically. We remembered a formula. During the last time (in high school, I was taught directly to formula. We do not know when the formula is used. In your class, ...with the help of diagram, we know when it moves like a formula, like this. About the use of diagram, sometimes we just use the theory, logic does not immediately catch it. If we use diagrams, we think...like this ...*

Base on the interview results, we can argue that the students can follow the teaching and learning process. The teaching structure and the emphasis of using diagram are important points of EDI in supporting the improvement of students' MMA aspects as presented in Table 6, Table 7, and Table 8.

### 4.2.3 Reflection

Reflection mainly focused on the evaluation of the weakness of the learning structure. There was one stage of EDI model which the lecturer had difficulty to implement (from Table 4), i.e. "use reciprocal teaching approach in groups (there is a student as a guide for his/her group; he/she performs problem-solving by thinking-aloud)". The lecturer had difficulty in managing the class regarding the implementation of reciprocal teaching and thinking-aloud by the students in their groups. It needs more time for practicing the activities. We excluded two stages from the EDI structure. To obtain the final model, we carried out a revision of the structure.

### *4.3 Final Model*

After the revision process, we obtained a final model of EDI, as presented in Table 8.The final model is more simple than the previous one. To optimize the potential aspects of the model, we give a short description in the implementation. For example, enrichment of the teaching with a modeling of problem-solving was done with thinking-aloud. This component is intended that when a student interacts with other students, we could identify their problems, ideas, and conceptions. Modeling on the use of time in the problem-solving process, especially in the stages of problem representation and the process of variables identification and constructing a diagram are simultaneously shown by the lecturer.

Table 8. Hyphotetical and final model of EDI

| Hyphotetical Stages of Model (Darsikin & Mansyur, 2015) | Stages of Final Model |
|---|---|
| Elicite initial knowledge | Elicite initial knowledge |
| Inform learning goal | Inform learning goal |
| Give instruction and explanation (explaining mode of students' involvement in the learning) | Give instruction and explanation (explaining mode of students' involvement in the learning) |
| Gradually, present learning material. There is exercise(s) in each step. In the problem exercise, the lecturer model the problem-solving steps by thinking-aloud; give time for problem understanding step with its proportion is more than the other steps; emphasize the proportion in presenting the problem example; emphasize the use of a diagram, emphasize the simultaneous use of diagram and identification of the given and required variables. | Gradually present learning material. There is exercise(s) in each step. In the problem exercise, the lecturer model the problem-solving steps by thinking-aloud; give time for problem understanding step with its proportion is more than the other steps; emphasize the proportion in presenting the problem example; emphasize the use of a diagram, emphasize the simultaneous use of diagram and identification of the given and required variables. |
| Provide reciprocal teaching approach (in small scale). One or more students perform problem-solving process by thinking-aloud. | Provide reciprocal teaching approach (in small scale). One or more students perform problem-solving process by thinking-aloud. |
| Guide students during initial practice. | Guide the students during initial practice. |
| Ask a large number of questions, check students' understanding, and obtain responses from all students (insert the use of multiple representations). | Ask a lot of questions, check students' understanding, and obtain responses from all students (insert the use of multiple representations). |
| Form groups. | |
| Provide practice for the students (insert information of external representation and its transformation). | Provide practice for the students (insert information of external representation and its transformation). |
| Use reciprocal teaching approach in groups (there is a student as a guide for his/her group; he/she performs problem-solving by thinking-aloud). | |
| Provide explicit instruction and practice for seatwork exercises and monitor the students during seatwork. | Provide explicit instruction and practice for seatwork exercises and monitor the students during seatwork. |
| Provide systematic feedback and corrections. | Provide systematic feedback and corrections. |
| Provide independent task. | Provide independent task. |

Steps in the core activity such as preparation of diagram and other representations through variables identification and insertion of a transformation of external representation are important steps in forming students' MMA. The activity can support the ability to manipulate mental models based on propositions (Rosengrant et al., 2006). The students' ability to metacognitively monitor the construction process can form mental model through the modeling. The modeling of problem-solving emphasizes the importance of understanding problem stage by providing a greater proportion of time (Mansyur, 2015). We can improve reflective thinking habits through the suppression (Darsikin & Mansyur, 2015). The central issue in this context is that the students should be made aware of their learning habits, promoting them to a conscious facilitator in the knowledge construction process (Gerace & Beatty, 2005).

## 5. Conclusion and Recommendation

Based on the previous description, it can be concluded that we have developed an instructional design. The design includes the integration of the principles of macro-strategy of instructional design theory into direct instruction. The explicit stages of integration are further enriched by the micro-strategy to obtain the final model of enhanced direct instruction. This research provides some evidence of the effects of using enhanced direct instruction on the students' mental-modeling ability. In comparison, the enhanced direct instruction is more effective in developing a part of mental-modeling ability characteristics than 'normal' direct instruction. The enhanced direct instruction fosters these students' learning outcomes by engaging the students actively in solving problems and becoming aware of any phase of the process. Further research is needed to compare the model with other models in improving students' learning outcomes.

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## Appendix

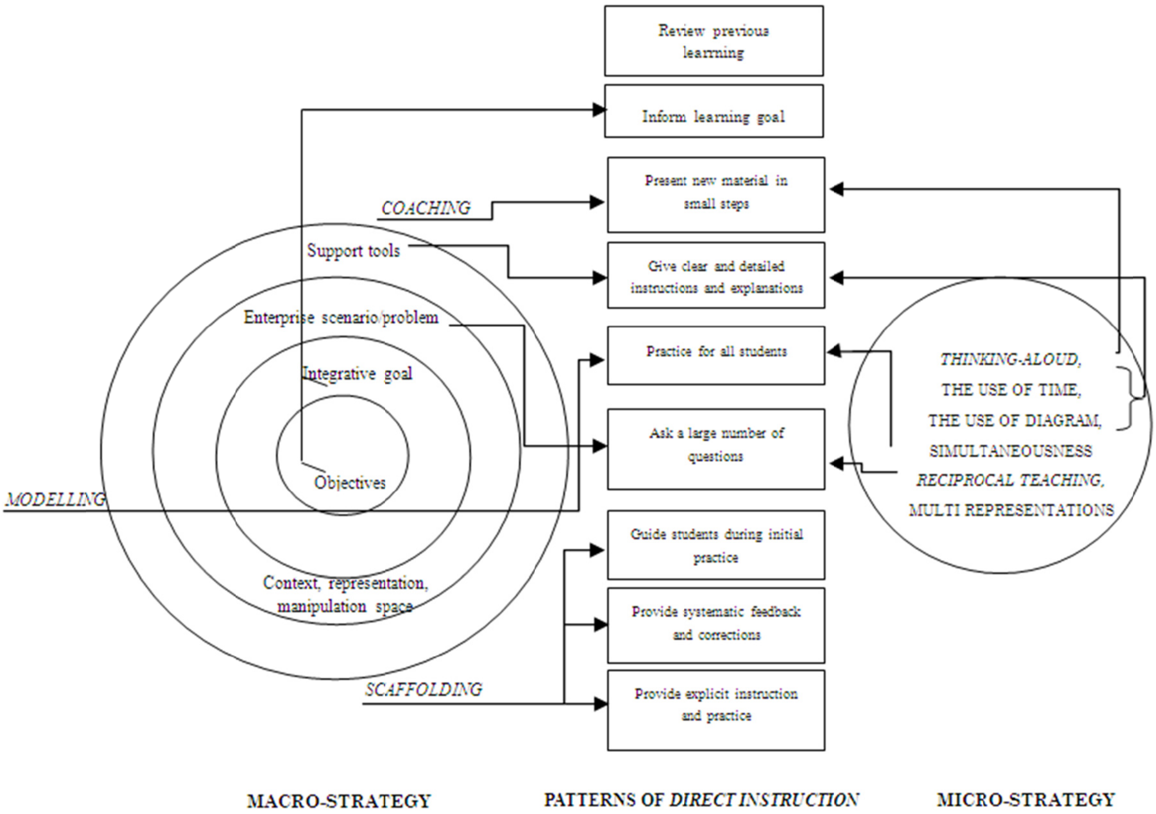

Figure 1. Hypothetical design of enhanced direct instruction