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Combination of Discovery Learning and Metacognitive Knowledge Strategy to Enhance Students' Critical Thinking Skills

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Abstract: The research aims to develop an instructional tool based on Discovery Learning (DL) combined with a Metacognitive Knowledge Strategy (MKS) to enhance students' Critical Thinking Skills (CTSs). In doing so, the study employed a Research and Development (R&D) method to develop such a tool. The developed instructional tool was tested for its validity by experts and practitioners' evaluation. Further, the empirical data were collected from the results of implementation in learning and the student's responses, while the data of tools effectiveness were acquired from the critical thinking tests given to students (analyzed by related t-test). The developed instructional tools were implemented in a limited-scale trial of 32 students and a large-scale trial of 59 students. The results show that: firstly, the DL and MKS-integrated instructional tools are stated as valid in terms of the lesson plan, student worksheet, and critical thinking test. Secondly, the practicality criteria have been successfully met; the learning implementation, students' activity, and students' responses were regarded as in accordance with the feasibility standard. Thirdly, the instructional tool was deemed effective in enhancing students' CTSs ($p = 0.05$).

Keywords: *Discovery learning, metacognitive knowledge strategy, learning strategy combination, critical thinking skills, science education.*

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Introduction

There are teaching strategies in science that develop metacognition among students. Seraphin et al. (2012) investigated the effectiveness of science teaching as a survey. They concluded that explicit instruction in metacognitive strategies increased students' metacognitive processes that are needed to understand and implement science and helped the development of critical thinking among them. Critical thinking skills (CTSs) remain as a matter of debate in the study of science, especially biology. CTSs contribute to students' success, considering that students who are capable of thinking critically succeed at school and at work. Such students are accustomed to thinking clearly and rationally. CTSs are in the top demand for a better quality of life (Alghafri & Ismail, 2014). By that, teaching such skills at schools or educational institutions is of paramount importance. Learning processes are among the step to enhance students' CTSs (Burrell, 2014; Iwan et al., 2020). School teachers are now urged to produce critical thinkers. However, this process is not an easy task to accomplish. A specific set of skills are essential for teachers to develop a learning activity that stimulates students' CTSs. Although teaching CTSs takes time, teachers should start to develop learning programs for enhancing students' CTSs, or otherwise, producing critical thinkers might be impossible.

A study has revealed that 70 high school students have poor CTSs; surprisingly, only 28% of fourth-year university students are able to perform good CTSs (Chartrand, 2010). Other studies report students' low (Akhdinirwanto et al., 2020) to poor CTSs (Aripin et al., 2019; Puspita et al., 2017; Santika et al., 2018). Such findings further emphasize the necessity to enhance CTSs. All educational institutions, regardless of their levels (Sahika, 2018) and disciplines (Davies, 2013), are responsible for cultivating such skills. In biology subject, CTSs development is crucial as these skills will help

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students analyze the complexity of biological systems (Saenab et al., 2021). CTSs have been an integral part of the subject to stimulate students to formulate solutions as they will face increasingly complex challenges in real life (ŽivkoviL, 2016). Development processes are at their maximum if students have good CTSs (Hashemi, 2011). Teachers play a significant role in producing critical thinkers. This goal requires an appropriate learning strategy, and Discovery Learning (DL) is one example.

Several studies have indicated that DL is an innovative alternative to cultivate CTS. This learning strategy instills the quality of critical thinkers in students. Changes in the curriculum, such as the implementation of DL, are beneficial to enhance several aspects of teaching and learning activities, e.g., HOTS (higher-order thinking skills), active learning, and self-directed learning (White et al., 2013). In one experimental research, it is revealed that DL implementation results in a better CTS score of 72.94 on average; the score is higher than those who were taught using conventional learning methods (Wartono et al., 2018). The traditional class focuses on the lesson being taught, and thus the students become passive learners who quietly absorb information from teachers' long lectures (Duran & Dökme, 2016). Changing such methods to a system that focuses on cultivating students' performance is essential, requiring teachers' innovation. However, the modification should fit the needs of students in facing global challenges. Students are demanded to be critical in responding to every phenomenon. Becoming a critical thinker also eases them to find solutions. Processes to be a critical thinker should start from the teachers' initiative to incorporate CTS-enhancement strategies in classroom activities.

In the implementation of DL, teachers are not the source of information. Students instead receive information from other accessible resources. Many students prefer obtaining information from listening to experts, for example, their teachers (Kornell & Hausman, 2017). Teaching by relying on explanations from the teacher causes a cognitive burden on students (Trninic, 2018). This model should not be applied in the class as the teacher is supposed to be a facilitator. Otherwise, the teacher will dominate the class; this notion contrasts with the paradigm of contemporary learning. Contemporary learning demands all students to be active in their learning to discover while the teacher facilitates the students' activities. On that ground, developing strategies that stimulate students' activeness and thinking skills is a must for a teacher.

Despite the advantages of DL, one should take into account several factors prior to implementing this learning model in the class. As seen in Alfieri et al. (2011), DL does not incorporate conceptual understanding, and thus the students are responsible for gaining knowledge through available resources with zero supervision from their teachers. This situation, in turn, hinders them from comprehending a task. Moreover, the teaching and learning activity is deemed deficient as the teachers do not monitor their students (Kirschner et al., 2006), whether directly in the classroom or remotely. Teachers are supposed to provide information that students should learn (Trninic, 2018). Providing no information also leads to adversity among students, considering no examples that students can access during the learning activities (Kirschner et al., 2006). One should not implement such an unstructured DL in his class (Mayer, 2004).

Teachers' supervision is integral to learning processes. Nevertheless, teachers should not be dominant as the students will be passive and unable to think critically. The consequence of minimum supervision in DL results in students' low participation in learning, and thereby, taking into consideration the students' learning behavior is a must (Xu et al., 2018). Although results seen in Xu et al. (2018) report a significant improvement, the outcome of minimum supervision does not reach the superior level. The study suggests incorporating challenging questions to cope with such a situation. In this context, student metacognitive strategies are necessary to minimize teachers' supervision yet retain the optimum learning outcome. Metacognitive strategies stimulate students' thinking skills systematically before they deal with problems in real-life contexts. For this reason, the combination of DL and metacognitive strategies is innovation in learning.

Teachers are demanded to come up with strategies in dealing with problems in the classroom and real-life situations. They should teach the students how to think critically in different contexts. Metacognitive strategies offer an alternative solution to complement the DL method. There are three components of metacognitive strategies: declarative knowledge, procedural knowledge, and conditional knowledge (Schraw et al., 2006; Schraw & Dennison, 1994). These components are related to the types of long-term memory in information-processing model that are declarative, procedural, and conditional (Alghafri, 2011). Students should have a strong grounding in procedural knowledge in addition to conceptual knowledge. This eases their process of adaptation to a new environment. Further, the students can think critically to find out solutions in any situation. The learning activities and the development of metacognitive strategies are supposed to be all teachers' work standards. Metacognition correlates with adjusting students' cognitive process, i.e., developing, organizing, associating memorization, critical thinking, and problem-solving in new situations (Al-Gaseem et al., 2020; Nowińska & Praetorius, 2017; Nunaki et al., 2019). Emphasizing declarative knowledge for enhancing conceptual knowledge is in line with procedural knowledge and strategy development (Carr, 2010). Consistency and teaching strategies are of paramount importance in implementing metacognitive strategies. This paper aimed at incorporating DL and metacognition concepts in teaching-learning materials for enhancing students' CTSs.

Methodology

Research Design

The present work employed a research and development design 4-D model by Thiagarajan et al. (1974); its steps consisted of define, design, development, and dissemination. However, the dissemination step was skipped in this study. The needs of the learning process were delineated in the first step (defining). In the first step, all parties involved and the analysis of students' data, assignment concepts, and learning objectives determined. A preliminary study was performed by observing the class and interviewing teachers. Furthermore, the development of the lesson plan, student worksheets, and critical thinking tests (CTST) were established. The teaching and learning materials for the topic of genetics were developed for four meetings. The first meeting discusses chromosomes. The second meeting explores the issue of Gene. Following the second topic were the discussion of DNA, RNA, and DNA replications. The fourth meeting explores protein synthesis.

All lesson plans, student worksheets, and tests were developed in the previously mentioned step. The lesson plan incorporates the concept of metacognition-based DL. The worksheets were also designed by integrating metacognition questions and problems. In this present work, there are five aspects of CTS that are measured: assumption, interference, deduction, interpretation, and evaluation.

The development step consisted of the validation of tests by an instructional tool expert and learning design expert. The instructional tool expert was a lecturer with expertise in genetic studies. The learning design expert was a lecturer with expertise in educational studies. Practitioner tests administered by biology teachers aimed at retrieving inputs regarding the lesson plans, student worksheets, and CTST. The practicality was measured based on the activities of teachers and students. Following this step were the limited-scale and large-scale trials; these tests investigated the classroom learning to obtain inputs for improvement. The results of the effectiveness test were displayed in the percentage of the students' CTS and the difference in the achievement of the pre and post-test. The large-scale trial comprised pre-test and post-test without control groups.

Participants

The participants consisted of three experts in learning design and experts in the instructional tool. The practitioner involved one teacher. A total of 32 twelfth-grade students majoring in sciences (from a public high school in a regency) participated in the limited-scale test. In the large-scale trial, the students were from two schools. The first school, referred to here as CS, was located in the province's capital; 27 students participated in the test. The second school, referred to here as RS, is a school located in a regency; 32 students partook in the test. The total of participants of the large-scale trial is 59 students.

Data Collection and Instrument

All data were collected from instruments, namely learning implementation worksheets for teachers and student activity sheets. Analysis of students' CTSs was performed before and after the learning. Observations were made during the limited-scale test to examine the learning implementation by the teachers and student activities. By the end of the meeting, a questionnaire was distributed to each student; this aimed to obtain students' responses regarding the learning. The learning implementation and student activities were also observed during the large-scale trial; however, this test also analyzed the students' CTSs. The research instruments were deemed feasible based on the score of the expert validation and limited-scale test.

Data Analysis

The analysis of the teaching-learning materials' feasibility took into account each validator's score, practicality score, and students' responses. Categories of feasibility are based on the one seen in (Akbar, 2013). The materials are deemed feasible or applicable if the score ranges from 85 to 100. If the score ranges from 70 to 84, the materials are applicable, but minor revision is required. A significant revision is inevitable if the score ranges from 50 to 69. The teaching-learning materials are considered invalid if the score is below 50. There were several tests in determining the effectiveness of the materials during the large-scale trial. Those involved testing each CTSs indicator's attainment, percentages of students who passed every CTSs indicator, n-gain (normalized gain) to assess the increase of CTSs, practicality, and related t-test (effectiveness test). The related t-test was performed during the pre-CTSs and post-CTSs. The Kolmogorov-Smirnov test was used to calculate the normality of the data. Students' CTSs levels comprised several categories seen in (Ismail et al., 2018). The categories are very weak (VW, score 0-19), weak (W, score 20-39), sufficient (S, score 40-59), good (G, score 60-79), and excellent (E, score 80-100).

Results

The present work is intended to develop teaching-learning materials that incorporate the concept of DL and metacognitive knowledge. Provided in the following are the validity data, practicality data, and effectiveness of the combination of DL and metacognitive strategies for enhancing students' CTSs.

Define

This step was started by interviewing students and teachers to identify the learning needs. According to the interview, several learning models have been applied in the class. However, the DL model was yet implemented. The students mostly listen to lectures, and not all teachers have comprehended metacognitive learning. Student evaluation tests mainly examine the C1-C3 level. The students have high learning motivation, and they are used to studying via reading, memorizing lessons, summarizing the lesson, and working on multiple-choice tests. Ultimately, the students find it challenging to complete problem-solving tests and other tests requiring high analytical skills, such as creative thinking. All of these conditions underpin the process of designing the teaching-learning materials (including lesson plans, student worksheets, and CTST) for the genetic topic.

The materials train students' skills to comprehend, analyze, formulate, and predict a phenomenon (specifically the ones from the lessons, i.e., structures and functions of gen, DNA, chromosome, and protein replication and synthesis). The students' needs, if correlated with the metacognition goals, focus on three knowledge: declarative, procedural, and conditional. The process started from delivering the lesson to more complex steps, i.e., explaining, comprehending, analyzing, and predicting phenomena in different contexts.

Design

Designing Lesson Plan by Implementing DL Model Combined with MKS

In the present work, the lesson plan was developed by providing DL-based instructions to the students; these instructions integrate metacognitive knowledge levels. Steps in designing the lesson plans follow the DL model, namely (a) stimulation (provision of responses to students), (b) problem statement (problem identification), (c) data collection, (d) data processing, (e) verification, and (f) generalization (conclusion drawing). The metacognition knowledge in the lesson plan includes declarative, procedural, and conditional knowledge.

The integration step was started by providing students with pictures related to the lesson. All students were expected to ask questions and correlated the pictures with the topic. In the identification step, all students should state the problem correctly. The students were asked several metacognitive questions stated in the student worksheets. During the data collection step, all students were assigned to find out learning resources; they were also asked to correlate (using declarative knowledge) the problems with theories and concepts they learned. All students completed questions regarding the procedural and conditional knowledge in the data processing step. In this step, the students demonstrated declarative knowledge to work on tasks requiring procedural and conditional knowledge. Theories and concepts were also applied to solve problems. That way, the students were able to determine the appropriate time and rationales of using strategies to prove theories and problem-solving concepts. The last two steps, i.e., verification and generalization, were carried out during the class discussion.

Student Worksheet Design

The development of student worksheets (SW) focused on giving students some problems regarding the lesson, i.e., genetics. These problems are primarily conceptual and contextual. Further, the problems are in the form of questions based on declarative, procedural, and conditional knowledge. The questions were arranged systematically following the order of the concepts. Declarative questions cover several interrelated concepts; this helps students deal with misconceptions. Upon working on the declarative questions, the students began working on procedural questions. Conditional questions revolving around contextual problems in different settings were asked to the students after ensuring that the students can accomplish the procedural questions.

Declarative questions in the student worksheets aim at reinforcing students' mastery of the concepts of genetics. These questions consisted of factual and conceptual questions. Factual questions ask students several terminologies and specific elements of the lesson, while the conceptual questions test students' mastery of theories, models, and structures regarding genetics. Declarative questions were arranged based on the cognitive levels C1 and C2, i.e., memorizing, determining, and explaining. Procedural questions are questions about correct and appropriate procedures. Conditional questions seek to test students' problem-solving regarding a phenomenon, condition, and situation in real-life contexts that correlate with the topic covered in the present work.

CTST Design

All items in the pre and post-tests were based on the skills of a critical thinker. The critical thinking tests or CTST are in the form of essay tests. The Waston and Glasser indicator was used as the indicator of critical thinking (Watson &

Glasser, 1994). The aspects of that indicator are (1) inference (skills to distinguish which one is correct and which one is incorrect), (2) introduction to assumptions, (3) deduction or skills to determine specific conclusions that require a learner to follow information in questions or premises, (4) interpretation or the skills to consider facts and generalize conclusions based on particular data, and (5) evaluation or skills to distinguish strong and weak arguments (relevant or irrelevant). A total of forty CTST items were designed and used to measure students' CTS. Each test has a four-scaled score, ranging from 0 to 3.

Develop

Three experts and one practitioner validated the teaching-learning materials. Provided in Table 1 below is the feedback.

Table 1. Feedbacks by Instructional Tools Expert

Instructional tools	Experts' feedback
Lesson plan	• Clarify the combination of the DL model and metacognitive strategies. • The observation sheets and student worksheets should follow the syntax of DL.
Student worksheets	• Please improve the indicators and the operational verbs to match with that of the HOTS. • Please improve the construction of declarative and procedural questions to differentiate these from lower-order thinking skills. • Please generate more contextual conditional questions so that the questions examine students' problem-solving skills.
Critical thinking tests	It is better to use the same score range (i.e., 3, 2, 1, and 0) for the essay test rubric

The feedback results were improved by the experts. Moreover, the final product was tested in two phases: limited scale and large scale. The limited-scale trial was conducted on 32 students, while the large-scale trial was conducted on 59 students. Table 2 below displays the product feasibility assessment results.

Table 2. Results of Product Validity Assessment

Instructional tools	Score	Category
Lesson plan	93.75	Very Feasible
Worksheet of student	95.00	Very Feasible
Test of critical thinking	95.00	Very Feasible
Limited-scale		
Learning implementation	83.82	Very Feasible
Students' activities	71.25	Feasible
Students' response	92.20	Very Feasible
Large-scale trial		
Learning implementation	88.60	Very Feasible
Students' activities	80.63	Very Feasible

Table 2 indicates that the developed instructional tools have met the validity criteria; therefore, a limited-scale trial was conducted. The limited-scale trial involved a practicality test of learning implementation, students' activity, and students' responses. As based on the indicator of students' activity, the developed instructional tools were deemed feasible to be implemented. On top of that, the score of learning implementation and students' responses indicates that the developed tool was highly valid to be tested in a large-scale trial. On the large-scale trial, the learning implementation score increased by 4.78; the students' activity score increased by 9.38, deemed as highly valid. The measurement results of students' CTSs on a large-scale trial were displayed in Table 3-5 and Figure 1. The results of mean, SD, Gain, and N-Gain of students' CTSs are displayed in Table 3, while Table 4 shows the students' CTSs level, ranging from "weak" to "excellent". On top of that, Table 5 depicts the effectiveness of the DL and MKS-integrated model. Figure 1 displays the achievement score for each indicator of CTSs.

Table 3. The mean, SD, Gain, and N-gain of CTSs

Data	N	Mean	SD	Gain	N-gain
Pre-CTSs	59	27.80	4.288	55.02	0.76
Post-CTSs	59	82.82	4.341		
Pre-CTSs of CS	27	28.52	4.794	54.85	0.77
Post-CTSs of CS	27	83.37	4.682		
Pre-CTSs of RS	32	27.19	3.891	55.16	0.76
Post-CTSs of RS	32	82.35	3.940		

As shown in Table 3, the students' CTSs increased significantly; the N-Gain value was at 0.76-0.77 or exceeded 0.70. In addition, the mean of students' CTSs increased at the end of measurement; the value was at 83.37 in CS, 82.35 in RS, and 82.82 overall. Such values indicate that the students' CTSs were deemed "excellent".

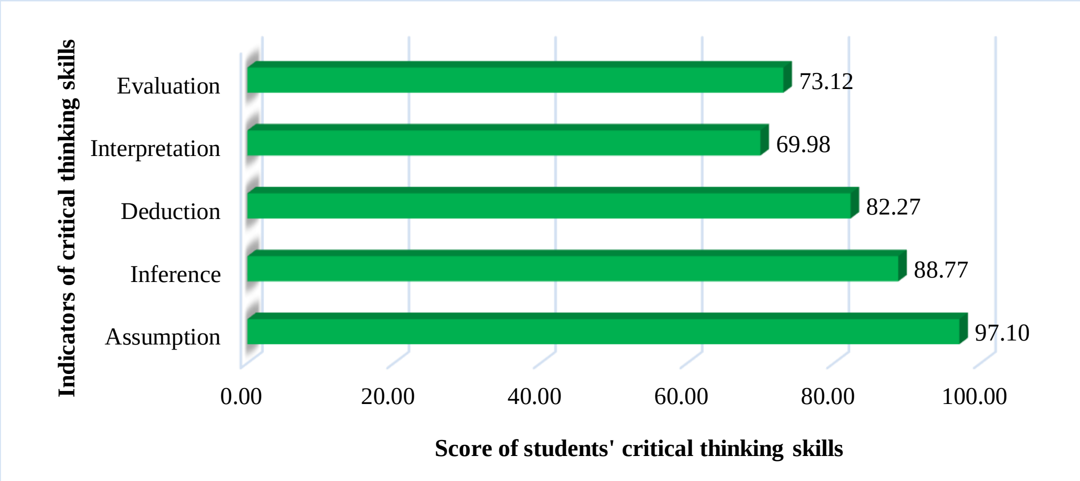

Figure 1. The score of each CTSs indicator

As displayed in Figure 1, the indicators of evaluation and interpretation were at the "good" category for overall score, while the other three indicators (assumption, inference, and deduction) arrived at the "excellent" category. That said, no indicator was recorded to be at "sufficient" up to the "very weak" category. The measurement of students' CTSs level is elaborated further in Table 4.

Table 4. Students' CTSs level

Level	% students	
	Pre-CTSs	Post-CTSs
VW	1.69	0
W	98.31	0
S	0	0
G	0	16.95
E	0	83.05

Based on Table 4, in the pre-CTSs, there were 1.69% of students who reached the very weak CTSs level of the total students. Most of the students (98.31%) arrived at a weak CTSs level. After implementing DL and MKS-integrated instructional tools, all students' results increased and there were no students in "very weak" - "sufficient" level. The students' CTSs level ranged from "good" to "excellent"; most of the students arrived at the "excellent" category. As many as 83.05% of students showed excellent CTSs levels and 16.95% of students arrived at the "Good" category. A related t-test was employed to test the effectiveness rate of the developed instructional tool. The data was first tested for normality, the results showed that $p = 0.20 > 0.05$ (pre-test data) and $p = 0.197 > 0.05$ (post-test data). The p-values of both pre-test and post-test indicate that the data is normally distributed. The related t-test can be used. Table 5 below shows its analysis results.

Table 5. Results of Related t-test of Instructional tool Effectiveness

Pair	Mean	SD	t	df	p	Cohen's d
Post-CTSs – Pre-CTSs	55.01119	5.23184	80.765	58	0.000	10.515

The p-value in Table 5 exceeded 0.05; such a value depicts that the developed instructional tool significantly enhances students' CTSs. Cohen's d value indicates a strong effect.

Discussion

The developed instructional tool that applies Discovery Learning (DL) and Metacognitive Knowledge Strategy (MKS)-integrated model is proven to enhance the students' CTSs successfully. In addition to that, the instructional tool has met the validity and practicality criteria. Based on actual implementation in the classroom, the instructional tool was deemed effective to enhance students' CTSs. In an effort to implement new innovations in learning, previous studies have incorporated the DL method and MKS method, respectively, in the learning process. The present study has successfully developed an instructional tool that combines both methods. Three experts and a practitioner validated the developed tool; the results are deemed valid (see Table 1). The instructional tool has fulfilled particular objectives and characteristics; it also has met the criteria of validity and effectiveness (Pandiangan et al., 2017) according to the expert validators (Murgado-Armenteros et al., 2012). Despite that the instructional tool has met the validity criteria, a limited-scale trial is required to validate the developed tool's feasibility further to be implemented in an actual classroom. The limited-scale trial aimed to validate learning implementation criteria, students' activity, and students' responses.

Moreover, a large-scale trial was also implemented to test the effectiveness of the instructional tool. As the findings suggest, the instructional tool has generated significant positive effects on the students' CTSs. Most of the students achieved an excellent level of CTSs (see Table 3). The comparison of students' CTSs level pre- and post-treatment indicates a significant difference. Thus, it is proven that the DL and MKS-integrated instructional tool is the suitable combination to enhance students' CTSs level. The DL method aims to incorporate assignments that demand the students to express their ideas in a better way (Alfieri et al., 2011). Previous studies have shown that the lack of guidance in the DL method had caused its implementation to be less optimal in supporting the students' cognitive process. Instead, the students felt frustrated and overwhelmed by the "cognitive burden"; in some cases, such problems caused misconception (Kirschner et al., 2006), and superficial thinking (Yuan et al., 2017). The combination of DL and MKS methods is capable to tackle the problems and enhance the students' CTSs. The increase in student CTSs is high, which is indicated by the n-gain value of 0.76.

The DL method indeed influences the students' critical thinking (Noer, 2018). The incorporation of challenging problem-solving assignments aims to increase the students' reasoning ability and critical thinking skills. However, such a method lacks systematic guidance to the students' thinking structure. The DL method only provides guidance for the students if needed. On the other hand, the metacognitive method is capable of boosting students' performance in CTSs. The MKS aids in optimizing the students' discovery process in learning by focusing on the knowledge. With adequate knowledge, students can perform more optimally in their critical thinking process. The focus on metacognitive skills aids the students to enhance their problem-solving skills, helps create a helpful learning experience, and influences the students' performance. Such results inspire the present study to integrate both methods to compensate for the DL method's lack of systematic guidance.

The present study accommodates DL's lack of optimality through the incorporation of assignments in MKS-based SW that guides the student to think critically and systematically. MKS incorporates three core elements that help students develop their CTSs: declarative knowledge, procedural knowledge, and conditional knowledge (Veenman et al., 2006). In the meantime, DL is a constructivist learning method that demands the students' effort to construct their knowledge. By DL, students can associate new phenomena to their pre-developed scheme of thinking. The scheme is referred to as an individual's mental abstraction used to comprehend a matter, find out any possible alternatives, or solve problems. During the learning process that implemented the developed tool, students can develop or change their pre-existing scheme. In addition, the students undergo an assimilation process of new experiences they discover; such a process keeps the students from having misconceptions in learning. The developed instructional tool involves students' worksheets (SW) as an example of the teacher's initial external guidance (Van Merriënboer, 1997). It is the initial phase that aids the student to apply CTSs in solving problems and achieving learning success. SW is designed in ways that the student acquires new experiences through MKS-based questions (declarative, procedural, and conditional). The students' knowledge is placed into a pre-existing structure of concept; this way, they are able to develop the concepts into new thoughts.

The developed SW consists of questions that are controlled systematically. The SW incorporates metacognitive knowledge with questions that show the correlation between declarative and procedural concepts. The declarative questions avoid too complex concepts that can lead to misconceptions in thinking. After successfully answering the declarative questions, students can then proceed to procedural and conditional questions. The students employ their declarative knowledge (knowledge on "what" and "why") to comprehend procedural knowledge ("why") and conditional knowledge ("how"). The conditional questions aim to guide the students to apply their procedural knowledge to different knowledge conditions (conditional). On top of that, discovery learning enables the students to discover a piece of information and apply it in different contexts. That said, the combination of DL and MKS methods is proven to direct students to adapt a systematic thinking process from conceptual knowledge to procedural knowledge and apply the knowledge in different conditions. In the DL method, the students learn to discover a piece of new information to be applied as a solution in different conditions. In addition to finding a solution, the students are guided to think critically and systematically. The whole process aims to direct the students' CTSs in ways that the students can comprehend the knowledge at a conceptual and procedural level and apply such knowledge in different conditions.

In DL, students must have pre-existing knowledge to construct new knowledge done by combining the pre-existing knowledge and new pieces of information that they acquire. Declarative knowledge is represented by "what" questions that direct students' critical thinking patterns (Zandvakili et al., 2019). The declarative knowledge is seen as the initial phase of development for procedural knowledge, particularly when the students apply the new knowledge that contrasts with previously adopted strategies (Carr et al., 1994). As the second element of MKS, procedural knowledge enables the students to think procedurally to discover new knowledge in the DL method. As the procedural questions

(Zandvakili et al., 2019), "why" questions enable the students to develop their CTSs. This way, the students must be able to elaborate, analyze, and solve problems. Moreover, conditional "how" questions focus on the students' ability to analyze and evaluate; the students are trained to solve problems in different conditions. Such WH-based questions are appropriate to develop CTSs (Sloan, 2010). This supports the argument of the study that the combination of DL and MKS methods helps students to hone their CTSs.

Several studies have employed a metacognitive strategy to improve the students' metacognitive knowledge. For instance, Radmehr and Drake (2020) implemented a metacognitive strategy to improve metacognitive knowledge. Moreover, a study by Susantini, Indana and Isnawati (2018) applies a metacognitive strategy to teach new learning strategies to the students. Another study displays that the combination of MKS and other strategies (e.g., inquiry and cooperative) is able to improve metacognitive knowledge (Syahmani et al., 2021) better than the MKS method only in improving collaboration ability (Susantini, Sumitro, et al., 2018). The present study embarks on different focuses towards the combination of MKS and DL methods to enhance students' CTS. The study focuses on CTS as a crucial element of education in class to improve students critical thinking. The incorporation of the developed tool is able to enhance students' CTS. The metacognitive method is not only related to knowledge, but also to the act of thinking and remembering. The DL method is more effective if combined with MKS (Mandrin & Preckel, 2009); the results are more effective than the DL method by itself (Singer & Pease, 1976). That said, the DL method itself is not as effective to be implemented to the students (Kettanurak et al., 2001; Kirschner et al., 2006; Mayer, 2004); it somewhat confuses the students (Dalgarno et al., 2014). The present study aims to tackle the weakness in the DL method. The combination of MKS and DL assists the students to think critically and learn systematically.

In the DL method, students are burdened with many procedures. In the meantime, the metacognitive strategy involves procedural knowledge that the students experience after the declarative knowledge. DL aids the students in constructing their knowledge. That said, the students can apply the correct discovery process to incorporate procedural knowledge in the learning process. Students must first understand procedural knowledge to generate new knowledge in different conditions (Chase & Abrahamson, 2018). Such a process is assisted by integrating MKS into the learning process, as the MKS also involves conditional knowledge. The construction process of students' metacognitive knowledge occurs during cognitive conflicts in small-scale group discussions. In such a setting, declarative, procedural, and conditional knowledge is nurtured and developed. This is in line with a study by Aktaş and Ünlü (2013) that small-scale groups effectively enhance students' CTS. In addition, the study involves 32 students (in RS) and 27 students (in CS), an appropriate number for the implementation of DL (Mukherjee, 2015). In such a setting, the MKS-based questions guide the students to think systematically; therefore, the students' discussions are more guided and the students are no longer confused about what they should learn and do.

Based on the implementation of the developed tool, 83.05% of the students arrived at excellent CTSs level. As based on the findings, the combination of the DL and MKS methods is appropriate in enhancing the students' CTSs. The appropriate integration and the incorporation of a proper number of students in class and small groups are supportive of the study.

Conclusion

This study concludes that the combination of Discovery Learning (DL) and Metacognitive Knowledge Strategy (MKS) can enhance the students' CTSs. It is reflected from the students' results that no one showed a lower level of CTSs. DL combined with MKS was designed to make students active critical thinkers and independent learners. In this design, the students are facilitated to develop their knowledge and thinking skills by using six procedures: stimulation, problem statement, data collection, data processing, verification, and generalization, all of them running through metacognition knowledge (declarative, procedural, and conditional knowledge) to improve their critical thinking skills (assumption, inference, deduction, interpretation, and evaluation). The DL and MKS-combined instructional tool is valid based on the expert validation results. Moreover, the learning process' practicality was met based on the learning implementation, students' activity, and students' responses. The instructional tool's effectiveness is indicated by the students' CTSs reaching the excellent level, where it significantly increased from the pre- to the post-test.

Recommendations

The application of DL and MKS combination is recommended in biology classes to help teachers improve their strategies to empower student's CTSs. The biology teachers could implement the procedure of DL combined with MKS, where teachers' role in this method to assist students in learning, thinking, and change learning and teaching activity into a good environment. Future research may use a combination of DL and MKS to measure process skills, cognition, and affective learning outcomes. Combining DL with metacognitive regulation can also be done in the future to empower students' CTSs.

Limitations

This study does not explore how students' metacognitive knowledge contributes to their CTSs in the developed tool. This leaves enormous potentials for future research in exploring the matter and the contribution of the learning process towards students' achievement and learning motivation. This research also has not found the effectiveness of the combination of DL and MKS in empowering students' cognitive, process skills, and emotion of affective learning outcomes.

Authorship Contribution Statement

Nusantari: Conceptualization, design, data collection, analysis, writing original draft. Abdul: Conceptualization, data collection, writing original draft. Damopolii: Conceptualization, analysis, data curation, writing—review and editing. Alghafri: Writing—review and editing, supervision, final approval. Bakkar: Writing—review and editing, supervision, final approval.

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