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**TÍTULO:** El desarrollo de instrumentos de aprendizaje genético basados en metacognitivos en la escuela secundaria superior.

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**RESUMEN**: El propósito de esta investigación es desarrollar instrumentos de aprendizaje que produzcan metacognición de instrumentos de aprendizaje y un libro de texto basado en metacognitivos sobre la genética. Esta investigación es una investigación de desarrollo mediante el uso de Definir, Diseño, Desarrollo, Diseminación (modelo 4-D Thiagrajan). Tanto el descriptivo cualitativo como el cuantitativo se utilizaron en el análisis de datos. Los resultados de la investigación son productos de instrumentos de aprendizaje y libros de texto cuyas características de presentación corresponden al orden de la ciencia metacognitiva, que consiste en conocimiento declarativo, de procedimiento y condicional. La validación experta y el resultado de la práctica muestran que estos instrumentos han cumplido con los criterios: muy válidos y muy ideales.

**PALABRAS CLAVES:** Instrumentos de aprendizaje, conocimiento metacognitivo, concepto de genética.

**TITLE:** The development of metacognitive-based genetic learning instruments at Senior High School.

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**ABSTRACT:** The purpose of this research is to develop learning instruments that produce learning instrument metacognition and metacognitive-based text book about genetics. This research is a developmental research by using Define, Design, Development, Dissemination (4-D Thiagrajan model). Both of the qualitative and quantitative descriptive were used in data analysis. The results of the research are learning instrument product and textbook whose presentation characteristics correspond to the metacognitive science order, which consist of declarative, procedural, and conditional knowledge. The expert validation and precision result shows that these instruments have satisfied the criteria: very valid and very ideal.

**KEY WORDS:** Learning instruments, metacognitive knowledge, genetics concept

## INTRODUCTION.

Genetics is a study about genes, genes reproduction, genes expression, and genes heredity. The most difficult concept of genetics faced by the students is genes heredity. Students will be easy to understand if they have a knowledge about the connection among concepts which are related to systematically heredity concept in their cognitive structures. Nusantari (2014, p. 12) in her research states that the connections among concepts refer to genetics' subject material correlation such as: genes, the mitosis and meiosis cell division, splitting process and genetics recombination, Mendel's Laws and the formation of gametes. Other related connections that have to be counted in heredity concept are crossing over, nondisjunction, linked genes on chromosomes, autosomes, and gonosomes. Another concept which is difficult to understand is the correlation between evolution concept and mutation.

Students can understand the genetics concept structurally if the materials presentation are also in good structure. Thus, a teacher needs to rearrange the materials concept presentation in a learning process. The presentation can be conducted by presenting the genetics concept from lower level to the higher level and connecting a concept with other concepts.

The problem learning genetics in high school is students' difficulties in understanding the heredity concept and the other related concept. It can be seen from their learning result that their score in genetics concept are low. It corresponds to the statement of Susantini (2010, p. 21) that the genetics substance material is more difficult than virus and endocrine system. Molina, Reynier Israel Ramírez, et al. 2018; Cavallo, 1996) stated that most genetics main materials have abstract concepts. Furthermore, Esiobu & Soyibo (1995) reported that there are many evidences show that there are more students who are poor in genetics.

The result of a research about the analysis of student's difficulties in undertaking the genetics test shows that the students are difficult to determine gametes and genotypes, crossing over, do not understand the heredity patterns, the causes of various heredity, and the application. Based on limited interview with a Biology teacher, it can be informed that during learning genetics, the students have a hard time to understand the genetics subject material. As the result, these students continue to bring this issue in their college life. They face the same problems in genetics subject. That condition shows that the students are not success in arranging the structure of genetics concept that can help them to solve genetics problems. This issue has to be overcome through a learning that applies a metacognitive science.

Curriculum 2013 develop some former curricula as follows Competence-based Curriculum, 2004 Curriculum, and KTSP Curriculum in 2006 which integrated knowledge, skill, and attitude. Metacognitive domain is an additional domain in Bloom Taxonomy revision. A metacognitive knowledge is student's acquired knowledge about cognitive processes, knowledge that can be used

to control cognitive processes. As related to student's understanding toward a concept, the better the comprehension concept, the better the metacognitive knowledge for a problem solving, the better and the tidier the cognitive structure. (Liu, & Zhang, 2016).

stated that metacognitive consists of metacognitive knowledge and metacognitive regulation. Metacognitive knowledge is a knowledge used for thinking process management. It consists of three categories: knowledge of person variables, task variables, and strategy variables. Metacognitive is student's awareness about how s/he learns and his/her ability to determine the difficulty of a problem, ability to observe the level of self-understanding, the ability to use various information to achieve learning purposes, and the ability to determine his/her own learning achievement or in the other words, if a student is able to manage his/her knowledge consciously, so s/he has achieved a meaningful learning process for his/her own self.

A support statement said that metacognition generally means higher level thinking about how a learning task will be handled, and making plans on processes of observing and evaluating comprehension. Ozsoy et.al (2009) said that metacognitive language requires one to accurately and exactly define his/her thought or knowledge. An individual's ability in problem solving depends on effective use of his/her knowledge. If an individual does not have a decent perception about his/her knowledge, he/she can consider.

There are three kinds of metacognitive knowledge; declarative, procedural, and conditional knowledge (Rompayom et al, 2010). A metacognitive knowledge is student's acquired knowledge about cognitive processes, knowledge that can be used to control cognitive processes. Handel, M et. Al. (2013) stated that declarative strategy knowledge is the awareness of strategies, that is, the awareness that a certain strategy exists. Procedural knowledge describes how a strategy works effectively, and conditional knowledge helps to understand which strategies are useful for solving a certain task. The development of metacognitive knowledge starts in kindergarten and continues to

develop beyond adolescence over the entire lifespan as long as educational processes continue to challenge the learner (Veenman et al., 2006).

As related to student's understanding toward a concept, the better the comprehension concept, the better the metacognitive knowledge for a problem solving, the better and the tidier the cognitive structure.

Student's success in organizing his/her cognitive structure can be known by utilizing his/her metacognitive knowledge in problem-solving. Metacognitive knowledge is related with student's understanding toward a concept, the better the comprehension concept, the better the metacognitive knowledge for a problem solving, the better and the tidier the cognitive structure. It means that if his/her cognitive structure is unorganized, theoretically it can be assumed that student's knowledge and concept comprehension in problem-solving is low.

It is in accordance with a result of research by Rompayom, P., et. Al (2010) in Thailand Bangkok which entitled "Metacognitive Inventory Development to Measure Student's Metacognitive Knowledge related to Chemical Bonds Concept". The research developed test instrument in a form of essay questions to measure student's metacognitive language. The result shows that the developed test instrument based on metacognitive knowledge category is appropriate and qualified to measure student's ability in problem-solving.

Based on the result of the research above, I develop a metacognitive-based learning tool which is used for learning genetics science at Senior High School Students. The purpose of this research is to produce metacognitive learning instruments that can be applied in genetics learning in the classroom.

**DEVELOPMENT.**

**Method.**

This research is a developmental research to develop metacognitive-based genetics learning tool. The development model in this research is a 4D model adapted from Thiagarajan (1974), consists of define stage, design stage, development stage, and disseminate. However, since the product is launched and implemented in broader scope, so the disseminate stage were not executed, and is ended on the development stage.

The instrument used in this research are needs analysis questionnaire for biology teacher at initial observation stage, expert validation sheet (material expert validator, learning expert, and Biology Teacher as practitioners), student's response questionnaire to respond the learning instruments by its language, content, and material. The data collecting technique is conducted in three stages which are: observation stage, development stage, and also small as well as large group experiment. The data collected was analyzed by using qualitative descriptive method. The revision suggestions from expert are explained narratively. The data of metacognitive-based learning instrument are exposed in Gutman Scale (Range: Very Good, Good, Fair, Poor, and Very Poor with scoring: 1-5) with interpretation: Very Good (*Sangat Baik/SK*) : 5, Good (*Baik/B*) : 4, Fair (*Cukup/C*) : 3, Poor (*Kurang/K*) : 2, Very Poor (*Sangat Kurang/SK*) : 1, then, the range score of each aspect is counted with following formula:

$$X = \frac{\Sigma^{x}}{n}$$

Notes:

$X$ = Average score

$\Sigma^{x}$ = Total score

n = Total reviewer

Changed the score of each quality aspect to quantitative marks according to scoring criteria. Marks conversion description of each aspect criteria can be seen in Table 1 below.

**Table 1: The Scoring Criteria of Metacognitive Knowledge Instrument Validity with Category: very good validity to very poor validity**

| No | Score Range (i) | Kategory |
|---|---|---|
| 1. | $X > M_i + 1{,}5\ SB_i$ | Very Good Validity |
| 2. | $M_i + 0{,}5\ SB_i < X \leq M_i + 1{,}5\ SB_i$ | Valid |
| 3. | $M_i - 0{,}5\ SB_i < X \leq M_i + 0{,}5\ SB_i$ | Fair Validity |
| 4. | $M_i - 1{,}5\ SB_i < X \leq M_i - 0{,}5\ SB_i$ | Poor Validity |
| 5. | $X \leq M_i - 1{,}5\ SB_i$ | Very Poor Validity |

(Sudijono, 1997).

Notes:

Mi = Ideal Mean (*Mean Ideal*)

= (1/2) (ideal highest score + ideal lowest score

SBi = Ideal Standard Deviation (*Simpangan Baku Ideal)*

= (1/3) (1/2) (ideal highest score – ideal lowest score)

Ideal highest score = total of criteria item x the highest score

Ideal lowest score = total of criteria x the lowest score

Next, counted the ideal percentage of metacognitive science instrument with following formula: P= Average score X 100%.

Highest score

The ideal percentage formula is counted based on Likert scale as follows:

**Table 2. Percentage scale of Ideal Scoring toward the the Quality of Metacognitive Science Learning Instrument**

| No | Interval | Criteria |
|---|---|---|
| **1.** | 81 % - 100 % | Very Good |
| **2.** | 61 % - 80 % | Good |
| **3.** | 41 % - 60 % | Fair |
| **4.** | 21 % - 40 % | Poor |
| **5.** | 0 % - 20 % | Very Poor |

Student's response sheets were composed based on Gutman's scale in questions format. The questionnaire is ranked with 0 -1. 0 for the answer "No" and 1 for the answer "yes".

To investigate student's responses toward learning instrument, the following formula had been used:

$$P = \frac{\text{Average score}}{\text{Highest score}} \times 100\%$$

Notes:

P: respondent's answers percentages

F: total of respondent's answers

N: total respondents

**Result and discussion.**

The result and the development of this research are explained based on four D model stages. Since the product is launched and implemented in broader scope, so the disseminate stage was not executed. Therefore, there are only three stages: define, design, and development stage.

**Define Stage.**

An initial observation is conducted in the define stage. The data about school's condition analysis, student's characteristic analysis, and teaching material context are gained on the initial observation. All the data are used to support the composing and developing process of metacognitive-based genetics learning instrument. The data are collected through systematic interview with Biology Teacher at the $12^{th}$ Grade, and direct interview with students. The systematic interview was conducted by giving an initial observation interview questionnaire which consisted of: some questions related to the Curriculum 2013 comprehension, metacognitive measurement, and teaching material. Based on the initial observation result, it is known that the application of Curriculum 2013 in all observed schools were not running well and the learning process did not fit student's learning need.

Genetics learning by applying metacognitive knowledge is composed the genetics concept in a form of questions hierarchically, based on cognitive domain level from C1 – C6 and are grouped into three knowledge dimension which are: declarative, procedural, and conditional knowledge. This learning process that is guided by focusing on genetics concept order is expected to facilitate students in understanding genetics subject material so the learning purposed of Curriculum 2013 can be achieved. Therefore, the learning instruments such as text book, metacognitive knowledge instrument are developed as a guidance in genetics learning process to organize student's cognitive structure and also as a measurement to determine student's metacognitive knowledge after she or he undertake genetics learning process that corresponds to the Curriculum 2013.

**Design Stage**

The design stage was conducted based on define stage results. The purpose of this stage is to design a metacognitive knowledge instrument which suit the steps of instrument development and also contain the components of metacognitive-based learning instrument that fits with define stage.

Therefore, it can produce a systematic metacognitive knowledge instrument designs and can be used to help students with knowledge mapping and also measure his/her metacognitive ability.

The design of metacognitive-based learning instrument is begun by formulating learning indicators which suits the basic competency of Curriculum 2013 syllabus. The next step is: specify the instrument's layouts.

**Table 3. The Design of Metacognitive Knowledge Instrument's Layout**

| Knowledge Dimension | Core Competency | Basic Competency | Material | Indicators | Questions' Indicators | Questions | Notes |
|---|---|---|---|---|---|---|---|
| Declarative | | | | | | | |
| Procedural | | | | | | | |
| Conditional | | | | | | | |

Then, formulate the questions items based on the instrument's layout. Next, specify the scoring guidelines. Scoring guidelines is a guideline that contains some criteria used to determine student's work result score. The score then is defined as a mark that is specified on each answer aspect of a question that contains lowest score and highest score range.

The next step is text book development based on the developed instrument that obeys a text book development rules. The order of concept presentation corresponds to the genetics concept orders which are used to compose metacognitive learning instrument.

**Development Stage**

The purpose of the development stage is used to develop a metacognitive-based learning tool at genetics subject material. It is conducted by developing the first product design through validation which consists of questions development format in metacognitive-based learning instruments that consist of declarative, procedural, and conditional questions development format. The developed metacognitive instrument becomes a reference in developing Student's Work Sheet and Genetics Text Book.

Metacognitive-based genetics learning instruments development stage is called *Draft I* (First Draft) that is validated by 2 expert lecturers. The material expert lecturer validates the consistency of basic competency with indicators and the authenticity of material. Meanwhile, learning expert lecturer validates the consistency of material based on metacognitive knowledge aspects. The result of validation produces a test result revision by an expert.

On the next step, the revision is validated by a Biology teacher as a practitioner. Some advices from the practitioner are taken as a basic revision instruments that produce a practitioner test result revision. Furthermore, to find and assess overall student's responses and opinion toward content and language quality, these learning instruments were tested on small group as much as 15 students and large group as much as 28 students.

The validation result of metacognitive based learning instruments on genetics subject material and some suggestions by subject material expert, learning expert, and Biology teacher are explained in Table 4, 5, 6, 7, 8, 9, 10.

Then, the validation results are improved and discussed on the Focus Group Discussion activity. The activity is undertaken by 3 lecturers and 2 Biology teachers. Involved lecturers are two expert lecturers from Genetics field and 1 expert lecture from learning design field. The purpose of Focus Group Discussion is to gain a deeper input from validator and practitioner.

**Table 4. The Content Validation Result of Metacognitive-Based Learning Instruments by Material Expert**

| Components | Suggestions | Revision |
|---|---|---|
| 1. Metacognitive instruments are composed appropriately with competencies (urgency, relevancy, usage, and continuity) | Metacognitive instruments are composed appropriately with competencies (urgency, relevancy, usage, and continuity) | Metacognitive instrument are appropriate with competencies (urgency, relevancy, usage, and continuity) |
| 2. The instruments are composed appropriately with learning indicators | Metacognitive learning instruments are appropriate with indicators refer to Basic Competency | Metacognitive learning instruments have been composed appropriately with indicators refer to Basic Competency |
| 3. The instrument material contents are appropriate with expected thinking ability stages | The material content of metacognitive instruments are appropriate with school's level and applicable curriculum | The instrument's content material is appropriate with curriculum and expected thinking ability |
| 4. The metacognitive instruments are using questions words or imperative that should be answered by explanation. | It should use question words or imperative corresponds to the action verbs | The questions and imperative have been revised corresponds to the action verbs |
| 5. Expected questions and answers limits are appropriate with metacognitive learning instruments | The answers correspond to the types of questions (declarative, procedural, and conditional) | The punctuation marks have been revised and is consistent with standardized Indonesian language |
| 6. There are some clear instructions about how to answer the questions on learning instruments. | There are some clear instructions but less systematic | The instructions have been written clearly and systematically |
| 7. The metacognitive instruments are equipped with scoring guidelines | The scoring guidelines is good enough | The scoring guidelines is good |
| 8. The sentences formula in metacognitive instruments are communicative | The questions is communicative enough | The questions is communicative |
| 9. The question items are in standardized Indonesian Language | The language used is good enough, however the use of the terms is need to be revised | The questions in the instruments are in standardized Indonesian Language |

| | | |
|---|---|---|
| 10. The metacognitive instruments do not use ambiguous words | Good enough, however there are some ambiguous questions | There are no ambiguous questions on the instruments |
| 11. The metacognitive instruments do not use taboo words | The language used is good because it is a standardized Indonesian language | It uses standardized Indonesian language |

**Table 5. The Content Validation Result of Metacognitive-Based Text Book by Material Expert**

| Components | Suggestion | Revision |
|---|---|---|
| 1. Metacognitive text book is composed appropriately with competencies (urgency, relevancy, usage, and continuity) | Metacognitive text book is composed appropriately with competencies (urgency, relevancy, usage, and continuity) | Metacognitive text book is appropriate with competencies (urgency, relevancy, usage, and continuity) |
| 2. The text book is composed appropriately with learning indicators | Metacognitive text book is appropriate with indicators refer to Basic Competency | Metacognitive text book has been composed appropriately with indicators refer to Basic Competency |
| 3. The text book contents is appropriate with expected thinking ability stages | The material content of metacognitive text book is appropriate with school's level and applicable curriculum | The text book's content material is appropriate with curriculum and expected thinking ability |
| 4. There are some clear instructions about how to answer the questions on text book | There are some clear instructions but less systematic | The instructions have been written clearly and systematically |
| 5. The question items in text book are in standardized Indonesian Language | The language used is good enough, however the use of the terms is need to be revised especially on instruments and text book | The questions in the text book are in standardized Indonesian Language |
| 6. The metacognitive text book does not use ambiguous words | Good enough, however there are some ambiguous questions | There are no ambiguous questions on the text book |
| 7. The metacognitive text book does not use taboo words | The language used is good because it is a standardized Indonesian language | It uses standardized Indonesian language |

**Table 6. Validation Results of Metacognitive-Based Learning Instruments by Learning Expert.**

| Components | Suggestions | Revision |
|---|---|---|
| 1. The consistency of metacognitive instruments design with metacognitive knowledge aspects (declarative, procedural, and conditional) | The consistency of metacognitive instruments design with metacognitive knowledge aspects (declarative, procedural, and conditional) is good enough | The metacognitive learning instruments design is appropriate with metacognitive knowledge aspects (declarative, procedural, and conditional) |
| 2. The connections among concepts in metacognitive learning instruments are based on declarative, procedural, and conditional knowledge categories | The connections among concepts in metacognitive learning instruments are based on declarative, procedural, and conditional knowledge categories are good enough but it has to be clarified | It shows a clear connection among declarative, procedural, and conditional knowledge |
| 3. Metacognitive learning instruments reveal the connections among concepts | Metacognitive learning instruments have revealed the connections among concepts enough | Metacognitive learning instruments have revealed the connections among concepts |
| 4. Metacognitive learning instruments concern toward a systematic thinking stages | Metacognitive learning instruments have enough concern toward a systematic thinking stages | Metacognitive learning instruments have concerned toward a systematic thinking stages |
| 5. Metacognitive-based learning instruments can help students with knowledge-mapping | The instruments are good enough to help students with knowledge-mapping but they are needed to be revised | The instruments can help students with knowledge-mapping |

**Table 7. Validation Results of Metacognitive-Based Text Book by Learning Expert**

| Components | Suggestions | Revision |
|---|---|---|
| 1. The consistency of metacognitive text book design with metacognitive knowledge aspects (declarative, procedural, and conditional) | The consistency of metacognitive text book design with metacognitive knowledge aspects (declarative, procedural, and conditional) is good enough | The metacognitive learning text book design is appropriate with metacognitive knowledge aspects (declarative, procedural, and conditional) |
| 2. The connections among concepts in metacognitive text book is based on declarative, procedural, and conditional knowledge categories | The connections among concepts in metacognitive text book is based on declarative, procedural, and conditional knowledge categories are good enough but it has to be clarified | It shows a clear connection among declarative, procedural, and conditional knowledge |
| 3. Metacognitive text book reveals the connections among concepts | Metacognitive text book has revealed the connections among concepts enough | Metacognitive text book has revealed the connections among concepts |
| 4. Metacognitive text book concerns toward a systematic thinking stages | Metacognitive text book has enough concern toward a systematic thinking stages | Metacognitive text book has concerned toward a systematic thinking stages |
| 5. Metacognitive-based text book can help students with knowledge-mapping | The text book is good enough to help students with knowledge-mapping but they are needed to be revised | The text book can help students with knowledge-mapping |

**Table 8. Validity of Metacognitive-Based Learning Instruments on Genetics Subject Material,**

**Each Aspect is Based on Validation Result by Material Expert and Learning Expert**

| No. | Aspects | Marks | Score Range | Category |
|---|---|---|---|---|
| 1. | Content | X = 16,5 | X > 16,05 | Very Valid |
| 2. | Construction | X = 13 | X > 12 | Very Valid |
| 3. | Language | X = 17,5 | X > 16,05 | Very Valid |
| 4. | Metacognitive | X = 20 | X > 19,95 | Very Valid |

**Table 9. Validity of Metacognitive-Based Text Book on Genetics Subject Material, Each Aspect is Based on Validation Result by Material Expert and Learning Expert.**

| No. | Aspects | Marks | Score Range | Category |
|---|---|---|---|---|
| 1. | Content | X = 17 | X > 16,05 | Very Valid |
| 2. | Construction | X = 14 | X > 12 | Very Valid |
| 3. | Language | X = 17 | X > 16,05 | Very Valid |
| 4. | Metacognitive | X = 21 | X > 19,95 | Very Valid |

**Table 10. The Ideality of Metacognitive-Based Learning Instruments on Genetics Subject Material, Each Aspect is Based on Validation Result by Material Expert and Learning Expert**

| No. | Aspects | Marks | Interval | Category |
|---|---|---|---|---|
| 1. | Content | 8 2% | 81 % - 100 % | Very Good |
| 2. | Construction | 85 % | 81 % - 100 % | Very Good |
| 3. | Language | 89 % | 81% - 100 % | Very Good |
| 4. | Metacognitive | 85 % | 61 % - 80 % | Good |

**Table 11. The Ideality of Metacognitive-Based Text Book on Genetics Subject Material, Each Aspect is Based on Validation Result by Material Expert and Learning Expert**

| No. | Aspects | Marks | Interval | Category |
|---|---|---|---|---|
| 1. | Content | 82,5 % | 81 % - 100 % | Very Good |
| 2. | Construction | 86,7 % | 81 % - 100 % | Very Good |
| 3. | Language | 87,5 % | 81% - 100 % | Very Good |
| 4. | Metacognitive | 80 % | 61 % - 80 % | Good |

**Table 12. Validity of Metacognitive-Based Learning Instruments on Genetics Subject Material, Each Aspect is Based on Biology Teacher's Assessment**

| No. | Aspects | Marks | Score Range | Category |
|---|---|---|---|---|
| 1. | Content | X = 18 | X > 16,05 | Very Valid |
| 2. | Construction | X = 13,5 | X > 12 | Very Valid |
| 3. | Language | X = 19 | X > 16,05 | Very Valid |
| 4. | Metacognitive | X = 22,5 | X > 19,95 | Very Valid |

**Table 13. Validity of Metacognitive-Based Text Book on Genetics Subject Material, Each Aspect is Based on Biology Teacher's Assessment**

| No. | Aspects | Marks | Score Range | Category |
|---|---|---|---|---|
| 1. | Content | X = 18,5 | X > 16,05 | Very Valid |
| 2. | Construction | X = 14 | X > 12 | Very Valid |
| 3. | Language | X = 18 | X > 16,05 | Very Valid |
| 4. | Metacognitive | X = 23 | X > 19,95 | Very Valid |

**Table 14. The Ideality of Metacognitive-Based Learning Instruments on Genetics Subject Material, Each Aspect is Based on Biology Teacher's Assessment**

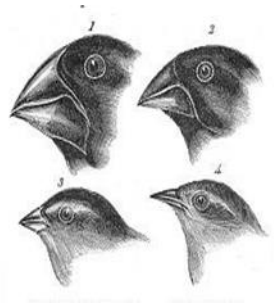
| No. | Aspects | Marks | Interval | Category |
|---|---|---|---|---|
| 1. | Content | 88 % | 81 % - 100 % | Very Good |
| 2. | Construction | 90 % | 81 % - 100 % | Very Good |
| 3. | Language | 90 % | 81 % - 100 % | Very Good |
| 4. | Metacognitive | 90 % | 81 % - 100 % | Very Good |

**Table 15. The Ideality of Metacognitive-Based Text Book on Genetics Subject Material, Each Aspect is Based on Biology Teacher's Assessment**

| No. | Aspects | Marks | Interval | Category |
|---|---|---|---|---|
| 1. | Content | 90 % | 81 % - 100 % | Very Good |
| 2. | Construction | 87 % | 81 % - 100 % | Very Good |
| 3. | Language | 95 % | 81 % - 100 % | Very Good |
| 4. | Metacognitive | 88 % | 81 % - 100 % | Very Good |

**Table 16. The Example of Metacognitive-Based Learning Instruments at Genetics Subject Material.**

| Concept | Declarative | Procedural | Conditional |
|---|---|---|---|
| Genetic Material | A gene is the smallest unit of genetic substances<br>a. Explain the function of a gene<br>b. How does a gene differentiate from an allele<br>c. Explain the relationship between a gene and a DNA<br>d. Explain the relationship between a gene and a chromosome | Look at the following figures<br><br>Based on the figures above, explain the structure of a chromosome from the smallest to the largest molecule. | Assess the following statements, true or false:<br>a. Based on the relationship of genes; DNA and chromosome, genetic material that have a role in eukaryotic living organism hereditary is DNA<br>b. Genetic material in a prokaryotic living organism is DNA not a chromosome<br>c. The genetic material in viruses is DNA or RNA |
| Mendel Law | Explain:<br>a. What is Mendel I and Mendel II?<br>b. How is the correlation between Mendel Law I and Monohybrid Cross?<br>c. How is the correlation between Mandel Law II and Dihybrid Cross?<br>d. Where does Mendel Law I and Mendel Law II occur? | You have crossed-pollinated a plant (tanaman berbiji bulat berwarna kuning/BBKK) that has yellow round seed that is dominant toward a plant that has green wrinkled seed (tanaman berbiji kisut berwarna hijau/BBKK), how is the ratio of F2, if the offspring plant (F) is crossed-pollinated with the same variety? | When you have crossed-pollinated a plant (tanaman berbiji bulat berwarna kuning/BBKK) that has yellow round seed that is dominant toward a plant that has green wrinkled seed (tanaman berbiji kisut berwarna hijau/BBKK), can we get a plant that has green wrinkly seed as the offspring plant? Explain the reason |
| Meiosis Splitting | 1. Explain the correlation between meiosis splitting and Mendel Law I and also Mendel Law II!<br>2. Explain the correlation between | In humans, men and women has the same amount of chromosome which are 46 chromosomes, when they are married and get a child, the child's chromosomes | A gamete in human is splitting up. When it reaches anaphase I in meiosis I, the homologues chromosomes fail to separate. Then the gamete fuses with |

| | | | |
|---|---|---|---|
| | meiosis splitting and heredity in eukaryotic living organism! | are still 46. Analyze why that is happened | other gamete during fertilization. Predict how the possibility of the zygote created from that fertilization process is! |
| Protein Synthesis | Explain the definition of protein synthesis! Explain what is codon and anticodon | Gene expression is a converted process of a gene into an amino acid sequence that occurs during the synthesize of protein, which are transcription and translation Explain the details of the transcription and translation process | A Biology expert is testing a protein synthesis process in a cell. The expert finds a peculiar thing in the translation result amino acid sequence. It is assumed that a mutation occurred in the third codon sequence. According to you, what is the effect of the codon mutation? |
| Genes Mutation and Evolution | What is gene mutation? Is the mutation advantageous or disadvantageous? What are the benefits of mutation in evolution process? | On his journey to Galapagos, Darwin found nine species of finches that have diversity in their beaks based on their habitat  Explain how the nine-species beak are formed? Are finches adapting them selves with their habitat or it is caused by natural selection? | A population A is on a territory but then encounter a geographic isolation because of natural disaster. After decades, the population A has shown a differentiation or phenotype changes from its original population. Explain, how it can be called as an evolution process? There are 8 species of mice in America, each of them inhabits a territory in Atlantic Coast. They have various colors. All eight species adapt with the inhabited soil colors. P.p. subgriseus species live on dark soil and |

| | | | |
|---|---|---|---|
| | | | have dark fur. P.p leucocephalus species live on brilliant white sands and has light fur.<br>Analyze how the variation are formed in those 8 species because of gene mutation! |

**Table 17. The Result of Student's Responses Test towards Metacognitive-Based Text Book at Genetics Subject Material**

| Components | Responses Results | Category |
|---|---|---|
| 1. Genetics concept presentation on the text book clarify genetics concept comprehension | 85% | comprehensive |
| 2. The connections among concept on text book are explained clearly | 85 % | clear |
| 3. Figures and examples of the text book increase student's comprehension about genetics | 90 % | Very comprehensive |
| 4. The instruction of the questions is clear | 94 % | Very clear |
| 5. The use of standardized Indonesian Language | 95 % | Very Good |

**Table 18. The Result of Student's Responses Test towards Metacognitive-Based LKPD (Student's Work Sheet) at Genetics Subject Material**

| **Components** | **Responses Results** | **Category** |
|---|---|---|
| 1. Genetics concept presentation on Student's Work Sheet clarify genetics concept comprehension | 85% | comprehensive |
| 2. The connections among concept on Student's Work Sheet are explained clearly | 80 % | clear |

| | | |
|---|---|---|
| 3. Figures and examples of Student's Work Sheet increase student's comprehension about genetics | 90 % | Very comprehensive |
| 4. The instruction of the questions is clear | 94 % | Very clear |
| 5. The use of standardized Indonesian Language on Student's Work Sheet | 98 % | Very Good |

In Curriculum 2013, a metacognitive knowledge standard becomes a passing standard for Senior High School Students with some expectation that it can improve student's thinking ability. Metacognitive become one of parameters that has to be achieved by senior high school students in Curriculum 2013. Metacognitive parameter is considered as an important thing because it can support students learning achievement. Metacognitive will push student's ability in problem solving and develop their thinking skills higher.

The developed main instrument contains genetics subject material which is composed that fits concept order and is mapped based on knowledge dimension for a knowledge structure mapping as a measurement of genetics concept for $11^{th}$ Grade Students of Senior High School, and as learning evaluation tool that correspond to the Curriculum 2013.

The result of an assessment by learning design and material expert toward validity criteria shows that metacognitive-based learning instrument is in very valid criteria. Based on Biology teacher's assessment, the category of the metacognitive-based learning instrument is very valid. The result of an assessment by learning design and material expert toward instrument quality criteria show that metacognitive-based learning instrument is in very good criteria and the result of Biology teacher's assessment shows that category of metacognitive-based learning instrument is also very good.

As Coutinho (2007) shows knowledge refers to knowledge of cognition such as knowledge of skills and strategies that work best for the learner, and how and when to use such skills and strategies.

This research has developed a metacognitive knowledge instrument product in genetics subject material for Senior High School Students.

A similar research was conducted that develops a metacognitive knowledge instrument for Chemistry subject at middle school. The instrument was developed to extract declarative, procedural, and conditional knowledge.

Since the instruments measure a target that related to a high-level achievement category, so the developed test is in a form of essay test. The composed instruments then are validated by material expert and learning expert. Instrument validity review is based on the compatibility of the item questions with indicators, the correlation between concept, material presentation, the use of language and the instrument compatibility with metacognitive knowledge dimension.

This metacognitive learning instrument becomes a basic component in composing student's work sheet that can train their metacognitive ability in genetics subject.

The next is the composing of text book that compatible with an established thinking order in metacognitive learning instruments. The development of this text book is conducted by considering the organizing of material presentation that fit metacognitive knowledge order that are declarative, procedural, and conditional. It is started with presentation of declarative genetics concept, and presentation of procedural concept that contains problem and the way to solve it, and also conditional knowledge that contains techniques or strategies which have been chosen to solve a problem. Besides, the language use (Scientific Indonesian language), the substance of the text book is presented in order and step-by-step according to the order in metacognitive learning instrument. The information about theories, exercises, and tasks, also reflection activity are organized systematically. The organization of teaching material is conducted based on pedagogy principles that are reflected on systematic teaching material.

The result of text book development is very valid. The text book has different characteristic from the older one. Since the text book is composed from the easiest to the hardest hierarchy concept, only related concept is being presented. The unrelated concept was not presented because it may lead to the student's misconception. Furthermore, students are expected to solve the procedural problem which is discussed in the text book. The students also have to possess the concept that related to conditional knowledge so this text book plays its roles in explaining genetics.

The experiment on students shows that as much as 85% of students understand the material, the 85% of students stated that the correlation among concept is clear, there are 90% of students stated that genetic material can be understood, as much as 94% of students stated that they understand with the instruction, and 95% of students stated that the instruments and the text book use standardized Indonesian language.

The result of responses test showed that the students understood the questions order on student's work sheet and material order on student's text book. The LKP contains some questions that fall in three thinking ability categories. The first question is related to declarative knowledge that aims to recognize and understand that concept. The procedural questions are aimed to solve a problem to achieve genetics concept analysis and application ability. Students are expected to have some strategies to solve a procedural problem with a concept or a problem evaluation ability as an achievement including the text book that has been composed by regarding the easiest thinking order to the complex thinking order.

This research is expected to overcome student's difficulties in understanding genetic material, because many proves show that many students are poor in understanding genetics (Esiobu & Soyibo, 1995 in Susantini, 2010) as well as a research stated that students potentially have preparation in developing their metacognitive skill. However, in its actualization, students are failed to achieve metacognitive knowledge. The data shows that students' metacognitive knowledge is

poor. Therefore, learning process and guidance from their teacher are expected to attract students' actual zone (poor metacognitive knowledge) to the ideal zone (higher metacognitive knowledge)

The result of is very significant to improve students' thinking ability as it based on declarative, procedural, and declarative knowledge which consist of high order thinking questions. As the result of the research by Zohar, Anat, 1999 shows that metacognitive knowledge of thinking skills is essential for the design of high-quality new learning activities because the design process requires thinking about thinking skills as explicit goals of the learning activity. Furthermore, metacognitive knowledge of thinking skills is essential for systematic teaching of higher order thinking. Thus, the students are expected to learn with metacognitive knowledge design.

Students' achievement in organizing their cognitive structure can be seen from their way in utilizing their metacognitive language in problem solving, by finding concepts from reliable learning source. In addition, metacognitive knowledge is closely related to students' comprehension toward a concept. Metacognitive is student's awareness about how s/he learns and his/her ability to determine the difficulty of a problem, ability to observe the level of self-understanding, the ability to use various information to achieve learning purposes, and the ability to determine his/her own learning achievement or in the other words, if a student is able to manage his/her knowledge consciously, so s/he has achieved a meaningful learning process for his/her own self (Jonassen, 2000:14).

Based on the exposition above, it is obvious that metacognitive learning has its own excellences in the process of learning genetics. For that reason, this developing product can be used to improve students' higher thinking ability in Senior High School broadly.

**CONCLUSIONS.**

Based on the developing research, it can be concluded that this research produces metacognitive-based genetics learning instrument, text book, and student's work sheet at Senior High School. The

learning instruments product that consist of learning instrument, text book, student's works sheet on metacognitive-based genetics subject material for 11th Grade Natural Science Students are very valid and have a very good quality.

Furthermore, this learning tool can be used in learning genetics so student's metacognitive ability can be trained. It produces learning instruments that includes lesson plan, text book, and metacognitive learning instrument in a form of student's work sheet. The learning instrument also used as student's learning achievement evaluation tool at the end of the lesson.

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