

Table of contents

Volume 947

2018

◀ Previous issue Next issue ▶

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Preface

OPEN ACCESS 011001

Mathematics, Informatics, Science and Education International Conference (MISEIC)

+ Open abstract  View article  PDF

OPEN ACCESS 011002

Peer review statement

+ Open abstract  View article  PDF

Papers

OPEN ACCESS 012001

The Effect of Sodium Hydroxide Molarity on Strength Development of Non-Cement
Class C Fly Ash Geopolymer Mortar



A Wardhono

+ Open abstract  View article  PDF

OPEN ACCESS 012002

Kinetic Parameters of Thermal Decomposition Process Analyzed using a Mathematical
Model

A B D Nandiyanto, R Ekawati and S C Wibawa

+ Open abstract  View article  PDF

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012003

The Classification of Diabetes Mellitus Using Kernel k-means

M Alamsyah, Z Nafisah, E Prayitno, A M Afida and E M Imah

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012004

Iris Recognition Using Feature Extraction of Box Counting Fractal Dimension

C Khotimah and D Juniati

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012005

Gaussian Process Regression Model in Spatial Logistic Regression

A Sofro and A Oktaviana

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012006

Some Basic Properties of Uniformly Symmetrically Continuous (Real Valued) Functions on Metric Spaces

Manuharawati, D N Yunianti and M Jakfar

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012007

Student's Critical Thinking in Solving Open-Ended Problems Based on Their Personality Type

L D Fitriana, Y Fuad and R Ekawati

[+ Open abstract](#) [View article](#) [PDF](#)

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012008

Designing Tasks to Examine Mathematical Knowledge for Teaching Statistics for Primary Teachers

T Y E Siswono, A W Kohar and S Hartono

[+ Open abstract](#) [View article](#) [PDF](#)

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012009

The improvement of autism spectrum disorders on children communication ability with PECS method Multimedia Augmented Reality-Based

Taryadi and I Kurniawan

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OPEN ACCESS 012010

The Role of Self-Assessment in Foundation of Mathematics Learning

Masriyah

+ [Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012011

Multiple Sensing Application on Wireless Sensor Network Simulation using NS3

I F Kurniawan and R Bisma

+ [Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012012

Students' Creativity: Problem Posing in Structured Situation

I K Amalina, M Amirudin and M T Budiarto

+ [Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012013

Critical-Inquiry-Based-Learning: Model of Learning to Promote Critical Thinking Ability of Pre-service Teachers

S Prayogi, L Yuanita and Wasis

+ [Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012014

Students' Spatial Performance: Cognitive Style and Sex Differences

U Hanifah, D Juniati and T Y E Siswono

+ [Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012015

Designing PISA-Like Mathematics Tasks In Indonesia: Experiences and Challenges

Z Zulkardi and A W Kohar

+ [Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012016

High-Impact Aerobic and Zumba Fitness on Increasing VO₂MAX, Heart Rate Recovery and Skinfold Thickness

T J Suminar, N W Kusnanik and O Wiriawan

+ [Open abstract](#) [View article](#) [PDF](#)

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012017 

Students' Covariational Reasoning in Solving Integrals' Problems

N V Harini, Y Fuad and R Ekawati

[+ Open abstract](#) [View article](#) [PDF](#)

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012018

Students' Misconceptions on Properties of Rectangles

R W Ningrum, M Yulianti, D D Z Helingo and M T Budiarto

[+ Open abstract](#) [View article](#) [PDF](#)

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012019

Mathematics Literacy of Secondary Students in Solving Simultaneous Linear Equations

R S I Sitompul, I K Budayasa and Masriyah

[+ Open abstract](#) [View article](#) [PDF](#)

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012020

Teacher's Mathematical Communication Profile in Facilitating and Guiding Discussion

R Umami, I K Budayasa and St Suwarsono

[+ Open abstract](#) [View article](#) [PDF](#)

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012021

Improving Science Process Skills for Primary School Students Through 5E Instructional Model-Based Learning

N L Choirunnisa, P Prabowo and S Suryanti

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012022

Refractive Thinking Profile In Solving Mathematical Problem Reviewed from Students Math Capability

M Maslukha, A Lukito and R Ekawati

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012023

The Creativity of Reflective and Impulsive Selected Students in Solving Geometric Problems

R N Shoimah, A Lukito and T Y E Siswono

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012024 

The Physiological Profile of Junior Soccer Players at SSBB Surabaya Bhakti

M Nashirudin and N W Kusnanik

[+ Open abstract](#) [View article](#) [PDF](#)

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012025

Flexibility in Mathematics Problem Solving Based on Adversity Quotient

N A Dina, S M Amin and Masriyah

[+ Open abstract](#) [View article](#) [PDF](#)

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012026

Process Skill Assessment Instrument: Innovation to measure student's learning result holistically

K N Azizah, M Ibrahim and W Widodo

[+ Open abstract](#) [View article](#) [PDF](#)

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012027

Laboratory Activity Worksheet to Train High Order Thinking Skill of Student on Surface Chemistry Lecture

B Yonata and H Nasrudin

[+ Open abstract](#) [View article](#) [PDF](#)

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012028

Student Teachers' Proof Schemes on Proof Tasks Involving Inequality: Deductive or Inductive?

A H Rosyidi and A W Kohar

[+ Open abstract](#) [View article](#) [PDF](#)

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012029

The Implementation of Cumulative Learning Theory in Calculating Triangular Prism and Tube Volumes

M Muklis, C Abidin, M D Pamungkas and Masriyah

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012030

Students' Relational Thinking of Impulsive and Reflective in Solving Mathematical Problem

M A Satriawan, M T Budiarto and T Y E Siswono

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OPEN ACCESS 012031

Creativity of Field-dependent and Field-independent Students in Posing Mathematical Problems

N Azlina, S M Amin and A Lukito

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The Use of Open-Ended Questions with Giving Feedback (OEQGF) for Effective Mathematic Learning

I Sabilah and J T Manoy

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012033

The Effectiveness of Guided Inquiry Learning for Comparison Topics

Asnidar, S Khabibah and R Sulaiman

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012034

The Development of Inquiry Learning Materials to Complete Content Life System Organization in Junior High School Students

F Mayasari, Raharjo and Z A I Supardi

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012035

Slow Learner Errors Analysis in Solving Fractions Problems in Inclusive Junior High School Class

N Novitasari, A Lukito and R Ekawati

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012036

Statistical Literacy: High School Students in Reading, Interpreting and Presenting Data

M Hafiyusholeh, K Budayasa and T Y E Siswono

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OPEN ACCESS 012037

Problem Solving-based Learning Materials on Fraction for Training Creativity of Elementary School Students

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012038

Representation of Students in Solving Simultaneous Linear Equation Problems Based on Multiple Intelligence

Y R Yanti, S M Amin and R Sulaiman

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012039

Students' Relational Understanding in Quadrilateral Problem Solving Based on Adversity Quotient

A N Safitri, D Juniati and Masriyah

[+ Open abstract](#) [View article](#) [PDF](#)

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012040

The Effect of Acceleration Sprint and Zig-zag Drill Combination to Increase Students' Speed and Agility

O Bana, E Mintarto and N W Kusnanik

[+ Open abstract](#) [View article](#) [PDF](#)

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012041

Junior high school students' reflective thinking on fraction problem solving: In case of gender differences

M A Rasyid, M T Budiarto and A Lukito

[+ Open abstract](#) [View article](#) [PDF](#)

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012042

The Ability of Students' Mathematical Proof in Determining the Validity of Argument Reviewed from Gender Differences

Feriyanto

[+ Open abstract](#) [View article](#) [PDF](#)

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012043

Effect of Exercise Program Speed, Agility, and Quickness (SAQ) in Improving Speed, Agility, and Acceleration

K Azmi and N W Kusnanik

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Students' Algebraic Reasoning In Solving Mathematical Problems With Adversity Quotient 012044

F Aryani, S M Amin and R Sulaiman

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012045

Effects of High Intensity Interval Training on Increasing Explosive Power, Speed, and Agility

F Fajrin, N W Kusnanik and Wijono

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012046

Guided Inquiry with Cognitive Conflict Strategy: Drilling Indonesian High School Students' Creative Thinking Skills

A F Syadzili, Soetjipto and Tukiran

[+ Open abstract](#) [View article](#) [PDF](#)

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The Development of Student's Activity Sheets (SAS) Based on Multiple Intelligences and Problem-Solving Skills Using Simple Science Tools

D S Wardani, T Kirana and M Ibrahim

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OPEN ACCESS 012048

Functional Thinking Profile of Junior High School Student in Solving Mathematical Problem Observed by Differences of Sex

A P Siregar, D Juniati and R Sulaiman

[+ Open abstract](#) [View article](#) [PDF](#)

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The Effectiveness of Guided Inquiry-based Learning Material on Students' Science Literacy Skills

E V Aulia, S Poedjiastoeti and R Agustini

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The Elementary School Students' Mathematical Problem Solving Based on Reading Abilities

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012051

Algebraic Thinking in Solving Linier Program at High School Level: Female Student's Field Independent Cognitive Style

N Hardiani, I K Budayasa and D Juniati

[+ Open abstract](#) [View article](#) [PDF](#)

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012052

Effectiveness of Cooperative Learning Instructional Tools With Predict-Observe-Explain Strategy on the Topic of Cuboid and Cube Volume

Nurhuda, A Lukito and Masriyah

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012053

Error Analysis of Indonesian Junior High School Student in Solving Space and Shape Content PISA Problem Using Newman Procedure

U Sumule, S M Amin and Y Fuad

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012054

Developing Media Module Proposed to Editor in Editorial Division

A Kristanto, Mustaji, A Mariono, Sulistiowati and D W Nuryati

[+ Open abstract](#) [View article](#) [PDF](#)

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012055

The blind student's interpretation of two-dimensional shapes in geometry

Andriyani, I K Budayasa and D Juniati

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012056

The Clinical Test of Nano gold Cosmetic for Recovering Skin Damage Due to Chemicals: Special Case

T Taufikurohmah, A P Wardana, S Tjahjani, I G M Sanjaya, A Baktir and A Syahrani

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012057

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Profile of Metacognition of Mathematics Pre-Service Teachers in Understanding the Concept of Integral Calculus with Regard Gender Differences

L Misu, I K Budayasa and A Lukito

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012058

Understanding fraction concepts of Indonesian junior high school students: A case of field independent and field dependent students

K Mamonto, D Juniati and T Y E Siswono

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012059

Students' Representation in Mathematical Word Problem-Solving: Exploring Students' Self-efficacy

A Sahendra, M T Budiarto and Y Fuad

[+ Open abstract](#) [View article](#) [PDF](#)

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012060

Students' Self-Monitoring on Mathematics Ability: Cube and Cuboid Problem Solving

N T Lusiana, A Lukito and S Khabibah

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012061

Algebraic Reasoning in Solving Mathematical Problem Based on Learning Style

N F Indraswari, I K Budayasa and R Ekawati

[+ Open abstract](#) [View article](#) [PDF](#)

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012062

Development of Problem-Based Learning Oriented Teaching Learning Materials to Facilitate Students' Mastery of Concept and Critical Thinking Skill

M Reza, M Ibrahim and Y S Rahayu

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012063

Training of Students' Critical Thinking Skills through the implementation of a Modified Free Inquiry Model

S A Hadi, E Susantini and R Agustini

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012064

The Profile of Student Misconceptions on The Human and Plant Transport Systems

M Ainiyah, M Ibrahim and M T Hidayat

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012065

Spatial Skill Profile of Mathematics Pre-Service Teachers

R O E Putri

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012066

A Metacognitive Profile of Vocational High School Student's Field Independent in Mathematical Problem Solving

L Nugraheni, I K Budayasa and S T Suwarsono

[+ Open abstract](#) [View article](#) [PDF](#)

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012067

Developing Learning Model P3E to Improve Students' Critical Thinking Skills of Islamic Senior High School

Bahtiar, Y S Rahayu and Wasis

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012068

Students' Thinking Processes on Quadrilateral Concept: A Case of Providing Non-Examples

E B Rahaju

[+ Open abstract](#) [View article](#) [PDF](#)

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012069

Technological Pedagogical Content Knowledge of Prospective Mathematics Teacher in Three Dimensional Material Based on Sex Differences

M A Aqib, M T Budiarto and P Wijayanti

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012070

The written mathematical communication profile of prospective math teacher in mathematical proving

K V Pantaleon, D Juniati, A Lukito and K Mandur

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012071

Drilling Students' Communication Skill through Science, Environment, Technology, and Society (SETS)-Based Learning

B L Al-Farisi, Tjandrakirana and R Agustini

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012072

Students' metacognitive activities in solving the combinatorics problem: the experience of students with holist-serialist cognitive style

B N Trisna, I K Budayasa and T Y E Siswono

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012073

Critical Thinking Skills of an Eighth Grade Male Student with High Mathematical Ability in Solving Problem

Ismail

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012074

Quadcopter Path Following Control Design Using Output Feedback with Command Generator Tracker LOS Based At Square Path

A T Nugraha and T Agustinah

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012075

Introducing Nine-Point Circle to Junior High School Students

S Fiangga, M A N Azizah, R N K Rini and A N Hidayanti

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Training of Students' Critical Thinking Skills through the implementation of a Modified Free Inquiry Model

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Hunaidah *et al*
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Training of Students' Critical Thinking Skills through the implementation of a Modified Free Inquiry Model

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Abstract. This research aimed at training students' critical thinking skills through the implementation of a modified free inquiry learning model. The subjects of this research were 21 students of Mathematics Semester II. Using *One-Group Pretest-Posttest Design*, the data were analyzed descriptively using N-gain indicator. The results indicate that the modified free inquiry learning model was effective to train students' critical thinking skills. The increase in the students' critical thinking skills viewed from the value of *N-Gain* has a range of values with the categories of medium and high with a score between 0,25-0,95. Overall, the change in *N-Gain* score of each student and each indicator of critical thinking skills is as increasing with a moderate category. The increase of *N-Gain* value is resulted from the fact that the students were directly involved in organizing their learning process. These criteria indicate that the modified free inquiry learning model can be used to train students' critical thinking skills on photosynthesis and cellular respiration materials. The results of this research are expected to be nationally implemented to familiarize students with andragogy learning style which places the students as the subjects of learning.

1. Introduction

Critical thinking is a sensible idea of what is believed and what needs to be done [1]. Critical thinking skills can also be interpreted as the ability to think logically, reflectively, and productively to assess the situation in order to make the right decision [2]. The students' thinking skills are important to be improved, in line with the discourse of improving the quality of education in accordance with learning objectives. The purpose or the success of a learning process is achieved when it meets three important criteria, namely the aspects of knowledge, attitude and skills. These three criteria are formed from the habits and reinforcement that become the character which relies on someone's mindset [3].

Learning activities should be designed to direct the students in developing their attitudes, knowledge, and critical thinking skills in varying combinations and emphases [4]. Practicing critical thinking skills in varying emphases can be accessed in some indicators achieved in a learning process. The indicators selected in this research included: making decisions to prepare the steps of problem-solving experiments, analyzing, making inferences, evaluating, and drawing conclusions. These indicators were adapted from Ennis [1]. The efforts to direct students in practicing critical thinking skills can be accomplished using student-centered learning models. The students' which is already at the formal operational stage (adults) tend to perform *independent* learning styles that allow them to gain a deep understanding of an issue in accordance with the purpose of critical thinking skills [5].



Critical thinking skills which are identical to *independent* learning style can be applied by using constructivist learning models, such as inquiry-based learning. Learning models with investigation activities, such as inquiry, involve students fully in the teaching and learning activities either in groups or individual, which is one way to develop students' critical thinking skills [6]. The inquiry learning model is used to train students' critical thinking skills because the syntax of inquiry has a correlation with the indicators of critical thinking skills developed in this research. The selected five indicators had been adjusted to the cognitive level of the students who were in the formal operational phase. The abilities at the formal operational stage consist of thinking abstractly, testing hypothesis, and forming concepts which do not depend on physical reality [7]. The students' cognitive level became the reference for the researcher to determine the appropriate level of inquiry for the sample of the experiment, by applying the modified free inquiry model.

The results of the observations conducted in July 2016 showed that the students' critical thinking skills, especially the subjects of this research, were still relatively low. The students tended to listen to the explanations from the lecturer without being actively involved in the learning process. The material that should have been implemented in investigation activities which involved students actively was not optimal because it was delivered by using lecturing method. Such learning activities tend to make the students memorize the material without understanding the content of the learning material presented. The topic in this research, photosynthesis and cellular respiration, is chosen regarding the fact that this material required the students to understand, apply, analyze factual, conceptual and procedural knowledge. The students' curiosity related to the process of photosynthesis and cellular respiration may influence their learning positively so that the students could process, reason and present the information related to the learning material.

There have been several studies investigating the training of critical thinking skills through the implementation of inquiry learning model by previous researchers, such as Qing *et al.* The study suggests that the critical thinking skills of prospective teachers increased when inquiry-based learning was implemented [8]. Greenwald *et al* state that the inquiry-based learning is an alternative solution substituting conventional learning to improve the students' critical thinking skills and clinical reasoning [9]. Sutarma *et al* state that there is an increasing trend in the students' critical thinking skills with the implementation of inquiry learning model compared with the direct learning model [10]. Nevertheless, the previous research conducted by researchers did not explain the level of inquiry of the sample used, so that it did not give an illustration of the types of inquiry applied to the research sample. Therefore, in this research, a modified free inquiry model was implemented to train students' critical thinking skills with various considerations that had been previously analyzed.

2. Research methods

The type of this research is pre-experimental research with *one group pretest-posttest design*. The subjects of this research were 21 mathematics students in the mathematics and natural science faculty of IKIP Mataram who were joining Basic Biology course. This research was conducted for 3 weeks starting from 17th to 29th of May 2017. The learning materials which were applied to train the students' critical thinking skills were developed by the researcher. The modification of free inquiry-based learning material on photosynthesis and cellular respiration material is developed as learning material. The learning materials implemented in this research had passed the validity test with valid results.

The research instrument used to measure the students' critical thinking skills was an essay test instrument consist of 5 items. The test was said to be sensitive to differentiate the students' ability before and after receiving the learning process because the test instrument had a positive sensitivity index with scores between 0,52 – 0,68 [11]. This test was given in two stages, the *pretest* and the *posttest* to determine the students' critical thinking skills before and after the learning process.

The teaching and learning process was carried out for 3 meetings supported with a student worksheet on each learning material to be discussed. The student worksheet was developed with the orientation of the modified free inquiry model, so that the percentage of students' involvement in the learning process became more dominant. The steps provided in the student worksheet involve problem orientation,

formulating problems, formulating hypotheses, identifying and defining variables, developing work procedures, analyzing data, compiling inferences, evaluating, and drawing conclusions. Students could develop their critical thinking skills through the steps provided in the student worksheet.

The score of students' critical thinking skills derived from subsequent tests is categorized according to the level of critical thinking skills of each student. Critical thinking skill level consists of 4 levels, that are very less critical level with test score t satisfy $25.00 < t \leq 43.75$, less critical level with test score t satisfy $43.75 < t \leq 62.50$, critical level with test score t satisfy $62.50 < t \leq 81.25$ and very critical level with test score t satisfy $81.00 < t \leq 100.00$ [12].

A improvement of the students' score of critical thinking skills was analyzed by using *N-Gain* equation [13]. The *N-Gain* value of the students' critical thinking skills can be defined by the criteria of score as the following: high > 0.70 ; Moderate $0.3 - 0.70$; Low < 0.30 [14]. The results of the students' critical thinking skill level analysis and the increase of *N-Gain* score become the benchmark in determining whether this developed learning tool is effectively used to train students' critical thinking skills.

3. Results and Discussion

3.1. The Scores of Students' Critical Thinking Skills

The score of the students' critical thinking skill and the increase of *N-Gain* score are presented in Table 1.

Table 1. Results of *N-Gain* analysis of students' critical thinking skills

Students'	Scores		Category	<i>N-Gain</i>	Category
	<i>Pretest</i>	<i>Posttest</i>			
A1	10	65	Critical	0,61	Middle
A2	10	60	Less Critical	0,55	Middle
A3	0	25	Very Less Critical	0,25	Low
A4	20	60	Less Critical	0,5	Middle
A5	15	50	Very Less Critical	0,41	Middle
A6	35	90	Very Critical	0,85	High
A7	0	70	Critical	0,7	High
A8	0	60	Less Critical	0,6	Middle
A9	0	70	Critical	0,7	High
A10	10	60	Less Critical	0,55	Middle
A11	10	60	Less Critical	0,55	Middle
A12	10	70	Critical	0,67	Middle
A13	0	70	Critical	0,7	High
A14	0	80	Critical	0,8	High
A15	20	85	Very Critical	0,81	High
A16	0	95	Very Critical	0,95	High
A17	15	60	Less Critical	0,65	Middle
A18	0	60	Less Critical	0,6	Middle
A19	5	70	Critical	0,68	Middle
A20	20	95	Very Critical	0,94	High
A21	0	75	Critical	0,75	High

Table 1 shows that, in *the pretest*, none of the students achieved the minimum accepted score that had been set, which was 60. While, in *the posttest*, 19 students achieved the minimum accepted score and 2 students did not pass the test because of several factors, such as the students' activities were not productive, the inability of the students in understanding the concepts, and several internal factors faced by the students themselves. Unproductive activities, such as do not paying attention to lecturer's explanation, became a crucial cause of student's failure in passing the test. The intensity of the student's attention toward learning had an effect on the level of memorization/absorption of information [14].

Students were said to complete the teaching and learning classically with the percentage of 90.48%. Thaiposri and Wannapiroon in their research state that the learning activities with an inquiry-based learning model can help students develop their critical thinking skills [15]. The samples used in the research of Thaiposri and Wannapiroon were junior high school students, while the samples of this research were the first-semester university students.

The students' incompleteness of the critical thinking skill test could also be caused by the concept understanding on the photosynthesis and respiration material. The level of the students' concept understanding on the learning material had an effect on their ability in solving the critical thinking skill test questions. The students with the code A3 and A5 who did not pass the test or not complete showed that their concept understanding was still low. This finding is evidenced with answers of students A3 and A5 on critical thinking skills tests that deviate far from the concept of the answer that should be. The A3 and A5 student answer sheets are shown in Figure 2. The failure in understanding concepts would results on the inability to complete the critical thinking skill tests. Concept understanding has a positive correlation with students' critical thinking skills. Asmawati in her research states that critical thinking skills are the basic requirement for the students in understanding the concepts in the discipline [16]. The research by Asmawati did not explain the importance of concept understanding in order to be critical in a problem solving as presented in this research.

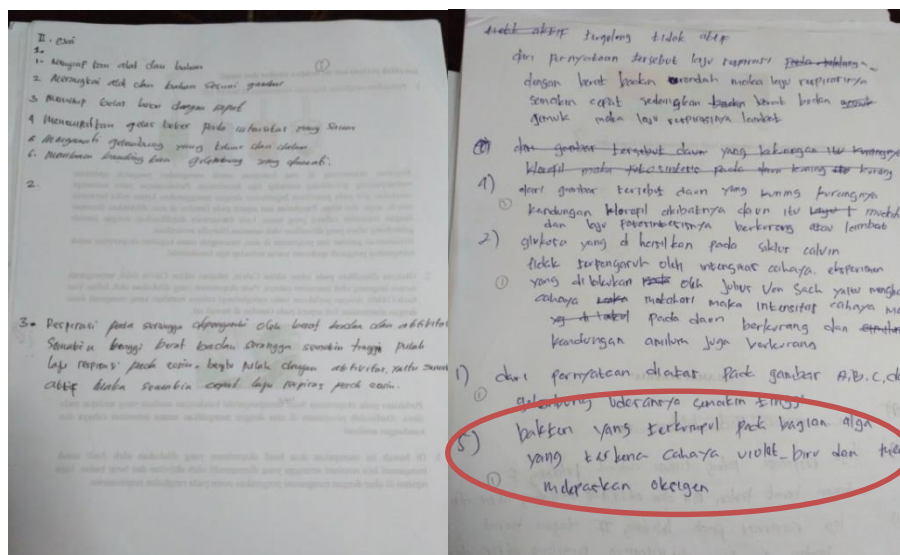


Figure 1. The A3 & A5 Student Response Sheet indicating the concept of incomprehension

Figure 1 shows that, students A3 and A5 have not mastered the concept of photosynthesis and cellular respiration well. The answer given by the students are not based on the correct concept. For example, in number 5 answer, students stated "bacteria collected in algae that gterkena violet light, blue and red release oxygen". The correct concept is "all algae release oxygen as a by-product of the process of photosynthesis carried out by algae. Algae exposed to violet, blue, and red light release the most amount of oxygen compared to light-induced algae with other color spectra. The abundance of oxygen released by algae, invites aerobic bacteria to gather more around the algae releasing more oxygen, which is exposed to violet, blue and red lights". The student's answer in Figure 1 shows that A3 and A5 students have not mastered the concept well so that it becomes one of the causes of his unresponsiveness in answering critical thinking skills test.

3.2. The completeness of the Indicators of Critical Thinking Skills

The indicators compiled in this research are important to be analyzed whether they were stated to be completed or not, because the indicators are the teachers' references in determining whether the learning

process in the class is successful. The completeness of the critical thinking skill indicators is presented in Table 2.

Table 2. Results of N-Gain analysis and completeness of each critical thinking indicator

Indikator	Proportion Scores		Category	N-Gain	Category
	Pretest	Posttest			
Develop an experimental procedure	0,07	0,7	Complete	0,68	Middle
Analyze	0,12	0,64	Complete	0,6	Middle
Arrange inferences	0,1	0,77	Complete	0,75	High
Evaluate	0,1	0,67	Complete	0,63	Middle
Compile conclusions	0,05	0,62	Complete	0,6	Middle

The results of the analysis of the increase in the score of critical thinking skills (*N-Gain*), which has been presented in Table 2 show that none of the indicators were completed in the *pretest*, while in the *posttest* all indicators were completed. The *N-Gain* value of each indicator ranges from 0.6 to 0.75 with medium and high categories. These criteria indicate that the learning process using a modified free inquiry model is effective to train students' critical thinking skills on photosynthesis and respiration materials. The level of critical thinking skills of students after the application of learning tools developed, put the students at critical level and very critical although there are 2 students who are still at a less critical level. These results are supported by Kitot *et al* their research, stating that the inquiry-based learning model is effective to be used to enhance students' critical thinking skills [17]. The research by Kitot *et al* only compares the inquiry learning model with conventional models without specifying the type of inquiry used. The indicator with the lowest score increase was analyzing and making conclusions. Students still had difficulties in analyzing and making conclusions because the students were still not maximal in preparing editorial sentences, but the students understood the concepts well. This was proven that the students were able to answer the questions although their sentences were not correctly organized.

4. Conclusion

Based on the result of the research, it can be concluded that the modified free inquiry learning model is effective to be used to train students' critical thinking skills on photosynthesis and respiration materials. This is evidenced by the increase in scores of the *N-Gain*, both the *N-Gain* of each student and the *N-Gain* of each indicator. The findings of this research indicate that critical thinking skills have a positive correlation with concept understanding.

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