TEACHING GENETICS THROUGH DIFFERENTIATED SCIENCE INQUIRY BASED ON RESEARCH RESULTS OF GENE VARIATION ANALYSIS TO INCREASE COGNITIVE LEARNING OUTCOMES UNDERGRADUATE BIOLOGY STUDENT

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Abstract

Paradigm change in 21st century poses a challange for higher education in teaching science as inquiry. In another side, teaching science as inquiry meet some problem because of every student in the classroom was different. This research is aimed to know effectiveness of differentiated science inquiry based on research results of gene variation analysis in genetics course to increase students cognitive learning outcome. This research used pre-experimental research design on one class that consist of 26 biology students. Statistical analysis used in this study is paired sample t-test on pre-test and post-test to measure students cognitive learning outcomes. If there are significances between the pretest and posttest, data analysis was continue to N-Gain score to determine the increasing category of students cognitive learning outcome. The average pretest score was 64,3 and posttest score was 77,2. The statistical analysis result showed there was a significant difference between students cognitive learning outcome ($p<0,005$), meanwhile the N-Gain score between pretest and postest is 36,2 and categorized a medium criteria. That result mean although there are difference students learning outcome before and after learning by using differentiated science inquiry model based on research result of gene variation analysis, that learning is not too recommended to increase students cognitive learning outcome.

Keywords: *Differentiated, Inquiry, Genetics, Learning Outcome*

1. INTRODUCTION

Paradigm change in 21st century poses a challange for higher education in teaching science as inquiry (Bybee 2013). The shift in learning theory from behaviorism to constructivism at higher education system, which initially placed students as passive learners and only received information from the teacher is no longer considered effective teaching and learning method at this time. (Eriksson 2008). Science teaching and learning should not only teach a set of facts and principles but can also provide opportunities for students to develop their thinking skills through an investigation process (National Research Council (NRC) 1996a).

Inquiry defined as various activity processes and ways of thinking that involve students in observing phenomena, raising questions, using tools to get data, interpreting data, and making explanations. (National Research Council (NRC) 1996b) Inquiry learning has the same principles as the process that carried out by scientists in developing science (Llewellyn 2012). Several activities in inquiry learning will provide deep and meaningful understanding to students (Sholikhan 2017). Students learning outcomes is known had a positive impact when the learning process carryout using inquiry based learning (Minner et al. 2010).

Inquiry learning is divided into four levels (Llewellyn 2010a) which is based on how much the teacher's role is in the investigative process. The first level in inquiry learning is demonstration inquiry, at that level the teacher provide the whole stage in inquiry learning including posing the question, planning the procedure, and analyzing the results. The second level in inquiry learning is structured inquiry, at that level the teacher posing the question, and planning the procedure, but analyzing the results is carried out by students. The third

level in inquiry learning is guided inquiry, at that level the teacher only posing the questions but planning procedure and analyzing the results fully carried out by students. The fourth level in inquiry learning is self-directed inquiry or student-initiated inquiry, at that level students generate their own questioning and then design their investigation, identify variables, and carry out procedure to answer the question (Banchi and Bell 2008)

Inquiry learning in practice is usually carried out by selecting one of the four levels of inquiry. The application of one level of inquiry in the classroom eventually creates new problems due to the different characteristics of each student. Students with various characteristics will respond differently to the same learning model (Maeng and Bell 2015). The differences in these characteristics can be students readiness, learning styles, and interest in learning. The implementation level of inquiry learning should not carry out by teacher choices, but according to several aspects which allows the inquiry learning in the classroom is not only done at one level.

The implementation of inquiry learning model which allow not only one level inquiry conduct in the classroom has been developed by llywellyn (Llewellyn 2010b) and known as differentiated science inquiry (DSI). DSI basically has the same steps and stages as inquiry learning in general, but in DSI the teacher improves classroom learning by matching each individual need and student learning style at each level in inquiry learning then placing the individual into the same groups. DSI learning can provide opportunities for students who have more readiness and abilities to be able to develop their skills, but also do not ignore other individuals who have different readiness and learning styles.

One of the courses that can be carried out by DSI is genetics. Genetics course consists of a set of facts and principles that are considered difficult for biology students to learn, That statement was accorded with researched that has been done by Fauzi (2018) (Fauzi and Fariantika 2018). Learning genetics which only teaches a set of concepts, facts and principles makes students have a tendency to memorize and remember concepts without learning them meaningfully. (Çimer 2012; Almroth 2015).

Factual and contextual problems are needed as a phenomenon that can be used in carrying out inquiry learning. The phenomena and questions used to initiating inquiry learning can come from various sources such as research results, the environment, books and articles (Babione 2015). One of the research results related to genetics course and can be used as a phenomenon in inquiry learning is the analysis of genetic variation and function research.

The research results of analysis genetic variation and function is a gene sequence. Gene function analysis is the process of analyzing gene sequence and matching with several amino acid, the results of the forecasting are the percentage of matches with protein databases on sites such as *Expassy translate, phyre-2* or *Swiss model*. The gene function analysis research can then be used to teach the topic of the genetic code. Genetic variation analysis research is the process of comparing DNA sequences in certain genes and looking at variations in the sequences caused by mutations among several species in a population using genetic analysis applications software such as MEGA X. The genetic variation analysis research can then be used in teaching mutations and the application of mutations.

2. METHOD

This research was a pre-experimental research which used a pretest–posttest one group design. The population used in this research was all 4th semester biology students who take a geneticst course in State University of Malang. One class were randomly selected as the sample and consisting of 26 students. The pre-experimental research design can be seen in table 2**.** Independent variables of this research was differentiated science inquiry learning based on research results of gene variation and function analysis, while the dependent variables were students cognitive leraning outcome. Before conducting learning, group mapping was carried out to determine groups with certain levels of

inquiry based on student readiness and interest. Readiness was measured by short questions while student interest was measured using a modified questionnaire from Llewellyn (Llewellyn 2010b), the questionnaire can be seen in table 2. Learning process carried out is limited only 2 topics (genetic code and mutation) which each topic was conducted in one meeting. At the first meeting, a pretest was given which consisted of 5 essay questions. The instrument used in this learning activity was a student worksheet and test item. The instruments had been previously validated material experts, learning expert, and education practitioners (genetics lecture). The results of validation showed very valid for material expert, very valid for learning expert, and valid for field practitioner. At the last meeting, a posttest was given using the same questions as the questions given at the pretest. The statistical analysis used was the paired sample t-test on pretest and posttest result. If there are significances between the pretest and posttest, data analysis was continue to N-Gain score to determine the increasing category of students cognitive learning outcome. The formula to count N-Gain score and criteria is adapted from (Hake 1999) and can be seen in table 1 .

$$N - Gain = \frac{Posttest\ score - Pretest\ score}{Score\ maximum - Pretest\ score} \times 100$$

Tabel 1 : N-Gain score criteria

N-Gain	**Criteria**
>70	High
30≤N-Gain≤70	Medium
N-Gain<30	Low

Tabel 2 : Research design

Group	*Pretest*	*Intervention*	*Posttest*
A	O_1	X	O_2

Tabel 2 : Questionnaire to determine the type of inquiry

NO	**Structured**	**Score**					**Unstructured**
1	Need a mentor (teacher)	1	2	3	4	5	Learn independently
2	Logical	1	2	3	4	5	Intuitive
3	Following the instruction	1	2	3	4	5	Planning independently
4	Explained	1	2	3	4	5	Explaining
5	Prefer clarity	1	2	3	4	5	Prefer vagueness
6	Task oriented	1	2	3	4	5	Idea oriented
7	Follow the rule	1	2	3	4	5	Create the rule
8	Rational	1	2	3	4	5	Creative
9	Like order	1	2	3	4	5	Like flexibility
10	Specific material	1	2	3	4	5	Extended material
11	Follow the procedure	1	2	3	4	5	Create own procedure
12	Reading and listening	1	2	3	4	5	Doing hands on activity
13	Defined	1	2	3	4	5	Defining
14	Summary is given	1	2	3	4	5	Create own summary
15	Step by step	1	2	3	4	5	Trial and error
16	An answer was given	1	2	3	4	5	Looking for the answer
18	Wanted to be told	1	2	3	4	5	Unwanted to be told
19	Like something consistent	1	2	3	4	5	Like things that are varied
20	Clear	1	2	3	4	5	Ambiguous

3. RESULT AND DISCUSSION

The value of student cognitive learning outcomes consisting of pretest and posttest scores is first tested for normality using Shapiro-Wilk test before statistical analytic paired sample t-test was carried out. The results of the normality test show a significance value (> 0.05) which indicates that the data is normally distributed. The results of statistical analysis using paired sample t-test showed a significance level of 0.000 (<0.05). The results of the statistical analysis can be seen in table 3. The average value of the post-test results shows an increase when compared to the average value of the post-test results (64,3 on pretest and 77,2 on posttest). These results indicate that there are differences in student learning outcomes before and after learning using the DSI model based on the research results of

gene variation and function analysis. The comparison between pretest and posttest scores can be seen in Figure 1.

Tabel 3 : Statistical analysis using paired sample t-test result

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	Pretest - Postest	-12,769	8,315	1,631	-7,830	25	,000

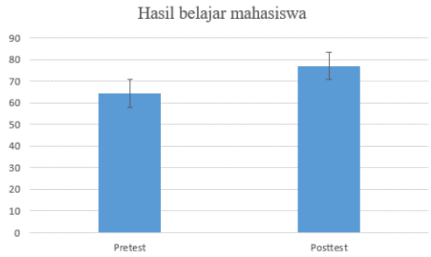

Figure 1 : Comparison of the average student cognitive learning outcomes

Because the paired sample t-test showed significance level, the data analysis then continue to N-Gain score analysis. The result of N-Gain score was 36,2 and categorized a medium criteria. These results can be interpreted that although the statistical analysis shows a significant difference, learning using the DSI model based on the results of the gene variation and function analysis is still considered not to effective when used to increase student cognitive learning outcomes.

The low increase in student cognitive learning outcomes can be caused by several factors. inquiry learning is new for the student in that classroom so they need to adapt with this new learning model (Dorier and García 2013), meanwhile using bioinformatics as a tool when doing investigation process in inquiry learning is never taught before to the students (Ai et al. 2012), it causes in its implementation many students experience difficulties and still need direction from the teacher.

Become an inquiry teacher is not short process (National Research Council (NRC) 2000). The teacher can't expected himself to become an inquiry teacher if just only have an experience teaching science as inquiry less than 1 year, the teacher may need 3-5 years to perfect their inquiry teaching technique (Llewellyn 2012). There are correlation between teacher readiness and confidence in conducting inquiry learning with teacher training experience, the teacher who have more training experience in iquiry are more comfortable with every stages of inquiry activities (Jill and Adelson 2011). The transformation from a traditional teaching and learning into an inquiry learning is a difficult journey, and it first attempt could be fail (Corder and Slykhuis 2011). Competence in conducting inquiry learning is a major problem felt by many teachers. (Fitzgerald et al. 2019).

The implementation of inquiry learning in the classroom takes a long time and sometimes there are some students do not fully complete their work (Bevins et al. 2018). The allocation time in genetics course is about 3 hours for one meeting each topic, at the end of the lesson it found there are one student groups that have not completed their work on the student worksheet and it causes not all the stages of inquiry learning process is not achive. Time estimating and activities management in the learning process are important factors that must be considered in the learning (Adams and Blair 2019).

In anotherside, Assessment that use when conducting inquiry learning is suggested should not only be done in a traditional way by using several questions (Quigley et al. 2011). Inquiry learning requires a variety of complex types of assessment (Liu et al. 2010), so that in its implementation, inquiry learning sometimes not only done by one teacher (Lepareur and Grangeat 2018). Meanwhile the success of inquiry learning is also depends on administrative support like curriculum (Towers 2012)

4. CONCLUSION

There are significant differences in student cognitive learning outcomes before and after learning genetics course using the Differentiated Science Inquiry (DSI) learning model, but the N-Gain score show the medium categorized criteria.

5. REFERENCES

Adams R V., Blair E. 2019. Impact of Time Management Behaviors on Undergraduate Engineering Students'

Performance. SAGE Open. 9(1):215824401882450. doi:10.1177/2158244018824506. http://journals.sagepub.com/doi/10.1177/2158244018824506.

Ai Y, Jermiin L, Firth N. 2012. Teaching bioinformatics: A student-centred and problem based approach. Int J Innov Sci Math Educ. 10(1).

Almroth BC. 2015. The importance of laboratory exercises in biology teaching ; case study in an ecotoxicology course. Pedagog Dev Interact Learn.(september):1–11.

Babione CA. 2015. Practitioner Teacher Inquiry and Research. United States of America: Wiley.

Banchi H, Bell R. 2008. The many levels of inquiry. Sci Child. 46(2):26–29.

Bevins S, Lehane L, Booth J. 2018. Comparative Perspectives on Inquiry-Based Science Education. 1st ed. United States of America: IGI Global.

Bybee RW. 2013. The teaching of science : 21st-century perspectives. USA: NSTA Press.

Çimer A. 2012. What Makes Biology Learning Difficult and Effective: Students' Views. Educ Res Rev. 7(3):61–71. doi:10.5897/ERR11.205.

Corder G, Slykhuis J. 2011. Shifting to an Inquiry-Based Experience. Sci Child. 48(9):60–63. https://eric.ed.gov/?id=EJ944172.

Dorier J-L, García FJ. 2013. Challenges and opportunities for the implementation of inquiry-based learning in day-to-day teaching. ZDM. 45(6):837–849. doi:10.1007/s11858-013-0512-8. http://link.springer.com/10.1007/s11858-013-0512-8.

Eriksson I V. 2008. Science Education in the 21st Century. New York: Nova Science Publishers.

Fauzi A, Fariantika A. 2018. Courses perceived difficult by undergraduate students majoring in biology. Biosfer. 11(2):78–89. doi:10.21009/biosferjpb.v11n2.78-89. http://journal.unj.ac.id/unj/index.php/biosfer/article/view/7714.

Fitzgerald M, Danaia L, McKinnon DH. 2019. Barriers Inhibiting Inquiry-Based Science Teaching and Potential Solutions: Perceptions of Positively Inclined Early Adopters. Res Sci Educ. 49(2):543–566. doi:10.1007/s11165-017-9623-5. http://link.springer.com/10.1007/s11165-017-9623-5.

Hake R. 1999. Analyzing Change/ Gain Score. Indiana: Indiana University.

Jill L, Adelson JL. 2011. An Investigation of Preservice Teachers ' Confidence Regarding Educational Inquiry A Stance toward Inquiry : :69–95.

Lepareur C, Grangeat M. 2018. Teacher collaboration's influence on inquiry-based science teaching methods. Educ Inq. 9(4):363–379. doi:10.1080/20004508.2018.1428037. https://www.tandfonline.com/doi/full/10.1080/20004508.2018.1428037.

Liu OL, Lee H-S, Linn MC. 2010. Multifaceted Assessment of Inquiry-Based Science Learning. Educ Assess. 15(2):69–86. doi:10.1080/10627197.2010.491067. http://www.tandfonline.com/doi/abs/10.1080/10627197.2010.491067.

Llewellyn D. 2010a. Differentiated Science Inquiry. United States of America: Corwin.

Llewellyn D. 2010b. Differentiated Science Inquiry. United Kingdom: Corwin.

Llewellyn D. 2012. Teaching High School Science Through Inquiry and Argumentation. United Kingdom: Corwin.

Maeng JL, Bell RL. 2015. Differentiating Science Instruction: Secondary science teachers' practices. Int J Sci Educ. 37(13):2065–2090. doi:10.1080/09500693.2015.1064553. http://www.tandfonline.com/doi/full/10.1080/09500693.2015.1064553.

Minner DD, Levy AJ, Century J. 2010. Inquiry-based science instruction-what is it and does it matter? Results from a research synthesis years 1984 to 2002. J Res Sci Teach. 47(4):474–496. doi:10.1002/tea.20347. http://doi.wiley.com/10.1002/tea.203

47.
National Research Council (NRC). 1996a. National Science Education Standadrs. Washington DC: National Academies Press.
National Research Council (NRC). 1996b. National science education standards. Washington DC: National Academies Press.
National Research Council (NRC). 2000. Inquiry and the National Science Education Standards: A Guide for Teaching and Learning. Washington DC: National Academies Press.
Quigley C, Marshall JC, Deaton CCM, Cook MP, Padilla M. 2011. Challenges to Inquiry Teaching and Suggestions for How to Meet Them Challenges to Inquiry Teaching and Suggestions for How to Meet Them - ... Sci Educ. 20(1):55–61.
Sholikhan S. 2017. Understanding Concepts Through Inquiry Learning Strategy. IOSR J Res Method Educ. 07(01):97–102. doi:10.9790/7388-07010597102.
Towers J. 2012. Administrative supports and curricular challenges: New teachers enacting and sustaining inquiry in schools. Can J Educ. 35(1):259–278.

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