

Research Article

Application of genetic problem base online discussion to improve genetic literacy of prospective teachers

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ARTICLE INFO

Article history

Received: 22 February 2022

Revised: 2 March 2022

Accepted: 4 March 2022

Published: 31 March 2022

Keywords

Genetic literacy

Genetic problem

Online discussion

ABSTRACT

Genetics is a subject that is quite difficult according to students. Various strategies and methods are used to understand genetics in learning to have genetic literacy. One way of increasing genetic literacy in students is to apply genetic problems based on an online discussion in genetics lectures. The research was conducted to determine the effect of genetic problem-based online discussion on increasing students' genetic literacy. The research design used a pre-posttest control group design. It was carried out experimentally on three treatment groups: the genetic problem base of students, the genetic problem base of educators - students, and the genetic problem base of educators. According to the genetic literacy domain, genetic literacy is measured through multiple-choice tests, including genetic models, meiotic models, and molecular models. Manova analyzed the value of gene literacy, and a post-doc further test was performed to differentiate genetic literacy in the three treatment groups. The results showed that genetic literacy increased in all treatment groups, with the highest increase in the group that applied a genetic problem base focused on student problems.

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How to cite: Maryuningsih, Y., Hidayat, T., Riandi, R., & Rustaman, N. Y. (2022). Application of genetic problem base online discussion to improve genetic literacy of prospective teachers. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 8(1), 65-76. <https://doi.org/10.22219/jpbi.v8i1.19035>

INTRODUCTION

Genetics is a compulsory subject for biology education students. Based on a preliminary study that has been conducted using student questionnaires, it was found that genetic content is content that is difficult to learn because of its abstract nature. Some students have difficulty understanding the concept of genetics, including inheritance, replication, protein synthesis, genetic modification in organisms and other genetic concepts. Genetics is the basis of modern biology, so prospective biology teachers must master the concept of genetics. This is necessary for them to prepare for their future when they become educators, where they have to teach genetics to students (Seager, 2014; Andrews et al., 2012). Genetics is difficult to teach and learn because the process is cellular and molecular (Karagöz & Cakir, 2011). This is also the reason why many high school graduates do not have a basic understanding of the concept of genetics (Castro-Faix, Duncan, & Choi,

2021). Various educational literatures report that genetic learning to improve mastery of genetic concepts is pursued by various strategies, such as by analogy to improve scientific reasoning, project base instruction to improve mastery of concepts (Alozie, Eklund, Rogat, & Krajcik, 2010), and other strategies that have been carried out by many educational practitioners, such as with online discussion activities (Trezise, 2020; Morreale, Valenzano, & Bauer, 2017; Nold, 2017).

Several educational articles from 2019 to 2021, as many as one hundred thousand articles recommend the application of online discussion in learning and as many as fifteen thousand recommend in learning biology. Online discussion activities increase student activity in the learning process through the responses given (Maryuningsih, Hidayat, Riandi, & Rustaman, 2020b, 2020a). The online discussion learning environment allows educators and learners to interact, collaborate, exchange ideas, and engage in dialogue (Andrade, 2015; Nold, 2017), students are challenged to present problems and try to solve them using more strategies and methods (Knippels, Waarlo, & Boersma, 2005; Poehnl, Bogner, & Bogner, 2013). The application of problem base learning with online discussion is a learning approach that is characterized by flexibility and diversity in the implementation of learning in various disciplines in various contexts (Allison & Pan, 2017; Edens, 2000), so that it is interesting to apply in genetics learning. Learning with problem-based learning is widely recommended in various educational articles, but very few articles that report problem-based learning are applied in online discussion activities. The application of problem-based learning is reported to improve problem-solving skills (Edens, 2000; Hammes & Duryea, 1986; Karantzas et al., 2013; Rausch, Schley, & Warwas, 2015; Terblanché, 2015); critical thinking skills (Karantzas et al., 2013; Maryuningsih, Hidayat, Riandi, & Rustaman, 2019; Maryuningsih, Hidayat, Riandi, & Rustaman, 2020; Novick & Catley, 2018), and other skills needed in the 21st century. Problem-based learning in online discussion activities is interesting to apply in learning, especially in genetics learning. The application of online discussions with the themes of various genetic problems needs to be applied, so that prospective teachers explore the thought process to understand themselves about mastering the concept of genetics. In line with that, Machová & Ehler, (2021) stated that the criteria in determining the design of genetic learning is to consider learning difficulties in genetics and teaching genetics which includes: the separation of inheritance, reproduction and meiosis in the curriculum is an abstract trait of genetics, and the level of biological organization contributes to it increasing the mastery of genetic concepts in prospective students teacher.

Mastery of the concept of genetics needs to be possessed by prospective teachers as a provision for later becoming a teacher. According to the teacher's mastery of biological concepts (Duncan, Castro-faix, & Choi, 2015), several misconceptions of biological concepts were found, and one of them was genetics. For this reason, it is necessary to conduct a genetic study through online discussion activities to understand the concept of genetics and reduce misconceptions. There are several articles on the application of online discussions to improve student learning activities, but none have measured the mastery of genetic concepts. The mastery of the genetic concept was first introduced with the term genetic literacy (Freidenreich, Duncan, & Shea, 2011; Thomas, Kavas, Meaburn, & Tolmie, 2015). The application of online discussions with a problem-based learning approach to genetics learning is expected to increase the mastery of genetic concepts, especially genetic literacy for prospective teacher students.

Freidenreich et al., (2011) suggested that understanding the concept of genetics is characterized by genetic literacy, namely mastering three models of genetic concepts. The three models of genetic literacy cover basic knowledge and are interrelated with other aspects of genetic literacy. The first model is the genetic model (mendelian genetics) explaining the inheritance patterns observed in sexually reproducing species, the phenotype (traits) resulting from a genotype (genetic combination), and the probability of obtaining offspring with a particular phenotype. The second model, the meiotic model, describes the cellular processes that underlie the segregation and independence of various genes into sex cells, which are the basis for the transfer of genetic information from one generation to the next. The third model is the molecular model, explaining the molecular and cellular mechanisms carried by genes regarding their physical effects in individuals (mechanisms that link genotype to phenotype).

Genetics as a cornerstone of modern biology and understanding genetics is a critical aspect of scientific literacy, this domain is difficult to teach and study because of the many cellular components and molecular process entities involved. Various studies have shown that many students do not have the fundamental understanding in genetics needed to make informed decisions about problems in the genetics domain (Castro-Faix et al., 2021; Thomas et al., 2015; Andrews et al., 2012; McElhinny, Dougherty, Bowling, & Libarkin, 2012; Karagöz & Cakir, 2011; Alozie et al., 2010; Smith, Wood, & Knight, 2008; Knippels et al., 2005) noted that genetic literacy not only involves understanding separate models, but also integrating the three models and producing a coherent and comprehensive explanation of genetic phenomena. Students have difficulty connecting genetic and meiotic models (Reinagel & Speth, 2016; Seager, 2014; Chu & Reid, 2012; Freidenreich et al., 2011). Students tend to study algorithms for predicting the outcome of genetic crosses

(Smith & Gericke, 2013), and tend to understand the interaction between dominant and recessive alleles as a form of gene competition, as the dominant gene suppresses the recessive gene (Burian, 2013; Smith & Gericke, 2013), cellular, genetic engineering and molecular models are challenging for students to understand (Coan & Covey, 2021; Reinagel & Speth, 2016; Seager, 2014; Burian, 2013; Erickson & Franciszkowicz, 2010).

Genetic literacy is an understanding of genetics as a direct impact of developing phenomena on daily life in the life of the post-genomic era, where DNA sequencing technology is available. Advances in post-genomic technology have a direct impact on consumers, where the technology is commercially available and promises to improve health prospects for all of humanity. Research on socio scientific issues (SSI) in the field of contemporary genetics further enhances genetics' understanding of health, their perceived behavior towards contemporary genetic products, and the various genetic identities of organisms have been identified. The main goal of science education is to educate students for genetic literacy, have adequate knowledge about the genome and its properties (Reinagel & Speth, 2016; Seager, 2014; Burian, 2013; Freidenreich et al., 2011), so that teaching genetics is aimed at genetic literacy students. Genetic learning discusses genetic content and practice and uses genetic literacy as a basis for making decisions related to SSI explicitly showing the interconnection between content knowledge, practice and decision making in the field of genetics, needs to be trained in genetics learning. The study of genetics builds the foundation of genetic literacy so that students are able to develop appropriate argumentation and decision-making skills. Complete mastery of genetic concepts and have genetic literacy skills with three literacy models, it is hoped that genetic misconceptions can be avoided and students are able to solve various problems related to genetics. Given the importance of mastering genetic concepts for prospective teachers, it is necessary to analyze the mastery of genetic concepts in students through the application of problem-based online discussion activities. So far, there have been reports of increasing students' critical thinking skills through problem-based online discussion activities, but there is very little data on students' mastery of genetic concepts, in this case genetic literacy. For this reason, it is necessary to study and examine the mastery of the concept of genetics, namely genetic literacy in students through the application of online discussions based on genetic problems that are applied in genetics lectures.

METHOD

This research was conducted quasi experimental with a pre post control group design. The sample of this research is the entire population taking genetics courses in the academic year 2021/2022. The implementation of learning is carried out in three different classes. Class division is related to the different approaches applied in the implementation of problem-based synchronous online discussions. The first class is a class that implements problem-based learning with problems from students as experiment 1 (E1), the second class with problems from students and educators as experiment 2 (E2), and the third class with problems from educators as control (C). The research design is described in Figure 1. E/C is class (Treatment group; consists of three classes, E1, E2 and C), O is genetic literacy pretest (consisting of 1 genetic model, 2 meiotic models and 3 molecular models), O1 is posttest genetic literacy (consisting of 1 genetic model, 2 meiotic models and 3 molecular models), X is the treatment of the online discussion approach consisted of X1 (E1), X2 (E2) and X3 (C).

E1	O 1, 2, 3	X1	O ₁ 1, 2, 3
E2	O 1, 2, 3	X2	O ₁ 1, 2, 3
C	O 1, 2, 3	X3	O ₁ 1, 2, 3

Figure 1. Research design

Genetic learning is carried out on a mobile basis through an online discussion forum with a problem approach using the Gen 21cs learning application (Maryuningsih, Hidayat, Riandi, & Rustaman, 2019). The implementation of learning is applied to fifth semester students who teach genetics courses in biology education at one of the universities in West Java. The stages of problem-based online discussion are shown in Table 1.

The online discussion based on genetic problems is carried out with the discussion stages in Table 1. Online discussion activities based on problem solving are carried out with the aim of providing genetic literacy. Genetic literacy is provided by applying online discussions based on genetic problems using themes that are in accordance with genetic literacy and carried out in a sequential manner, starting with the genetic model, then the meiotic model and the molecular model. The online discussion study based on genetic problems was

carried out for fifteen weeks, with the discussion themes and techniques for collecting data on student genetic literacy data for each genetic literacy model as shown in Table 2.

Table 1. Steps to problem-based in online learning

No	Syntax	Activities of online discussion participants
1	Clarify and agree working definitions unclear terms and concepts	Communication and collaboration between discussion participants, committed to solving unsolved problems and concepts
2	Define the problem and agree which phenomena require explanation	discussion participants describe the problem, define the problem and choose the focus of the problem that requires solving
3	Analyse the problems	Analyze problems from various sources
4	Arrange explanations into a tentative solution	Organize problem solving as a tentative solution in terms of various alternative problem solving
5	Generate and prioritize learning objectives	Generate problem solutions and prioritize learning objectives
6	Research the objectives through private study	Evaluate problem solving through reference studies and independent investigation
7	Report back, synthesize explanations and apply new information to the original problems	Report back problem solutions, synthesize various problem solutions and apply new information to original and new problems

Table 2. Problem-based online discussion themes

Genetic literacy	Concept	Discussion theme	week
Genetic model Meiotic model	Mendel and ideas about Gen	a) Examine some examples of genetic crosses in plants, animals and humans.	1-2
	Chromosomal basis of inheritance	b) Studying sex chromosome-linked and sex chromosome-delimited genes and solving the problem of crossing cases	3-5
	Molecular basis of inheritance	c) Name and examine some examples of genetic disorders due to changes in the number and structure of chromosomes then look for solutions to problems and respond if the case is found in the closest person	6-7
Molecular model	Gene Expression: From Gene to Protein	d) Troubleshooting genetic testing and counseling cases	8
	Gene expression regulation	e) Describe the mechanism of bacterial response in responding to environmental changes by regulating the transcription process	9-12
		f) Studying several examples of differential gene expression programs leading to different cell types in multicellular organisms and then analyzing and analyzing their implications for these organisms	
		g) Studying the process of proto-oncogenes triggering cancer	
		h) Assess and describe some examples of cancer; the causes and mechanisms of the formation of cancer cells	
Genetic engineering technology	i) Describe some examples of biologists' research using DNA technology to study gene expression and function	13-15	
j) Presenting some examples of cloned organisms and stem cells useful for basic research and other applications			
k) Provide some examples of practical applications of DNA-based Biotechnology affecting our lives in many ways			

Genetic literacy data retrieval was carried out by multiple choice tests conducted before and before the implementation of learning in each unit of genetic domain literacy activity consisting of three genetic literacy domain tests, namely genetic model test, meiotic model test, and molecular model test. The number of each genetic literacy test is twenty. The genetic literacy test instrument is a test instrument whose construction has been tested on twenty students who have graduated from genetics course. The test results stated that the genetic literacy test instrument was valid and reliable. The genetic literacy value of students between classes in each model was tested for differences in genetic literacy with the Manova test. The Manova test was conducted to determine the effect of online discussion based on genetic problems on genetic literacy in the three treatment groups. The value of genetic literacy in students was then carried out with a post Hoc test to determine differences in genetic literacy between classes.

RESULTS AND DISCUSSION

An online discussion based on genetic problems was applied using the Gen 21cs application. Gen 21cs is an android-based online learning application. In the Gen 21cs application, there are various features that

facilitate class division, group division and features that facilitate learning tools, both teaching materials and learning evaluations. An overview of the Gen 21cs application is depicted in Figure 2.

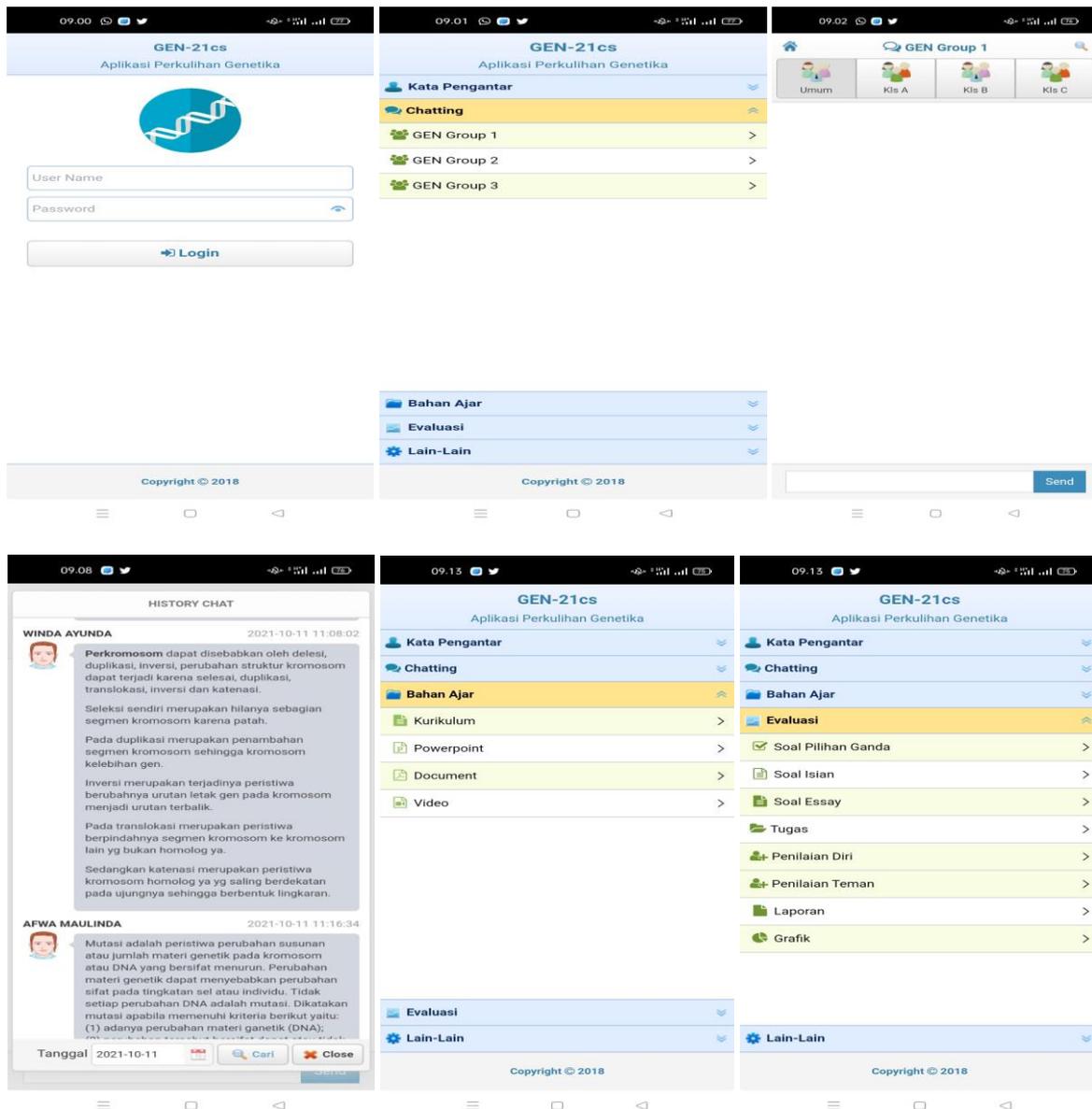


Figure 2. Overview of the features in the Gen 21cs learning application

Gen 21 cs is a learning application that has been developed by the author (Maryuningsih, et al., 2019). This application contains various features as needed in achieving learning objectives. Gen 21cs is a learning media that functions as a tool in the learning process. Online discussion activities using the Gen 21cs application are very effective in learning genetics in the era of the COVID 19 pandemic. Gen 21cs as a learning medium facilitates learning by applying certain models, strategies, and methods chosen by educators according to the learning objectives in each material content. Genetic learning in this study is an online discussion application based on genetic problems to improve mastery of genetic concepts, namely genetic literacy.

Mastery of genetic concepts measured in this study is genetic literacy. Genetic literacy includes genetic models, meiotic models and molecular models, with the average value of each genetic literacy domain in each treatment group shown in Figure 3.

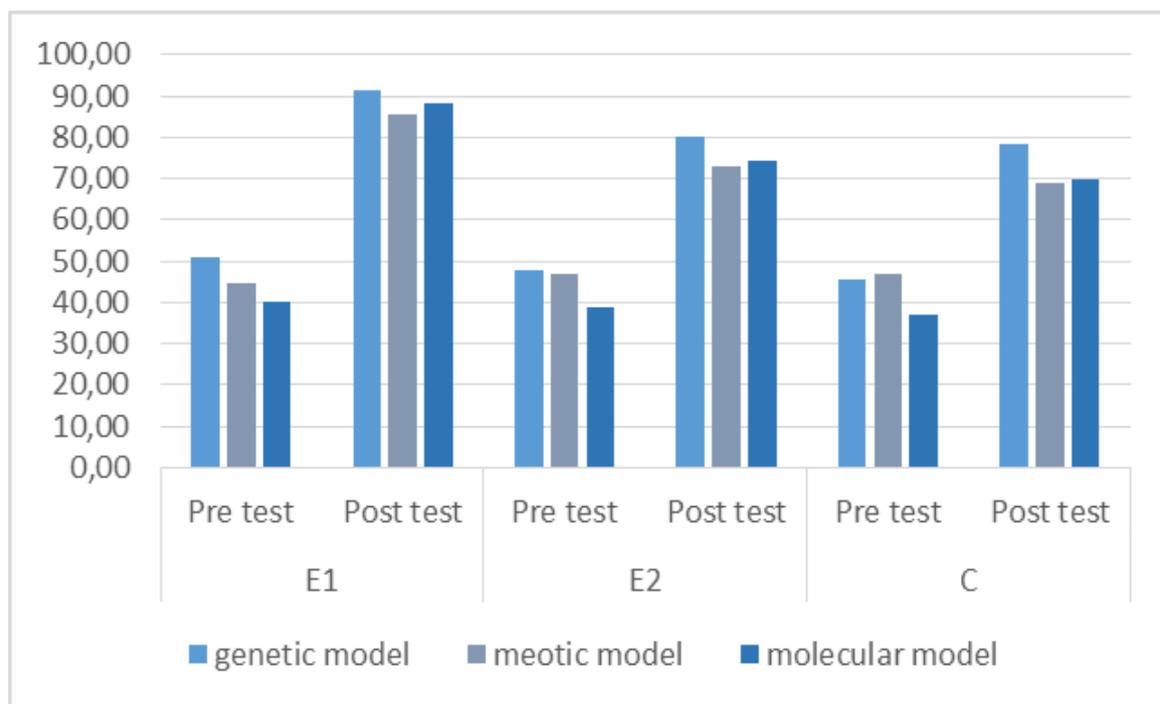


Figure 3. The average value of genetic literacy in each class

Figure 3 shows an increase in genetic literacy in both genetic, meiotic and molecular models. This can be seen from the increase in the value of genetic literacy on the posttest from the genetic literacy pretest. An increase in genetic literacy was found in all treatment groups or classes, both classes E1, E2 and C. The value of genetic literacy was then tested for normality and homogeneity, and it was found that genetic literacy in the three classes was normal and homogeneous. To find out the differences in the increase in genetic literacy between classes as a result of the different approaches in online discussion activities applied to each class, a different test for the average pre-test and post-test was carried out with the Manova test. The results of the genetic literacy test using the Manova test are shown in Table 3.

Table 3. The results of the Manova test for the value of genetic literacy

Test	Genetic models		Meiotic models		Molecular models	
	F	Sig	F	Sig	F	Sig
Pre test	1,997	0.141	0.707	0.496	1,535	0.221
Post test	51,825	0.000	13,640	0.000	81,917	0.000

Table 3 shows the significance value of the pretest which were all above 0.05 (> 0.005). This proves that the genetic literacy pre-test scores in the three classes are not different. Table 3 also shows the significance value of the post-test, all of which are below 0.05 (0.000), so this proves that the post-test value of genetic literacy in the three classes is different. The pre-test values for genetic literacy were not significantly different, indicating that the initial mastery of genetic literacy in the three classes did not differ, both in genetic, meiotic and molecular model literacy. The post test scores for genetic literacy were significantly different, indicating that the final mastery of genetic literacy in the three classes was different. This proves that the different approaches to problems in problem-based online discussion activities affect the mastery of genetic literacy in students. Furthermore, to find out the difference in the increase in genetic literacy in the three classes, a further test of genetic literacy scores was carried out with the Manova post Hoc test. Post hoc follow-up tests were carried out on pre-test and post-test scores of genetic literacy in each genetic literacy domain, namely genetic model, meiotic model and molecular model. The results of the post hoc genetic literacy test are shown in Table 4 for the pretest and Table 5 for the post test.

Table 4. The results of the different genetic literacy pretest scores

Class		Genetic models		Meiotic models		Molecular models	
		Sig.	Information	Sig.	Information	Sig.	Information
E1	E2	0.512	no different	0.561	no different	0.739	no different
	C	0.119	no different	0.553	no different	0.195	no different
E2	E1	0.512	no different	0.561	no different	0.739	no different
	C	0.654	no different	1.000	no different	0.580	no different
C	E1	0.119	no different	0.553	no different	0.195	no different
	E2	0.654	no different	1.000	no different	0.580	no different

Table 4 shows that there are no differences in the genetic literacy pretest scores of students in the three classes and in the three genetic literacy domains. This proves that the initial mastery of genetic literacy in the domain of genetic model, meiotic model and molecular model is not different in the three classes, meaning that the initial ability of genetic literacy in the three treatment groups is not different in ability. Genetic literacy of genetic, meiotic and molecular models after the implementation of the online discussion based on genetic problems in E1, E2 and C is shown in Table 5.

Table 5. The results of the different genetic literacy post test scores

Class		Genetic models		Meiotic models		Molecular models	
		Sig.	Information	Sig.	Information	Sig.	Information
E1	E2	0.000	Different	0.003	Different	0.000	Different
	C	0.000	Different	0.000	Different	0.000	Different
E2	E1	0.000	Different	0.003	Different	0.000	Different
	C	0.000	Different	0.003	Different	0.009	Different
C	E1	0.000	Different	0.000	Different	0.000	Different
	E2	0.000	Different	0.003	Different	0.009	Different

Table 5 shows that in each genetic literacy model, both genetic model, meiotic model and molecular model, there are significant differences between classes, both E1, E2 and C. This proves that there is an influence of the online discussion problem approach based on genetic problems on the mastery of genetic literacy models genetic, meiotic and molecular models. Tables 4 and 5 show that there is an increase in the mastery of genetic literacy in the three classes, and the increase in genetic literacy is different in the three classes. Descriptively, the highest increase in genetic literacy was in class E1, which is a class that implements online discussions based on genetic problems with a focus on student problems. This proves that genetic problem-based online discussions with a problem-focused focus on students can improve genetic literacy in students better than problem-focused educators.

The findings of this study are the application of genetic problem-based online discussions can improve genetic literacy in students. Genetic literacy in E1 with problem focus from students was found to be higher than in E2 with problem focus from educators and students. The majority of students in grade E1, can explain genetic problems and they work together to solve these problems, so that their genetic literacy scores are better than students in E2. Determining the themes of the study of the concept of genetics into the theme of the problem is an effective approach in providing genetic learning experiences to students. This is in line with several studies reported that the theme of genetic counseling (Cantor, Hippman, Hercher, & Austin, 2019), genetic information and its implications in social life (Castro-Faix et al., 2021; Duncan et al., 2015), and genetic problem solving in the post-genomic era (Stern & Kampourakis, 2017) is an appropriate theme to be applied in online discussion activities. Students explore thinking processes and understand themselves about the three conceptual models in genetics (Freidenreich et al., 2011) through online discussion activities to solve various genetic problems. Improving teacher candidates' conceptions of genetic phenomena has an effect on increasing their ability to understand the fundamental mechanisms of genetics (Castro-Faix et al., 2021; Stern & Kampourakis, 2017; Reinagel & Speth, 2016; Duncan et al., 2015; Andrews et al., 2012; Chu & Reid, 2012; Karagöz & Cakir, 2011; Duncan & Tseng, 2010).

Genetic literacy in prospective teachers is explored through habituation of online discussion activities by solving various genetic problems. Student activity in implementing genetic problem base discussion is to provide feedback, rebuttal and debate in the online discussion forum. Student responses in the discussion are a reflection of students' knowledge, attitudes, and perceptions in solving various genetic problems. That online

discussions make the transfer of knowledge insights, attitudes, and can increase students' perceptions of various problems, so that students try to solve problems (Cruz, 2020; Ari & Sadi, 2019; Duncan et al., 2015; Thomas et al., 2015; Andrews, et al., 2012). Various issues through the discussion. Learning that applies discussions of genetic engineering topics is a learning progress to better understand the mastery of genetic concepts, especially molecular genetics (Castro-Faix et al., 2021; Choden & Kijkuakul, 2020; Stern & Kampourakis, 2017; Bailey et al., 2010). Students share information in discussion activities. That online discussion is a recommended model to be applied in the learning process (Ebrahimi, et al, 2017; Andrade, 2015; Batardière, 2015; Mohamad & Shaharuddin, 2014). In addition, online discussions also authenticate the transfer of knowledge to students (Mohamad & Shaharuddin, 2014; Nedungadi & Raman, 2012) because of the activities of students who understand each other's cognitive presence in the online community (Crosswaite & Asbury, 2019; Beckmann & Weber, 2016; Kisa & Stein, 2015; Poehnl et al., 2013) so that the learning environment is constructive with the presence of learning interactions between students in online learning communities (Shan & Wang, 2021; Mallett, 2019; Ofstedal & Dahlberg, 2009).

Controversial themes such as cloning, stem cells and other themes are much debated in the world of biology, especially about the ethics of using them (Stern & Kampourakis, 2017; White, 2005; Best & Kellner, 2002). Genetic conceptions in students are also increasing on issues involving stem cells, gene cloning and its application in the health sector online discussions about stem cells and gene cloning can improve students' conceptions of stem cells and gene cloning (Alanazi, 2021; Halverson, et al., 2010). That knowledge is needed in building thinking patterns in responding to various social problems that arise related to the knowledge of genetics, genetic determination and some of its applications in everyday life that are related ethically (Alanazi, 2021; Crosswaite & Asbury, 2019; Halverson et al., 2010; Noordegraaf-Eelens, Kloeg, & Noordzij, 2019; Reinagel & Speth, 2016; Ylostalo, 2020). This can be facilitated through online discussion activities, so that students not only provide responses as a thought process, but also as a result of their mastery of genetic concepts.

Genetic literacy is the cognitive ability of students to understand genetics as part of everyday life as a result of the rapid development of post-genomic technology. Genetic literacy is the goal of genetic learning where students have adequate knowledge about the genome and its properties (Alozie, Grueber, & Dereski, 2015; Duncan & Tseng, 2010; Freidenreich 2011; Seager, 2014; Stern & Kampourakis, 2017), serves as a genetic consultant (Cantor et al., 2019), and solves various genetic problems in the post-genomic era (Ari & Sadi, 2019; Barthet, 2021; Buma & Nyamupangedengu, 2020; Stern & Kampourakis, 2017; Study, 2016; White, 2005) and its implications in social life. Genetic literacy of students with three conceptual models (Freidenreich, 2011) which includes genetic models, meiotic models and molecular models as cognitive abilities can be observed through student responses in genetic problem base discussion activities where students present argumentation and decision making in response to the genetic problems discussed. That discussion activities facilitate the sharing of information, knowledge and collaboration to solve problems (Beckmann & Weber, 2016; Ebrahimi et al., 2017; Enochsson, 2018; Kilinc & Anadolu, 2021; Maryuningsih, Hidayat, Riandi, & Rustaman, 2019b). Three models of genetic literacy were applied as the theme of the online discussion aimed at teaching genetics so that students are genetically literate. Students discuss genetic content and practice and use it as a basis for making decisions related to socio-scientific issues in the field of genetics. Genetic learning through online discussion activities is able to build the foundation of genetic literacy so that students are able to develop argumentation skills and appropriate decision-making related to genetic problems. The application of genetic problem base discussion in genetics lectures is a pedagogic approach where students exchange ideas, information and increase attention to other students' responses. That online discussions allow the exchange of ideas and increase sensitivity to other students' comments (Beckmann & Weber, 2016; Ebrahimi et al., 2017; Mohamad & Shaharuddin, 2014). In addition, students process information and response formats better through online discussions than face-to-face discussions (Beckmann & Weber, 2016; Chung, Sum, & Foon, 2011; Ebrahimi et al., 2017; Kilinc & Anadolu, 2021; Maryuningsih, Hidayat, Riandi, & Rustaman, 2019b; Mohamad & Shaharuddin, 2014). Online discussion activities that provide sustainable genetic literacy from genetic models to later on the meiotic model and then the molecular model, can improve the mastery of genetic concepts.

CONCLUSION

The application of genetic problem-based online discussions in genetics lectures increases genetics learning activities. Student responses in online discussion activities are their process in learning genetics. Online discussion activities based on genetic problems improve genetic literacy in students, namely genetic models, meiotic models, and molecular modules. The highest increase in genetic literacy was found in students who implemented online discussion activities based on genetic problems with a focus on student problems. The

advantages and disadvantages of this study are that discussion activities can be carried out without time restrictions because they are online so researchers must limit the discussion time so that the discussion time matches the scheduled time. The recommendation from this research is the need for a study and analysis of student responses in online discussion activities with critical thinking skills instruments, scientific argumentation or other skills that are 21st century skills.

ACKNOWLEDGEMENT

The author would like to thank all the research participants, namely the biology education students and IAIN Syekh Nurjati Cirebon.

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