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Flipped Classroom–Digital Game-Based Learning (FC-DGBL): Enhancing Genetics Conceptual Understanding of Students in Bilingual Programme

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ABSTRACT
The learning process with modern technology is an absolute requirement in the digital age. As a science subject with unique characteristics, biology also requires a unique and technology-based learning process. Flipped Classroom-Digital Game-Based Learning (FC-DGBL) is a learning model that combines flipped classrooms and evaluations using digital game-based learning Kahoot. This study on the effect of the FC-DGBL learning model on the conceptual understanding of Genetics was conducted on secondary school students in the grade nine bilingual program. The research was located at Penabur Christian Secondary School Kelapa Gading Jakarta, Indonesia. This study used a quasi-experimental design; the students involved were 46 students, and data on understanding genetic concepts were collected using a 12-question essay test that refers to Bloom's taxonomy. The analysis was performed by ANCOVA testing at the significance level a = 0.05. The results showed that FC-DGBL had a significant effect to enhance the conceptual understanding of the Genetics of bilingual secondary school students. Students who obtained the Flipped Classroom-Digital Game-Based Learning (FC-DGBL) significantly understood the Genetics concept than students with traditional learning models. Based on the dimensions of conceptual genetics understanding in the aspect of applying genetic knowledge, analyzing the concept of genetics, and proposing new ideas about genetics FC-DGBL had a higher increase, whereas the evaluating aspect of ideas related to genetics was lower than that of the control group. FC-DGBL is a good learning design for learning genetics in bilingual learning programs.

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Introduction

21st-century students are individuals who were born and raised in the digital era, making them familiar with digital technology and the internet. This fact makes 21st-century students are called digital natives (Bustami et al., 2021; Prensky, 2001b) or known as Net Generation (Tapscott, 1998). Nowadays students prefer learning using modern technology. This learning enables them to get better achievements (Hariyadi et al., 2018; Kara & Yeşilyurt, 2008; Movahedzadeh, 2011). This requires teachers to be able to incorporate learning using technology (Weng et al., 2019; Zubaidah et al., 2017).

Characteristics of Biology which are abstract, complex, and using Latin terms makes this subject a difficult subject for students (Çimer, 2012; Tekkaya et al., 2001). Characteristics of subject and unsuitable learning environment result in problems and a lack of interest in learning Biology (Roth et al., 2006; Zeidan, 2010), and students tend to learn by memorizing and do not have a meaningful learning process (Etobro & Fabinu, 2017). The understanding of biological concepts in various topics has received attention in various studies (Alkhawaldeh, 2007; Hazel & Prosser, 1994; Ozkan et al., 2004; Sungur et al., 2001). One of the effective ways to study biology is to create an interesting learning process (Çimer, 2012).

Flipped classroom (FC) is learning that is needed in digital eras, which is a method of internet-based learning techniques created by teachers in conveying information to students about learning materials (Stöhr & Adawi, 2018; van Vliet et al., 2015). Digital Game-Based Learning (DGBL) is a combination of learning content and computers (Prensky, 2001a). One of the DGBL applications, Kahoot, is an online quiz game that allows active learning, competitive and collaborative learning (Licorish et al., 2018; Wang, 2015). A literature study stated that the FC model improves student learning outcomes in developing countries (Kashada et al., 2017). FC provides learning experiences to students by learning virtually with the use of technology and face-to-face learning (Jensen et al., 2015; Lai & Hwang, 2016). Various research results reveal that the learning process with FC is carried out on various platforms such as Google Classroom, Microsoft Teams, Zoom Meeting, Google Meet, Edmodo, and Moodle (Ristanto et al.; Wicaksana et al., 2020; Darmawan et al., 2019; Hidayati et al., 2018; Permana et al., 2021; Permana & Chamisijatin, 2018; Wahyuni et al., 2020). The flexibility of viewing recording more than once and at the most relevant and convenient times improves student understanding and is an important asset in the FC model (Heijstra & Sigurðardóttir, 2017). Research on 44 fourth-grade students at the Directorate of Private Education in Amman, Jordan stated that the FC model shows significant differences in learning achievement (Elian & Hamaidi, 2018). FC facilitates students to use more of their learning time compared to classical learning in class (Styers et al., 2018). Teachers and students collaborate to achieve learning objectives by utilizing virtual classes through discussions or assignments (Rusdi et al., 2018). Broader learning opportunities and information on learning needs in the form of materials and discussions prepared by the teacher in a virtual classroom can help students reach better achievements (Ristanto et al., 2021).

Digital Game-Based Learning (DGBL) is a combination of learning content and computers, initiated to fulfill learning requirements that are more attractive to students in the digital generation (Prensky, 2001a). One of the DGBL applications, Kahoot, launched in 2013, is an online quiz game that allows active learning, competitive and collaborative learning (Licorish et al., 2018; Wang, 2015). The literature shows that Kahoot could help students achieve their biology learning goals (Chaiyo & Nokham, 2017; Orhan Göksün & Gürsoy, 2019). Studies show that energy and enthusiasm in the classroom are real during the learning process using DGBL (Öztürk & Korkmaz, 2019; Papadakis & Kalogiannakis, 2018). Students' competitive personality is revealed, and social interaction increases even involving calm and quiet students (Boden & Hart, 2018). The results of the study by Annetta et al. (2009) show that there are significant differences in genetic learning outcomes with the involvement of games in the learning process.

Genetics is a topic with a large and complex vocabulary, involves processes within the cell, which is abstract and complex and has mathematical content with various symbols especially on Mendelian genetics (Williams et al., 2012). Based on those characteristics, students and teachers need more time to carry out the process of understanding and experimenting (Bahar et al., 1999; Chu, 2008; Knippels et al., 2005). There have been many exploratory studies regarding the difficulties in the teaching and learning process of Genetics but the development and strategies to overcome them are still lacking (Knippels et al., 2005; Todd & Romine, 2018). Research shows that the bilingual program students' understanding of the biology concept is low (Kristiani et al., 2020). The focus of learning for bilingual students is learning using two languages, this is what further students have difficulty in mastering the concepts (Meyerhöffer & Dreesmann, 2019).

Characteristics of students in the digital era, the existence of bilingual classes that use foreign languages in the learning process (Meyerhöffer & Dreesmann, 2019). The students' low understanding of Biology concepts, the characteristics of Genetics topics, and the lack of Genetics learning strategies make it necessary to research to expand Genetics teaching and learning strategies (Miharja et al., 2019). The genetics learning process is still teacher-oriented by using the lecture method, teacher explanations, a little discussion, and less involvement of technology in providing learning facilities for students (Casanoves et al., 2017). Learning with a combination of Flipped Classroom and Digital Game-Based Learning (FC-DGBL) is expected to fulfill all these needs. The combination of FC which students do their own learning before entering the class, followed by class discussions and evaluations using DGBL, is expected to increase learning motivation and by itself can increase students' Genetics understanding.

There have been many kinds of research related to flipped classrooms (Da-Hong et al., 2020; Jensen et al., 2015; Rusdi et al., 2018), but currently, no one has combined it with a digital game on biology learning. Several research topics related to concept mastery have also been carried out in previous research (Darmawan & Surya, 2017; Denny Muhammad Fajar et al., 2020; Djamahar et al., 2020; Djamahar et al., 2019; Muhlisin et al., 2018; Ristanto et al., 2021), but research topics related to FC-DGBL learning design on concept mastery on the topic of genetics have not been carried out. Research related to the integration of metacognitive instruments and concept mastery has also been done before (Lestari et al., 2019), but this research is limited to the topic of Pteridophyta in universities, this research also uses integrated metacognitive instruments with mastery of concepts but on the topic of genetics. in middle school students. This study aims to measure the effect of learning with the combination of Flipped Classroom Digital Game-Based Learning (FC-DGBL) to the Genetics understanding in bilingual secondary school students. How is the implementation, influence, and response of students who are taught with FC-DGBL in learning genetics for bilingual students on concept mastery?

Methods

Research Design

The research was conducted at Penabur Christian Secondary School Kelapa Gading Jakarta, Indonesia in the even semester of the 2019/2020 academic year. This study used a quasi-experimental design (Sugiyono, 2012). The experiment consisted of an independent variable, the FC-DGBL model; and the dependent variable, Genetics conceptual understanding. The control variable is conventional learning. Conventional learning is a design that is usually applied by teachers to a learning process on a particular topic (Ristanto & Darmawan, 2020). In this study, conventional learning uses a teacher-centered approach through the lecture method and is interspersed with discussion and question and answer.

Study Group

The population of this study was all students of grade IX (nine) bilingual program at Penabur Christian Secondary School Kelapa Gading Jakarta, Indonesia in the 2019/2020 academic year. The total population is 47 people. Sampling was done by the simple random sampling technique and calculated using the Slovin formula (Ryan, 2013) which aims to determine the minimum sample of a number of research populations. The formula is as follows:

$$n = \frac{\mathrm{N}}{1 + \mathrm{Ne}^2}$$

Note:
n = number of samples
N = number of populations
e = error margin
Regarding the formula, the minimum sample size is 42 students. In this study, the sample used was 46 students. The sample was divided into a control group (23 students) and an experimental group (23 students).

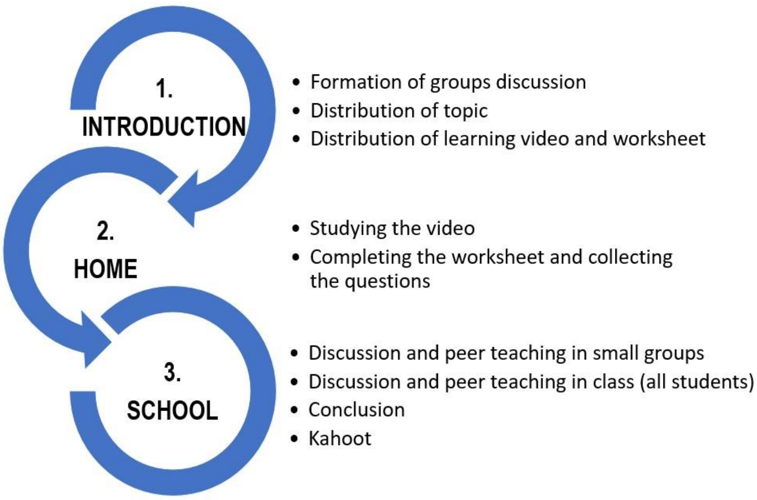
Implementation Process

This research procedure consists of several stages, the first stage is the preparation stage, which consists of 1) observation of the bilingual class at Penabur Christian Secondary School Jakarta; 2) prepare documents needed for the experiment which are syllabus, lesson plans, learning materials, student worksheets, and test instrument. Student worksheets and test instruments are in the appendix.

The second stage is the implementation stage. Before entering the learning process, both control and experimental class students were given a pre-test using the conceptual understanding test instrument. Then in the experimental class, students were given learning objectives and videos on topics to be discussed through Google classroom. The video was taken from YouTube related to the topic of learning objectives that have been formulated including applying genetic knowledge, analyzing the concept of genetics, evaluating ideas related to genetics, and proposing new ideas about genetics. Students studied the learning videos individually at home with the guide of the worksheet. Learning continued in-class group discussion. In each class, students are grouped according to the principle of cooperative learning, which consists of four students, so that in each class there are nine groups. Furthermore, presentations and discussions were conducted according to the topics that have been distributed to each group. After discussion in several meetings, students were given evaluation questions through Kahoot. Kahoot implementation during class, namely, students use their smartphones and are guided by the teacher. Meanwhile, the control class implementation stage is carried out through the direct instruction lesson from the teacher. The teacher involved in this study was a certified biology teacher who taught the experimental and control class. The experimental and control class learning process was carried out in 6 meetings. The schematic of the FC-DGBL learning syntax can be seen in Figure 1. At the end of the learning process, all students, both the control and experimental classes, were given a post-test using the conceptual understanding test instrument.

Figure 1

Scheme of the FC-DGBL Learning Syntax



Note. (Bergmann & Sams, 2012)

Data Collection Tools

The instrument of the Genetics conceptual understanding comprehension test was a cognitive test according to Bloom's taxonomy. It consists of 12 essay problems with the level of applying (C3), analyzing (C4), evaluating (C5), and creating (C6). Each cognitive level consists of 3 essay problems.

This study uses the same type of instrument at the pretest and posttest. Validation of the instrument consisted of two stages, expert validation, and empirical validation and reliability. The expert validation was done through the assessment by 2 (two) Genetics lecturers from the University of Jember, Indonesia, and the University of Muhammadiyah Malang, Indonesia. The average validation result of genetic learning experts shows 97%, so it can be categorized as a valid instrument (Arikunto & Jabar, 2010). The grid of Genetics Conceptual Understanding is shown in Table 1.

Table 1

Genetics Conceptual Understanding Grid

Num	Indicator	Number of Questions	∑ Questions
1	Applying (C3) Solve problems and turn them into new situations by applying knowledge, facts, techniques, and rules related to the principles of Genetics in different ways.	7, 10, 11	3
2	Analyze (C4) Examining and separating information about Genetics by identifying the causes. Make conclusions and find evidence to support generalizations.	1, 2, 4	3
3	Evaluating (C5) Present and defend opinions in matters related to Genetics and make judgments about the information, validity of ideas, or the quality of a procedure based on a series of criteria	5, 8, 9	3
4	Creating (C6) Compile information about Genetics by combining elements into new patterns or proposing alternative solutions	3, 6, 12	3
	Total		12

Empirical validation assessment of the instrument was carried out using the Pearson Product Moment formula. The empirical reliability assessment of the instrument was carried out using Cronbach's alpha formula. The validity and reliability test was carried out on students in other schools within the same scope of educational foundations and had the same characteristics and levels as the school where this research was carried out. The range of Cronbach's Alpha values, which shows that the instrument is reliable is 0.7 - 0.9 (Bland & Altman, 1997.

The results of the empirical validation and reliability of the instrument show that the value of r_{count} for all items was greater than the r_{table} value, this indicates that the instrument to be used is valid for measuring the Genetics conceptual understanding of secondary school students (Arikunto & Jabar, 2010). The reliability value of Cronbach's Alpha instrument was 0.739, it can be concluded that the items on the instrument are reliable and strong as a research data collection tool (Arikunto & Jabar, 2010; De Vellis, 2003).

Data Analysis

Obtained data from the pre-test and post-test scores were analyzed by descriptive test analysis and ANCOVA. In addition, to measure differences in the achievement of genetics learning objectives for each indicator, the t-test was also carried out using pre-test and post-test data. This aims to help identify and analyze the achievement of FC-DGBL learning and control on aspects of mastery of the concept of genetics. After the lesson, interviews were conducted with students regarding the implementation of FC-DGBL. The prerequisite analysis test consists of the Kolmogorov-Smirnov normality test and the Levene homogeneity test with a significance level of 0.05. The results of the normality test are shown in Table 2. The significance value of both the pre-test and post-test was above 0.05, indicating that all data came from a normal distribution.

Table 2

The Summary of Normality Test on the Pre-Test and Post-Test Scores of Genetics Conceptual Understanding

No.	Class	N	Pre-test Sig. value	Post-test Sig. value	α	Note
1	Experiment	23	0.668	0.575	0.05	Normal distribution
2	Control	23	0.648	0.299	0.05	Normal distribution

The results of the homogeneity test are shown in Table 3. The significance value of the pre-test and post-test were above 0.05. Those indicate that all data were homogeneous.

Table 3

The Summary of Homogeneity Test on the Pre-Test and Post-Test Scores of Genetics Conceptual Understanding

No.	Class	N	Pre-test Sig. value	Post-test Sig. value	α	Note
1	Experiment	23	0.395	0.258	0.05	Homogeneous
2	Control	23	0.395	0.258	0.05	Homogeneous

Findings

The summary of the Genetics conceptual understanding test results can be seen in Table 4. Based on the table, all average scores of post-tests are higher than pre-test in all indicators or cognitive domains studied (C3, C4, C5, and C6). The overall post-test average score of the experimental class was 8.41 higher than the control class. The standard deviation of the pre-test and post-test scores was between 13.56-17.83 in the experimental class and between 8.49-20.68 in the control class.

Table 4

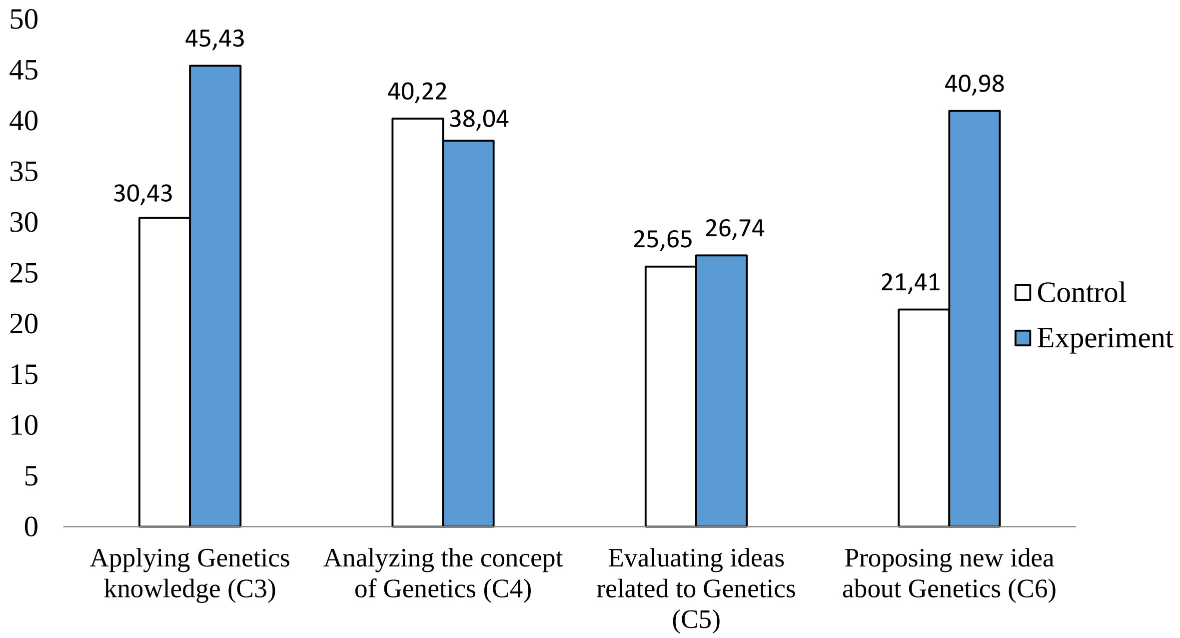
The Summary of Genetics Conceptual Understanding Test Results

Indicator	Experiment class					Control class				
	N	Pre-test (Mean±SD)		Post-test (Mean±SD)		N	Pre-test (Mean±SD)		Post-test (Mean±SD)	
Applying Genetics knowledge (C3)	23	28.48	(±16.41)	73.91	(±16.37)	23	36.96	(±8.49)	67.39	(±20.39)
Analyzing the concept of Genetics (C4)	23	39.40	(±17.82)	77.45	(+13.81)	23	32.61	(±17.47)	72.83	(±17.33)
Evaluating ideas related to Genetics (C5)	23	52.61	(±13.56)	79.35	(±16.19)	23	43.04	(±11.55)	68.70	(±20.68)
Proposing new idea about Genetics (C6)	23	30.11	(±14.63)	71.09	(±17.83)	23	37.83	(±10.75)	59.24	(±17.68)
Mean	23	37.65	(±15.60)	75.45	(±16.05)	23	37.61	(±12.07)	67.04	(±19.02)

Figure 2 shows that the highest increase in the experimental class score is in the cognitive domain of applying Genetic knowledge (C3), which is 45.43%. The lowest increasing score was in the cognitive domain of evaluating ideas related to Genetics (C5), which is 26.74%.

Figure 2

The Percentage of the Increasing Score for Each Indicator of Genetics Conceptual Understanding



The significance of the t-test for the pre-test score of each indicator shows that there is no significant difference between the control and experimental classes (Table 5.). This means that the control and experimental classes have balanced pre-test scores before the learning process for all indicators of Genetics conceptual understanding.

Table 5

The Summary of Pre-Test Scores Independent Sample T-Test of Each Genetics Conceptual Understanding Indicator in the Experimental and Control Class

Num	Indicator	Mean	α	t-test significance	Comparison between sig. and α	Conclusion
1	Applying Genetic knowledge (C3)	32.72	0.05	0.692	Sig. > α	No average difference
2	Analyzing the concept of Genetics (C4)	36.01	0.05	0.199	Sig. > α	No average difference
3	Evaluating ideas related to Genetics (C5)	47.83	0.05	0.013	Sig. > α	No average difference
4	Proposing new idea about Genetics (C6)	33.97	0.05	0.124	Sig. > α	No average difference

The post-test score of each indicator of Genetics conceptual understanding shows the t-test significance value less than 0.05 (Table 6.). This means that there is a significant difference in the post-test score between the experimental and control class in all indicators.

Table 6

The Summary of Post-Test Scores Independent Sample T-Test of Each Genetics Conceptual Understanding Indicator in the Experimental and Control Class

Num	Indicator	Mean	α	t-test significance	Comparison between sig. and α	Conclusion
1	Applying Genetic knowledge (C3)	70.65	0.05	0.015	Sig. > α	Average difference
2	Analyzing the concept of Genetics (C4)	75.14	0.05	0.000	Sig. > α	Average difference
3	Evaluating ideas related to Genetics (C5)	74.02	0.05	0.000	Sig. > α	Average difference
4	Proposing new idea about Genetics (C6)	65.16	0.05	0.029	Sig. > α	Average difference

The result of the hypothesis test for Genetics conceptual understanding using Ancova with a significance level of 0.05, is shown in Table 7. In the class analysis, the significance value is 0.016 less than 0.05. It means that the difference of class gives a significant effect on the post-test. Based on the data in Table 4, the post-test score of the experimental class was higher than the control class with an average difference of 8.41. It can be concluded that FC-DGBL has a significant effect on Genetics conceptual understanding. Students in the FC-DGBL model have a better conceptual understanding than students with traditional learning models.

Table 7

Result of Ancova of Genetics Conceptual Understanding

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3465.982[a]	2	1732.991	9.667	.000
Intercept	3552.167	1	3552.167	19.816	.000
Pretest_CUG	2461.091	1	2461.091	13.729	.001
Kelas	1123.000	1	1123.000	6.265	.016
Error	7708.203	43	179.261		
Total	240793.750	46			
Corrected Total	11174.185	45			

Hypothesis and descriptive test analysis of data show that the FC-DGBL model is effective in increasing the Genetic conceptual understanding. This correlates with studies that flipped classrooms (Karabatak & Polat, 2020; Kashada et al., 2017; Talan & Gulsecen, 2019) and Kahoot (Benhadj et al., 2019; Fuster-Guilló et al., 2019) can improve student learning outcomes.

Table 4. shows that the experimental and control classes have increased in score after the learning process. This illustrates that students' Genetics conceptual understanding increases, but the increase was different. The experimental class overall post-test average was 75.45, above the school’s Minimum Completeness Criteria (MCC). While the control class overall post-test average was 67.04, below the school’s MCC. The post-test mean score of the class with the FC-DGBL model was higher than the class with the traditional learning model in all indicators of Genetics conceptual understanding. In the experimental class, the indicators of applying Genetic knowledge (C3), analyzing the concept of Genetics (C4), and evaluating ideas related to Genetics (C5) have a post-test average above the school's MMC score (73). Only indicators creating new things about Genetics (C6) have an average score close to the MCC

Table 8

Interview Results of FC-DGBL Implementation to Student Representatives

Student 1	Answers
Response	Provide additional information that may not be included in the curriculum, so that we can understand more about the concept of genetics
Obstacles	Some students in groups are difficult to work with
Solution	Establishing communication between group members, making a schedule for discussion of material together so that everyone understands the learning topic
Recommendations	Activity is needed, in which students are asked to collect information from other sources from the video. The results were also presented to increase knowledge.
Student 2	Answers
Response	Videos help me understand the videos prepared by our teacher. About genetic cross and Punnett square
Obstacles	Nothing
Solution	Nothing
Recommendations	Give points to be more enthusiastic to compete
Student 3	Answers
Response	This learning improves the ability to understand the concept of genetics and public speaking
Obstacles	Sometimes several friends in a group find it difficult to coordinate
Solution	Learning constraints are internal to the group, done by increasing chemistry with the group
Recommendations	FC-DGBL is already good because this learning makes the learning atmosphere more interactive and less bored.
Student 4	Answers
Response	I became more independent in learning to prepare presentations and broadened my horizons through group discussions.
Obstacles	The results of the discussion still need to be confirmed by the teacher
Solution	Ask the biology teacher to confirm and explain again
Recommendations	Before learning, the teacher should provide a brief explanation regarding the topic of learning.

Discussion

The results of the FC-DGBL implementation interview with student representatives are summarized in Table 8. Student responses to learning, obstacles, difficulties, and recommendations to FC-DGBL learning reveal that this learning helps students facilitate mastery of genetic concepts and improve other skills such as public speaking and collaborating. This learning contains FC, the principles of cooperative learning, and gamification to provide a better experience for students. Recommendations are also important to note for the application of FC-DGBL in the next lesson.

Based on the average post-test score, it can be concluded that the experimental class students have successfully applied the knowledge to complete monohybrid crossing, crossing on sex-linked genes, and genetic engineering techniques; able to analyze the concept of monohybrid and dihybrid crossing; able to evaluate crossovers in sex-linked genes, human karyotypes, and crossing of blood groups. But they have not been able to compile genetic engineering techniques and design a form of crossover to get the desired offspring. This achievement is seen based on the average post-test score which is above the MCC score (Table 4). Meanwhile, the traditional class got the average post-test score above MCC only in an analysis of the Genetic concept (C4) indicator (Table 4). The whole C4 problem is a matter of Mendelian genetics. Mendelian genetics is a material that is closely related to mathematical calculations, so it can be estimated that control class students mastering this material because their mathematical basis is stronger than the experimental class. This can be seen from the average daily test scores of Mathematics they get in the odd semester. The average score of the control class mathematics daily tests was 88.30 while the experimental class was 83.52.

Before the learning process began, students were divided into groups of 3-4 people to create cooperative learning methods. This method has a positive effect on learning outcomes, increases information retention, communication skills, problem-solving, and creativity (Demet & Ozlem, 2019; Ferguson-Patrick, 2007; Slavin, 2015; Tran, 2014).

Before the first meeting, the teacher had shared learning videos and worksheets through the Google Classroom Learning Management System (LMS). According to research, the use of LMS can be maximized by teachers to increase the effectiveness of learning (AlJarrah et al., 2018; Nouri, 2016). Therefore, in the FC-DGBL model teacher shares the division of tasks, worksheets, learning videos and establishes communication-related to learning through the Google Classroom. Based on the observations, the bilingual program students of Penabur Christian Secondary School Kelapa Gading Jakarta, Indonesia have suitable conditions with the demands of e-learning. All students have digital equipment and an internet connection that is suitable with the minimum requirements. Since that the distribution of material through Google Classroom can be implemented properly.

According to the syntax of the learning model in Figure 1, flipped classroom begins with learning activities at home. Students carried out independent exploration with the help of instructional videos. Learning videos provide opportunities for students to study the material according to their individual learning speed (Bergmann & Sams, 2012; Nanclares & Rodríguez, 2016). In its implementation, some of the experimental class students repeated to study the learning videos during class discussions. This helps their learning process because the video can be played according to their individual needs. Students who have difficulty with certain concepts can playback the video until they gain understanding.

At the beginning of learning, students were not used to doing the learning process at home. Most of the students did not study the video given seriously and some students did not even open the video. Through several meetings, students are familiar with this learning model so they have studied the video and made better preparations. In connection with this, we conclude that controlling through LMS is very necessary. Scored the worksheet could increase their motivation.

The next stage of the flipped classroom is the meeting at school. The learning method used is active learning (Smallhorn, 2017). According to Figure 1, active learning in the FC-DGBL model was carried out through discussion and peer teaching in small groups followed by class presentations and discussions.

At the discussion stage students already have basic knowledge about the materials and the teacher can create learning activities that open the opportunities to improve students' understanding (Stöhr & Adawi, 2018; van Vliet et al., 2015) and create meaningful learning (Levine et al., 2008). Based on the observations, students were more prepared after studying the video given. Therefore, the required time for the understanding process in the experimental class occurs faster than in the control class. Experiment class students have more time to explore the material. The control class does not have preparation before the lesson. All materials were given by direct instruction, resulting in low learning motivation and a slow understanding process.

The cooperative learning in the experimental class was carried out through group work guided by structured worksheets (Djamahar et al., 2020; Ristanto & Darmawan, 2020). It helped students focus on the topic and build meaningful discussions (Ristanto, Rahayu, et al., 2021). Students who were going to do the presentations must understand their respective material. This matches with a study that stated that students who are involved in discussion and group work have a deeper understanding of the material and increase problem-solving skills (Davis, 2009). Peer tutoring is a learning method in which some students act as academic tutors by providing structured instructions, questions, and guidance for other students under the supervision of the teacher (Topping et al., 2013;

Zeneli & Tymms, 2015). Through this method, students can develop critical thinking skills, problem-solving, leadership, collaboration, and communication skills. The effects were the learning outcomes and students' satisfaction increase (Darmawan et al., 2020; Ristanto et al., 2020).

This method can also improve students' self-concept (Moliner & Alegre, 2020). In this study, the teacher selected several outstanding students in biology. They are students who had participated in science competitions or who had a high score in the previous lesson to act as tutors. Through this method, it can be seen that students who act as tutors and students who were guided got self-improvement (Berso & Lorente, 2020; Miquel & Duran, 2017). Several studies proved that the peer tutoring method improves student learning outcomes (Alegre et al., 2019; Berso & Lorente, 2020; Bulut, 2019; Ristanto et al., 2021). The experimental class students had proven this by obtaining an average score higher than the control class.

Learning evaluation through Kahoot as part of school meeting activities in the FC-DGBL model has a positive impact on the student learning atmosphere and makes the classroom more dynamic. The evaluation process was carried out at the fourth and sixth meetings. Students get the motivation to study complex genetic material because the teacher provided additional scores for the 3 (three) groups of students who got the highest score. In addition, the classroom learning atmosphere becomes more fun and varied. Quiet students were actively involved in the quiz without realizing it (Ristanto et al., 2020). However, based on the observation, it turned out that not all students carried out the appropriate analysis process, especially the concept of crossing, because the time limit for answering questions was very limited, some students were encouraged to answer by guessing the answer. All these facts prove that Kahoot creates a positive effect on the atmosphere and comfortable of student learning as well as class dynamics (Wang & Tahir, 2020). However, it is not fully correlated with the increase in knowledge. Kahoot's digital game-based learning also encourages active, competitive, and collaborative learning (Licorish et al., 2018; Wang, 2015) and this can be seen from the enthusiasm and collaboration of students in answering quiz questions.

Combination of a flipped classroom and digital game-based learning Kahoot open the possibility to create a learning atmosphere that enhances communication skills, collaboration, creative thinking, and critical thinking, the 21st-century skills (Al-Zahrani, 2015; Hamdani, 2019; Rodríguez et al., 2019; van Vliet et al., 2015; Wasriep & Lajium, 2019). Based on this research, the improvement of these skills occurs through discussion and peer tutoring activities in small groups and classes, preparation of presentation materials, asking and answering questions during discussion, and answering quizzes through Kahoot in groups. It also needs to be considered that most of these learning processes require the power of the internet and adequate digital equipment (Nouri, 2016; Rodríguez et al., 2019; Wang & Tahir, 2020).

Learning Genetics, which is complex, has mathematical content, and has a considerable time required for the understanding process as well as the demands of learning in English in a bilingual classroom, is strongly supported by the FC-DGBL model. The whole process carried out in this learning allowed students to have higher-order thinking skills (Chen et al., 2017; Estrada et al., 2019; Hwang et al., 2019). This is proved by the increase in the student's ability to answer questions at the analyzing (C4), evaluating (C5), and creating (C6) cognitive levels.

Conclusion and Implications

FC-DGBL significantly affects the Genetics conceptual understanding of bilingual secondary school students. Students with the FC-DGBL learning model have a better understanding of the concept of Genetics than students with traditional learning models. The post-test average score of students with the FC-DGBL model was 8.41 higher than students with traditional learning models. The FC-DGBL learning model can be used as an alternative learning model to increase understanding of concepts, especially for the topic of Genetics. It is necessary to develop a variety of face-to-face learning methods. This study is relevant with studies that flipped classrooms (Karabatak & Polat, 2020; Kashada et al., 2017; Talan & Gulsecen, 2019) and Kahoot (Benhadj et al., 2019; Fuster-Guilló et al., 2019) can improve student learning outcomes. Therefore, students remain enthusiastic and motivated in learning. Based on the dimensions of mastery of the concept of genetics in the aspect of applying genetic knowledge, analyzing the concept of genetics, and proposing new ideas about genetics FC-DGBL had a higher increase, whereas the evaluating aspect of ideas related to genetics was lower than that of the control class. FC-DGBL is a good learning design for learning genetics in bilingual learning programs. Further research is recommended to develop the FC-DGBL design by integrating it with learning that prioritizes the process of improving student skills at the evaluation level.

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Appendix 1

Student Worksheet

Watch the learning video from our group Google Classroom and complete your task below:

Group 1

Topic: Genetic Material → video 1

1. Please explain about:
- Gene
- DNA
- Chromosome
2. Explanation must contain:
   - Diagram
   - Definition
   - Structure and function
   - Characteristics

Group 2

Topic: Human Karyotype → video 2

Explain about human karyotype. Explanation must contain:

1. Description of chromatid and sister chromatid
2. Diagram of human karyotype
3. Description of
- Number of chromosome
- Haploid and diploid cell and example for each
- Autosome and gonosome (symbol, definition, and function)

Group 3

Topic: Introduction of Crossing → video 3 and 4

1. Explain about:
- Allele
- Genotype and phenotype
- Parental and filial
- Gamete
- Homozygous and heterozygous
- Dominant and recessive traits
- True breeding plant
- F1 and F2 generation in crossing
- Punnet square
2. Known:
   - H = hairy pig, h = hairless pig,
   - T = PTC taster, t = non-PTC taster,
   - P = polydactyl, p = normal.

Explain about the variation of genotype and phenotype for each trait above.

3. Explain about the gamete/gametes for each genotype below:
   - AA
   - Aa
   - AABb
   - AaBb
4. Explain about Mendel's Law (I and II) in crossing

Group 4

Topic: Monohybrid Crossing (Complete Dominance) → video 4 and 5

1. What is monohybrid crossing?
2. What is test cross?
3. Explain about monohybrid complete dominance crossing using:
    - Crossing diagram of PTC taster (Tt and Tt). Diagram must contains: genotype and phenotype of parental (parents), punnet square, genotype ratio and phenotype ratio of filial (offspring).
    - Crossings diagram of guinea pig (all combination of crossings). Each diagram must contains: genotype and phenotype of parental (parents), punnet square, genotype ratio and phenotype ratio of filial (offspring).

Group 5

Topic: Monohybrid Crossing (Incomplete Dominance) → video 4 and 6

There are 3 types of snapdragon-plant's genotype: RR, Rr, rr.

Explain the crossings of Snapdragon plants using diagram (all combination of crossings). Each diagram must contain: genotype and phenotype of parental (parents), punnet square, genotype ratio and phenotype ratio of filial (offspring).

Group 6

Topic: Dihybrid Crossing → video 7, 8, and 4 (for additional information)

Explain about dihydrid crossing: crossing in cat (video 7) and crossing in plant (video 8) using diagram of crossing. Each diagram must contain: genotype and phenotype of parental (parents), punnet square, genotype ratio and phenotype ratio of filial (offspring).

Group 7

Topic: Crossing of ABO Blood Type in Human → video 9 and 10

1. Explain about ABO blood group. Explanation must contain:
- Definition of immunoglubulin protein
- Type of allele in ABO blood group
- Definition of codominance
- Type of genotype and phenotype in ABO blood group
2. Explain about ABO blood type crossing using diagram:
    - Crossing between heterozygous A type with O type
    - Crossing between A type and B type; both of them are heterozygous (1st crossing), both of them are homozygous (2nd crossing).

Each diagram must contain: genotype and phenotype of parental (parents), punnet square, genotype ratio and phenotype ratio of filial (offspring).

Group 8

Topic: Human Disorder Traits → video 11, 12, 13, 14, and 15

1. Explain about crossing related to human disorders below:
- Albino, it is known that albinism controlled by "a" allele (recessive allele)
- Haemophilia, it is known that haemophilia is sex linked traits (allele H=normal, h=haemophilia). Cross normal male with haemophilia female.
- Colour blind, it is known that colour blind is sex linked traits (allele C=normal, c=colour blind). Cross haemophilia male with normal female.

Explanation using diagram of crossing must contain: genotype and phenotype of parental (parents), punnet square, genotype ratio and phenotype ratio of filial (offspring)

2. Explain about Down syndrome in genetics.

Group 9
Topic: Genetic Modified Organism → video 16, 17, 18, and 19
1. What is GMO?
2. Explain the steps to make GMO using terms below:
   - Vector DNA (Plasmid)
   - Donor DNA
   - Restriction enzyme
   - Ligase enzyme
   - Recombinant DNA
3. What is GMP? What is transgenic plant?
Give examples of GMP. What is Golden Rice plant?
4. What are the components to make GMP? Explain the process using these terms:
   - desired trait gene
   - plasmid
   - bacteria
   - gene gun
   - *Agrobacterium* mediated transformation
   - plant tissue culture
   -

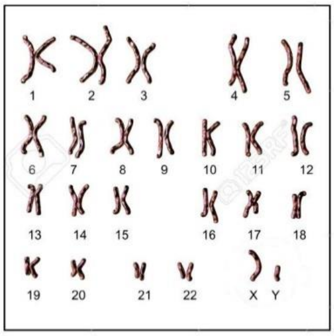
Appendix 2
PRETEST AND POSTTEST PROBLEM SET

Topic : Inheritance
Grade : Nine
Time : 90 minutes
Day/Date : ……

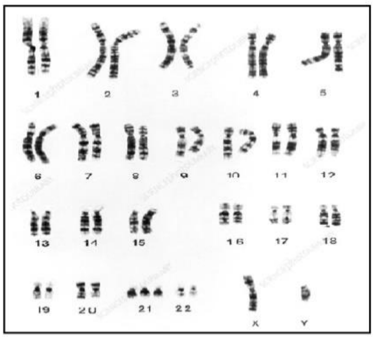
Answer the questions below with the correct and clear answer

1. The oval watermelon was crossed with the round watermelon. All the offspring were round. We collected the seed from this cross, grew F_1-generation plants, let them self-pollinate to get F_2 (second generation). F_2 produced 240 watermelons. Use alleles "**R**" and "**r**" in the crossing.
   A. Classify the crossing. Is that complete or incomplete dominance? Explain!
   B. How many oval watermelons will produce in F2? Write all the crossing and make your estimation! **(score: 5)**
2. Red and white colors of snapdragon flower are incomplete dominant (intermediate) traits.
   The crossing between two heterozygous snapdragon plants will produce 75% red flower plants. Is that statement correct? Explain!
   Use alleles "**R**" and "**r**" in the crossing! **(score: 5)**
3. Red colour in rose petal is completely dominant to yellow. Mark has two type of rose, red and yellow. How does Mark know the genotype of each plant? Create the crossing to help Mark! **(score: 10)**
4. We cross the black coats and brown eyes wolves with the brown coats and blue eyes wolves. The result from that crossing is all the offspring has brown coats and blue eyes. Analize the ratio of phenotype in the second offspring (F_2)! **(score: 10)**
5. A man with AB blood type married to a woman with O blood type. They have two biological children, and one adopted child. The children's blood types are: A, B, and O. Which child was adopted? Give your argument! **(score: 10)**

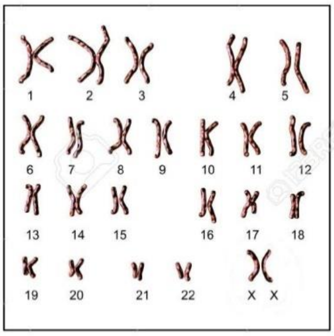
6. Vulnerable to pathogen and non-fragrant grain are dominant traits in *Oryza sativa*. The opposite of vulnerable is resistant and the opposite of non-fragrant grain is fragrant grain. Create a crossing to get a best quality of offspring with the biggest probability! Use alleles "**A**" and "**a**" for resistant trait, "F" and "f" for fragrance in the crossing! **(score: 10)**
7. In humans, haemophilia is a sex-linked condition and normal blood clotting (H) is dominant to the condition of haemophilia (h). A normal woman whose father was haemophilia marries a normal man. Determine the genotype of the woman and the man. Determine the ratio of genotype and phenotype for their children! **(score: 10)**
8. Color blind is sex-linked trait. John was born from a color-blind mother. He married Ruth. She isn't color blind. Ruth's mother is color blind. Predict the percentage of John and Ruth to get color blind son! **(score: 10)**
9. The following are diagrams of karyotype. Compare diagram A, B, C, and D (similarities and differences between A, B, C, and D)! **(score: 5)**



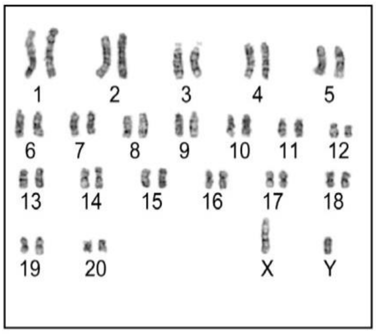
A



C



B



D

10. The allele for normal person is "**A"** (dominant trait), while allele for albino is "**a"** (recessive trait). Heterozygous person is normal. Genotype is symbolized using pair of alleles. **(Score: 5)**
    A. Jack has the genotype **aa**. Determine his phenotype. Explain!
    B. Jack doesn't want to g*et al*bino child. What should he do? Explain your answer using the crossing!
11. Insulin production is one of genetic engineering to maintain the health of people with diabetes mellitus. Develop the genetic engineering technique to help people with haemophilia! **(score: 10)**
12. The following are factors of GMO (Genetically Modified Organism): provitamin A gene, Ti plasmid, restriction enzyme, ligase enzyme, recombinant DNA, *Agrobacterium tumefaciens*, plant cell. Construct the GMO technique using those factors to get Golden Rice plant! **(score: 10)**