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Effects of Project-Based Learning with Project Guide E-book on Critical Thinking and Metacognitive Skills: A Case from Undergraduate Biology Students in Genetic 1 Course

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Abstract

Critical thinking skills bears a fundamental role in students' thinking process and achievement. Meanwhile, the cornerstone of critical thinking is a metacognitive activity that has a substantial function in measuring and evaluating the obtained information, as well as learning from the experience. This study aims to examine students' critical thinking and metacognitive skills before and after they participate in the PBL classroom using a project guide e-book for the genetic one course. The student's critical thinking skills were assessed using written tests using open-ended question items. Further, the obtained scores were analyzed using paired t-test. The data analysis suggested an increase in students' metacognitive and critical thinking skills after they attended the PBL class using the PBL-based project guide e-book for genetic 1. This increase was shown from the 0.000< α (α = 0,05) significance score of paired t-test. Thus, the PBL-based project guide e-book for the genetic 1 course is capable of enhancing students' metacognitive and critical thinking skills.

Keywords: project-based learning; project guide e-book; genetic; critical thinking skills; metacognitive skills

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INTRODUCTION

In order to face the 5.0 industry, students have to present great knowledge mastery, along with 21st-century skills, to broaden their ideas and solve their daily issues (Heong et al., 2012; Rahman, 2019). Critical thinking skills are one of the primary 21st-century skills (Alahmad et al., 2021). It is one of the cognitive skills with a particular function in the decision-making and assessment processes (Chartrand & Flander, 2013). Critical thinking skills are a crucial element in comprehending reliable information and formulating opinions after considering different viewpoints (Saadé et al., 2012; van Laar et al., 2019). It is also reported as an essential aspect of students thinking progression (King et al., n.d.), as well as students' effective problem-solving skills in social, scientific, and practical issues (Mahanal et al., 2019).

Experts have provided different definitions of critical thinking. Critical thinking is defined as the skills that develop from cognitive processes, such as implementing, analyzing, synthesizing, and evaluating information gathered through active observation, experience, reasoning, and communication (Facione, 2015). It is also described as the process of examining, organizing, clarifying, selecting, and prioritizing ideas in just, constructive, and thorough means (Treffinger & Isaksen, 2013). Besides, another study defines it as activating skills in analyzing evidence, evaluating evidence, identifying a question, and constructing logical conclusions (Mahanal et al., 2019). Therefore, critical thinking is a crucial talent that aids the learning process and empowers individuals to contribute creatively to their selection of professional path (Aizikovitsh-Udi & Cheng, 2015). This skill is significantly required due to the increasing number of complex issues faced by individuals during this rapid technological advancement and social movement (Ulger, 2018). Critical thinking skills can be measured through essay tests and scoring rubrics (Finken & Ennis, 2013; Zubaidah et al., 2018).

According to a number of research, Indonesia still struggles with critical thinking ability (Corebima, 2016; Kurniawati et al., 2016). Linearly, our preliminary observation suggested that the critical thinking skills of Biology students in the genetic 1 course are still categorized as low (level 1-2, underdeveloped or unobserved). Additionally, metacognitive activities are the fundamental aspect of critical thinking skills. These activities reflect students' thinking level in evaluating their reasoning and learning from experience (Corebima, 2009; Vezzosi, 2004).

The empowerment of metacognitive skills substantially influences students' critical thinking and cognitive skills (Amin et al., 2020; Warni et al., 2018). Metacognitive skills are essential as it impacts the acquisition, comprehension, retention, and implementation of the obtained skills and knowledge, along with students' learning efficiency, critical thinking, and problem-solving skills (Hartman, 1998). With high metacognitive skills, students can identify the ways to select and implement learning strategies, evaluate their effective individual strategies, and usage of evaluation in designing their future learning design (Stanton et al., 2019). The metacognitive skills can be measured from students' ability to present their work for a conceptual test analyzed using a scoring rubric (Corebima, 2009).

Even if cognitive skills are placed as essential skills, studies reported that Biology students still have low metacognitive skills (Erlin & Fitriani, 2019; Herlanti et al., 2019; Hilpert et al., 2021; Lestari et al., 2019). The results of our preliminary study also suggested that Biology undergraduate students' metacognitive skills in the genetic 1 course are still low. One of the viable alternatives for empowering students' critical thinking and metacognitive skills is the implementation of a learning model involving high-order thinking skills, such as project-based learning (PBL) (Amin et al., 2020; Corebima, 2016). PBL-based learning enhances students' metacognitive and critical thinking skills since they are given the opportunities to construct their beliefs, collaborate with other people, and conduct effective self-regulation (Cortázar et al., 2021; Rahmawati & Haryani, 2016).

In the Biology Department of Universitas Negeri Malang, the genetics course is one of the courses which adopts the PBL learning model. Project-based learning (PBL) has been reported present a more significant contribution in enhancing students' critical thinking and metacognitive skills, compared to conventional learning, since PBL facilitates students to collaborate in groups and feel content with their communal achievement (Yalçin, 2017). Accordingly, the usage of PBL-based learning material is recommended since it aids teachers in realizing students' active participation and improves students' critical thinking (Hayati & Syaikhu, 2020; Ngurah et al., 2018; Sianturi et al., 2021). Another research also uncovered that the PBL-based learning model is capable of facilitating students to construct their knowledge with unambiguous planning, observation, and behavioral evaluation (Pulmones, 2008).

In Universitas Negeri Malang, the genetic course is divided into genetic 1 and genetic 2 courses. Both courses adopt project-based learning. Their only difference is the type of materials, with fundamental materials in genetic 1 course and applicative materials in the genetic 2 courses. The topics of the genetic 1 course include the matting duration of *Drosophila melanogaster*, Mendel law 1, Mendel law 2, crossing over, error in meiosis, gen interaction, sex ratio, and effects of colchicine on the onion root mitosis. However, our observation results showed that the PBL-based learning in the genetic 1 course during the 2018/2019 academic year had not been carried out optimally, with less than 50% reported project data and low cognitive learning results. One of the causes of this problem is the absence of a project guidebook. The project guidebook enables the realization of optimum learning and helps students identify the authentic inquiry principle during the research process (Fauzi, 2017).

As a consequence, in this study, we used a guidebook in the form of an e-book since e-book presents quick distribution, low cost, and extensive accessibility through the internet connection. Our project guide e-book integrates the structure of a classical guidebook with electronic features and display [30]. A previous study reported that the use of a project guidebook with authentic context motivates students to complete a project (Susanti & Trisusana, 2018). Implementation of PBL-based learning with digital learning material stimulates students to read numerous different resources, as well as be more enthusiastic in attending to learning and completing the project (Lubis et al., 2020). Besides, a study proposed that genetic course should be regulated following the relevant learning resources with practicum activities that facilitates students' physical and psychological active participation (Sukmawati et al., 2016).

Therefore, this study aims to investigate the Biology undergraduate students' critical thinking and metacognitive skills after attending the PBL learning with project guide e-book in the genetic 1 course. The adoption of PBL-based learning with the project guide e-book is forecasted to promote students' meaningful learning experiences.

METHOD

This pre-experimental study used one group pretest-posttest design. As many as 30 undergraduate Biology students participated in this study. As for the learning process, it contained three stages, namely, pretest, PBL-based learning with the e-book, and posttest. For the research instrument, we used a learning plan in one semester, a course unit, and a project guide e-book for the genetic 1 course. The student's critical thinking and metacognitive skills were assessed using an open-ended assessment in the form of an essay test. Meanwhile, their test answers were analyzed using the special rubric of critical thinking skills, modified from the rubric developed by Finken and Ennis (Zubaidah, 2018) and Corebima (2009). The results were further calculated using Formula 1.

$$Y2 = \frac{Y1 + 2X}{3} \quad \text{……………………………………………………(1)}$$

Description:
Y1 = metacognitive skills score (from rubric)
Y2 = conceptual understanding score (non-rubric)
X = combined metacognitive skills and conceptual understanding scores

The results of the pretest and posttest on critical thinking and metacognitive skills were assessed using a normality test, followed by paired t-test using SPSS for windows 25.0. The treatment and measurement instruments had undergone validity and reliability test, attaining scores of 99.06 and 0.844, respectively. Therefore, the instruments are classified as valid and reliable to be implemented in the genetic 1 course.

RESULTS AND DISCUSSION

The results of our descriptive analysis signified increasing critical thinking and metacognitive skills in students before and after they participated in the PBL-based classroom using the project guide e-book. Detailed of the students' average pretest and posttest scores are listed in Table 1 and illustrated in Figure 1.

Table 1. Average, Friction, and Percentage of Students' Average Pretest and Posttest Scores

Variable	Average		Increase (%)
	Pretest	*Posttest*	
Critical Thinking Skills	26.33	68.33	159.51
Metacognitive Skills	38.76	79.60	105.37

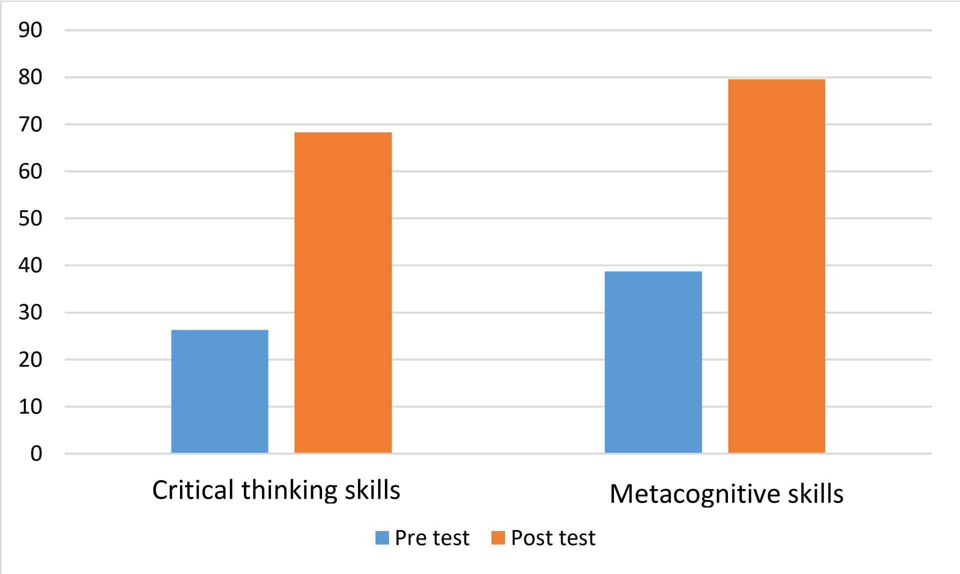


Figure 1. Average Students' Pretest-Posttest Scores on Critical Thinking and Metacognitive Skills

Prior to the paired t-test, we conducted a data normality test. The results of the data normality test presented in Table 2 suggested that the significance scores for the critical thinking and metacognitive skills are (0.375) > (0.05) and (0.428) > (0.05), respectively. The results indicated that our data have a normal distribution and were further analyzed using paired t-tests.

Table 2. Results of the Normality Test

	Statistic	df	Sig.
Metacognitive Skills	0.961	28	0.375
Critical thinking skills	0.964	28	0.428

Table 3. Results of Paired T-test

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	KBK*	-41.8	17.3	3.3	-48.5	-35.1	-12.8	27.0	0.00
Pair 2	KM*	-42.0	10.2	1.9	-45.9	-38.1	-21.9	27.0	0.00

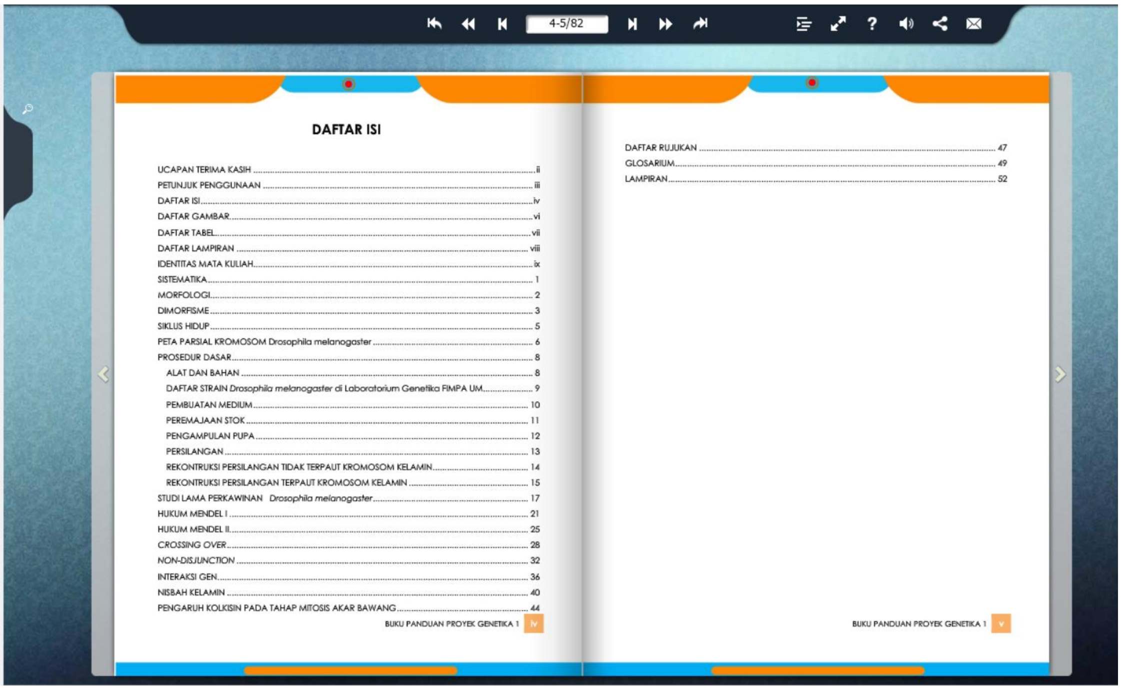
*KBK= Critical thinking skills; KM=Metacognitive skills

According to Table 3, the results of paired t-test showed a significant score of (0.00) > (0.05) for both critical thinking and metacognitive skills. Thus, the H_1 is accepted, suggesting the increase of students' critical thinking and metacognitive skills after they attended the PBL-based genetic 1 project using the project guide e-book.

Critical Thinking Skills

Increase of Critical Thinking Skills after Attending PBL-based learning using the Project Guide E-book

Our analysis results showed a 159.51% increase in undergraduate Biology students' critical thinking skills after they participated in the PBL-based genetic 1 course using a project guide e-book. It is linear with a study carried out by Kokotsaki reporting that the syntax of PBL motivates students to implement their project design in gathering evidence (Kokotsaki et al., 2016).



DAFTAR ISI

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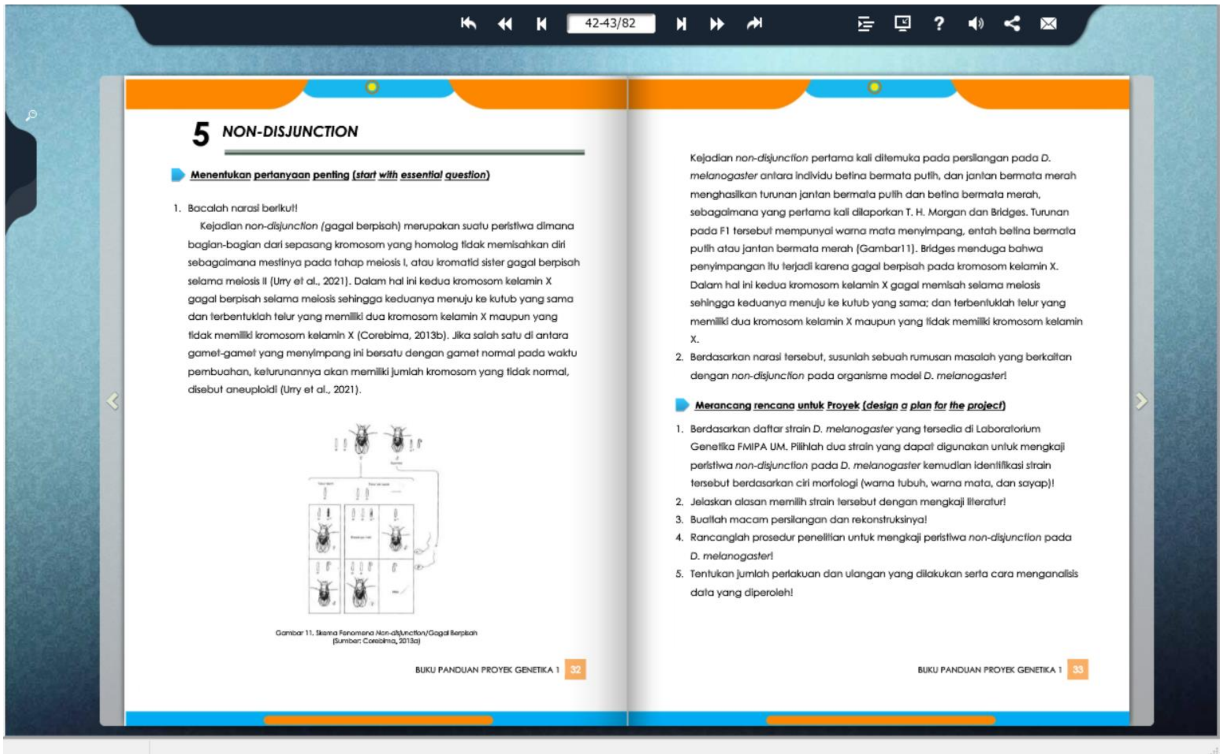
BUKU PANDUAN PROYEK GENETIKA 1 v

Figure 1. Table of Content from Project Guide Genetic 1 Course



5 *NON-DISJUNCTION*

Menentukan pertanyaan penting (*start with essential question*)

1. Bacalah narasi berikut!

Kejadian *non-disjunction* (gagal berpisah) merupakan suatu peristiwa dimana bagian-bagian dari sepasang kromosom yang homolog tidak memisahkan diri sebagaimana mestinya pada tahap meiosis I, atau kromatid sister gagal berpisah selama meiosis II (Urry et al., 2021). Dalam hal ini kedua kromosom kelamin X gagal berpisah selama meiosis sehingga keduanya menuju ke kutub yang sama dan terbentuklah telur yang memiliki dua kromosom kelamin X maupun yang tidak memiliki kromosom kelamin X (Corebima, 2013b). Jika salah satu di antara gamet-gamet yang menyimpang ini bersatu dengan gamet normal pada waktu pembuahan, keturunannya akan memiliki jumlah kromosom yang tidak normal, disebut aneuploidi (Urry et al., 2021).

Gambar 11. Skema Fenomena *Non-disjunction*/Gagal Berpisah (Sumber: Corebima, 2013a)

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Kejadian *non-disjunction* pertama kali ditemuka pada persilangan pada *D. melanogaster* antara individu betina bermata putih, dan jantan bermata merah menghasilkan turunan jantan bermata putih dan betina bermata merah, sebagaimana yang pertama kali dilaporkan T. H. Morgan dan Bridges. Turunan pada F1 tersebut mempunyai warna mata menyimpang, entah betina bermata putih atau jantan bermata merah (Gambar11). Bridges menduga bahwa penyimpangan itu terjadi karena gagal berpisah pada kromosom kelamin X. Dalam hal ini kedua kromosom kelamin X gagal memisah selama meiosis sehingga keduanya menuju ke kutub yang sama; dan terbentuklah telur yang memiliki dua kromosom kelamin X maupun yang tidak memiliki kromosom kelamin X.

2. Berdasarkan narasi tersebut, susunlah sebuah rumusan masalah yang berkaitan dengan *non-disjunction* pada organisme model *D. melanogaster*!

Merancang rencana untuk Proyek (*design a plan for the project*)

1. Berdasarkan daftar strain *D. melanogaster* yang tersedia di Laboratorium Genetika FMIPA UM. Pilihlah dua strain yang dapat digunakan untuk mengkaji peristiwa *non-disjunction* pada *D. melanogaster* kemudian identifikasi strain tersebut berdasarkan ciri morfologi (warna tubuh, warna mata, dan sayap)!
2. Jelaskan alasan memilih strain tersebut dengan mengkaji literatur!
3. Buatlah macam persilangan dan rekonstruksinya!
4. Rancanglah prosedur penelitian untuk mengkaji peristiwa *non-disjunction* pada *D. melanogaster*!
5. Tentukan jumlah perlakuan dan ulangan yang dilakukan serta cara menganalisis data yang diperoleh!

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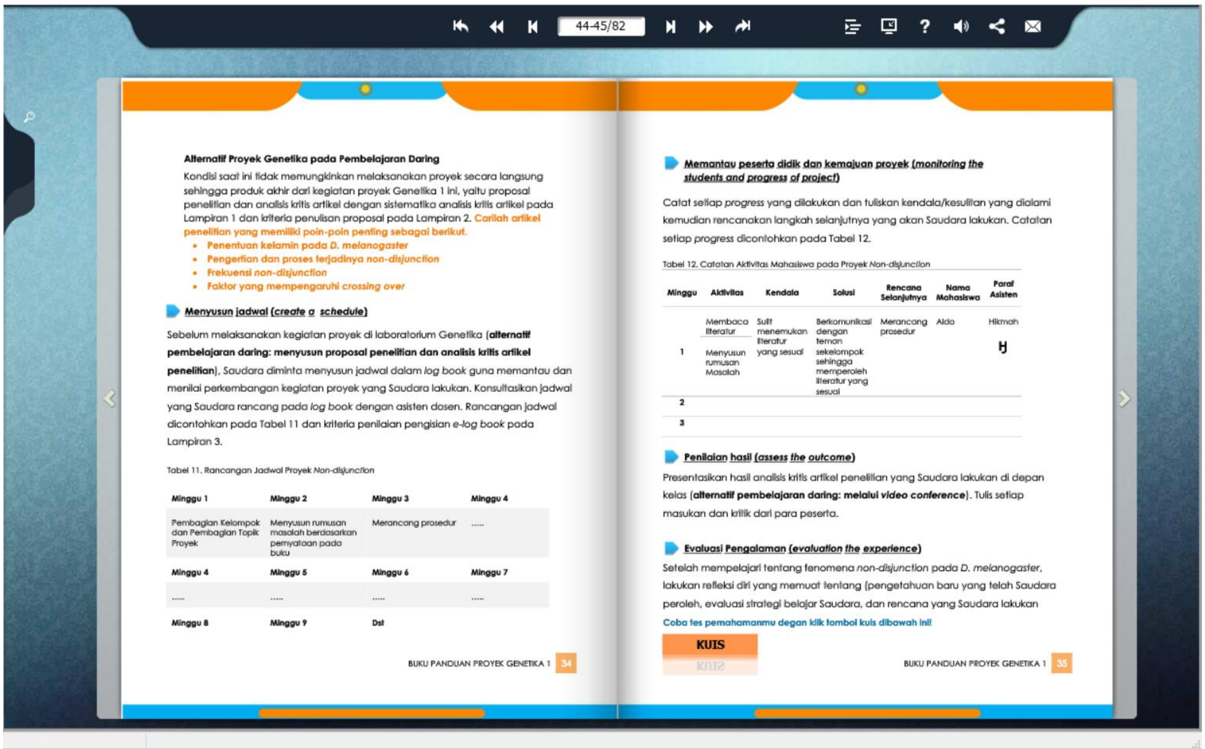
Figure 2. Phases of Determining Essential Questions and Designing Research in PBL-based Genetic 1 Project Guide E-book


44-45/82

Alternatif Proyek Genetika pada Pembelajaran Daring

Kondisi saat ini tidak memungkinkan melaksanakan proyek secara langsung sehingga produk akhir dari kegiatan proyek Genetika 1 ini, yaitu proposal penelitian dan analisis kritis artikel dengan sistematika analisis kritis artikel pada Lampiran 1 dan kriteria penulisan proposal pada Lampiran 2. **Carilah artikel penelitian yang memiliki poin-poin penting sebagai berikut.**

- **Penentuan kelamin pada *D. melanogaster***
- **Pengertian dan proses terjadinya *non-disjunction***
- **Frekuensi *non-disjunction***
- **Faktor yang mempengaruhi *crossing over***

Menyusun jadwal (*create a schedule*)

Sebelum melaksanakan kegiatan proyek di laboratorium Genetika (**alternatif pembelajaran daring: menyusun proposal penelitian dan analisis kritis artikel penelitian**), Saudara diminta menyusun jadwal dalam *log book* guna memantau dan menilai perkembangan kegiatan proyek yang Saudara lakukan. Konsultasikan jadwal yang Saudara rancang pada *log book* dengan asisten dosen. Rancangan jadwal dicontohkan pada Tabel 11 dan kriteria penilaian pengisian *e-log book* pada Lampiran 3.

Tabel 11. Rancangan Jadwal Proyek *Non-disjunction*

Minggu 1	Minggu 2	Minggu 3	Minggu 4
Pembagian Kelompok dan Pembagian Topik Proyek	Menyusun rumusan masalah berdasarkan pernyataan pada buku	Merancang prosedur	.....
Minggu 4	**Minggu 5**	**Minggu 6**	**Minggu 7**
.....	.....	.....	.....
Minggu 8	**Minggu 9**	**Dst**	

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Memantau peserta didik dan kemajuan proyek (*monitoring the students and progress of project*)

Catat setiap *progress* yang dilakukan dan tuliskan kendala/kesulitan yang dialami kemudian rencanakan langkah selanjutnya yang akan Saudara lakukan. Catatan setiap *progress* dicontohkan pada Tabel 12.

Tabel 12. Catatan Aktivitas Mahasiswa pada Proyek *Non-disjunction*

Minggu	Aktivitas	Kendala	Solusi	Rencana Selanjutnya	Nama Mahasiswa	Paraf Asisten
1	Membaca literatur; Menyusun rumusan Masalah	Sulit menemukan literatur yang sesuai	Berkomunikasi dengan teman sekelompok sehingga memperoleh literatur yang sesuai	Merancang prosedur	Aldo	Hikmah
2						
3						

Penilaian hasil (*assess the outcome*)

Presentasikan hasil analisis kritis artikel penelitian yang Saudara lakukan di depan kelas (**alternatif pembelajaran daring: melalui *video conference***). Tulis setiap masukan dan kritik dari para peserta.

Evaluasi Pengalaman (*evaluation the experience*)

Setelah mempelajari tentang fenomena *non-disjunction* pada *D. melanogaster*, lakukan refleksi diri yang memuat tentang (pengetahuan baru yang telah Saudara peroleh, evaluasi strategi belajar Saudara, dan rencana yang Saudara lakukan

Coba tes pemahamanmu degan klik tombol kuis dibawah ini!

KUIS

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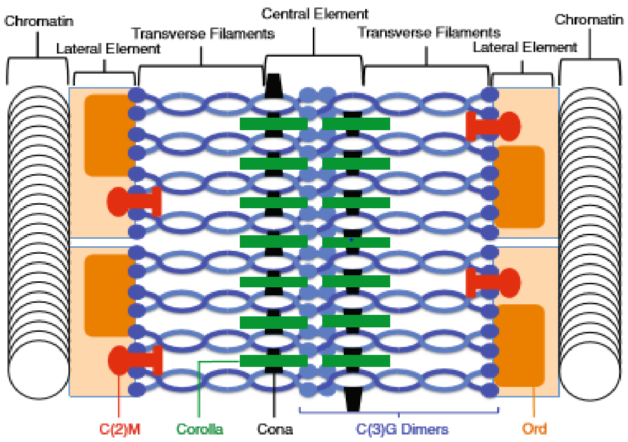
Figure 3. Stage of PBL in Designing Experience Evaluation Schedule from Genetic 1 Project Guide E-book

The PBL syntaxes promote students' critical thinking skills, starting from determining essential questions, designing a project plan, formulating a schedule, completing the project, assessing the project results, and evaluating experience after conducting the project, as illustrated in Figure 1-3. In PBL, students are obligated to collaborate and cooperate with their peers in exploring the knowledge during the project completion. PBL is one of the learning models that deepen students' independent and critical thinking through problem-solving, decision-making, investigation, presentation, and report formulation processes. Therefore, in PBL, students learning become more contextual. With this learning model, students can look for information from a number of sources, such as books and articles accessible on the Internet. Besides, the use of the project guide e-book also facilitates the PBL process during the genetic 1 course.

In addition, the PBL-based material e-book has been reported to improve students' critical thinking skills as it involves investigating examples from authentic daily life problems (Liana et al., 2021). A study carried out by Prihata et al. also uncovered that interactive e-book with a scientific approach develops students' critical thinking skill as it enables them to observe, ask a question, interpret, experiment, and present their work (Prihata et al., 2020). Meanwhile, (Ambarwati et al., 2019) described that interactive e-book assists students in analyzing, synthesizing, and evaluating information obtained during a learning

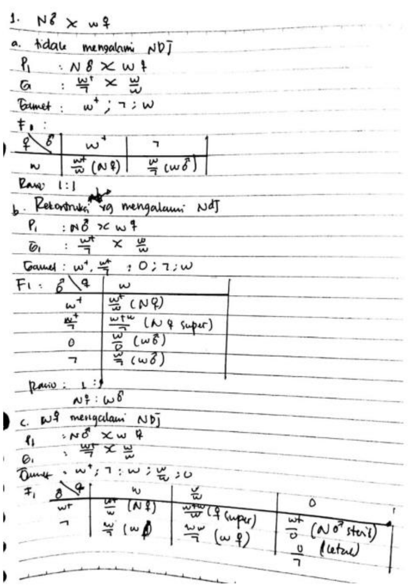
Students expanding critical thinking skills are observed from their essay test during the pretest and posttest. Table 4 illustrates question number 9 from the pretest. In this question item, many students had no capacity to answer the question. Following the implementation of the PBL-based learning with project guide e-book for the genetic 1 course, students showed better capacity in mentioning the components of the synaptonemal complex, along with each of their functions. Besides, students' increasing critical thinking skill was also observed from their answers in question item no 10 for the organization indicator. During the pretest, students gave the incorrect answer in this question with no supporting reason for their answers. Meanwhile, in the posttest, after students participated in the PBL-based learning using the genetic 1 project guide, they can provide reasoning for lower than 50% move values based on the crossing-over process. This finding signifies improved skills in supporting reason indicators. Additionally, in item number 11, students provided less accurate answers during the pretest, showing their inability to construct and determine individuals with non-disjunction. After attending the PBL-based genetic 1 course with a project guide e-book, students presented sufficient skills in constructing the non-disjunction crossing and determining the descendants with ndj. From students' answers in item number 11, they presented the ability to identify the number of individuals percentage from the data obtained in question number 12. Students' answers to questions number 11 and 12 suggest their improved skills in focus and reasoning indicators.

Table 4. Examples of Critical Thinking Question Items

<table>
<tr><th>Item No</th><th>Question</th></tr>
<tr><td>9.</td><td>The following is an illustration of the synaptonemal complex that facilitates crossing over.


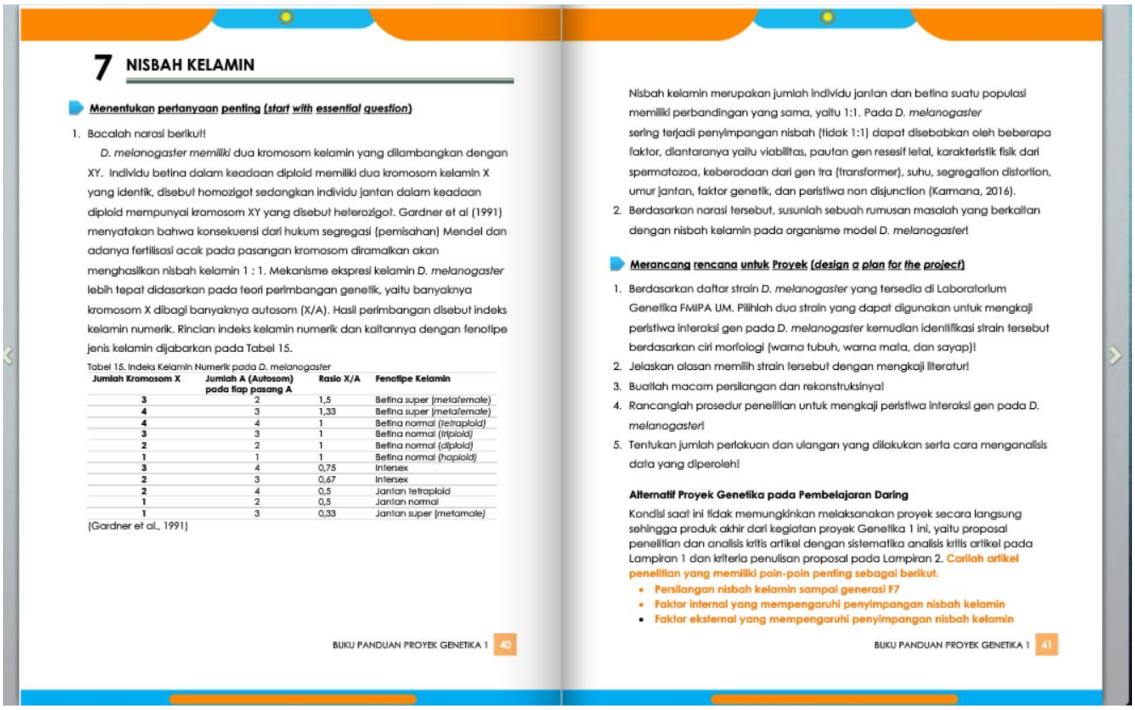
The synaptonemal complex contains a number of proteins, but not all of those proteins contribute to the crossing over. Do you agree with this statement? Please describe your reason.</td></tr>
<tr><td>10.</td><td>Crossing over is a process of exchange of genetic material from the non-sister chromatids of homologous chromosomes. The value of crossing over has never been more than 50%. Is this statement correct? Please explain your analysis.</td></tr>
<tr><td>11.</td><td>The crossing over between ♂N>< ♀w may show the non-disjunction occurrence. Please describe that statement using the construction of crossing over and determine the individual experiencing ndj.</td></tr>
<tr><td>12.</td><td>Andi and Nisa conduct a crossing over between ♂N>< ♀w. They obtain F1 descendants as described in the following table.
<table>
<tr><th>Fenotip</th><th>U1</th><th>U2</th><th>U3</th><th>U4</th><th>U5</th><th>U6</th><th>Total</th></tr>
<tr><td>♀N</td><td>22</td><td>23</td><td>17</td><td>27</td><td>11</td><td>15</td><td>115</td></tr>
<tr><td>♂N</td><td>2</td><td>1</td><td>1</td><td>2</td><td>1</td><td>2</td><td>9</td></tr>
<tr><td>♀w</td><td>1</td><td>2</td><td>0</td><td>0</td><td>2</td><td>1</td><td>6</td></tr>
<tr><td>♂w</td><td>13</td><td>12</td><td>17</td><td>18</td><td>15</td><td>15</td><td>90</td></tr>
<tr><td></td><td colspan="3">Total</td><td></td><td></td><td></td><td>220</td></tr>
</table>
From the data obtained by Andi and Nisa, please estimate the non-disjunction frequency on the ♂N>< ♀w crossing over!</td></tr>
</table>

Table 5. Example of HZ Students' Answer to Critical Thinking Question

Answer from Pretest	Answer from Posttest
9. 10. Nilai Pindah Silang (NPS) tidak dapat melebihi dari 50%, karena bila nilai NPS lebih dari 50% tidak akan terjadi *crossing over* pada antar gen di dalam kromosom. Komparasi masing-masing kromosom dari induk jantan dan betina adalah maksimal 50% untuk membentuk variasi individu baru. Jika lebih dari 50% tidak memungkinkan terjadinya pindah silang antar gen, sebab melebihi kapasitas maksimal pembentukan kromosom. 11. Rekonstruksi yang mengalami nondisjunction P1 : N♂ >< w ♀ Genotip : + ¬ >< Gamet : w+,¬ ; w , , 0 12. Frekuensi NDJ: N♂ = 9/220 x 100% = 4,09% w ♀ = 6/220 x 100% = 2,72%	9. Protein : a. Protein ORD membantu dalam segregasi dan membantu secara tidak langsung proses rekombinasi pada meiosis akan tetapi fungsi ORD lebih cenderung pada kesatbilan synaptonemal complex. b. Protein C(2)M berperan dalam membantu pembentukan lateral elemen. c. Protein COROLLA dan CONA menyokong struktur tengah yang utama dari Synaptonemal complex. COROLLA dan CONA berfungsi promoter pematangan DSB dan membantu kinerja dari protein C(3)G. d. Protein C(3)G inilah yang berperan langsung dan memfasilitasi terjadinya rekombinasi. e. Hemmer (2016) juga menyatakan bahwa C(3)G merupakan protein dalam bentuk dimer pada bagian Transverse Filaments yang bertanggung jawab untuk pembentukan synapsis, mengkonversi celah pada strand menjadi crossingover dan memfasilitasi perpindahan gen untuk berekombinasi. 10. Karena hanya dua dari empat kromatid saja yang ikut mengambil bagian pada peristiwa pindah silang dan pindah silang ganda akan mengurangi banyaknya tipe rekombinasi yang dihasilkan. 11. Rekontruksi  Rasio 2:1:1:1 Individu yang mengalami NDJ adalah 12. Frekuensi NDJ: N♂ = 9/220 x 100% = 4,09% w ♀ = 6/220 x 100% = 2,72%

Improved Metacognitive Skills after Participating in PBL-based learning using Project Guide E-book

Our data analysis suggested a 105.37% increase in metacognitive skills after students learned using the PBL-based method with the project guide e-book. This increase in metacognitive skills was also observed from the results of paired t-test. Therefore, the phases of PBL syntax with project guide e-book aid students in enhancing their metacognitive skills. Those phases include determining the essential question, designing a project plan, arranging the schedule, conducting the project, assessing the project results, and evaluating the experience after conducting a project. The completion of a project assists students in developing their research, gathering information, correlating information, formulating a conclusion, and constructing an evaluation of the project's findings, independently (Aldabbus, 2018).



7 NISBAH KELAMIN

Menentukan pertanyaan penting (*start with essential question*)

1. Bacalah narasi berikut!

D. melanogaster memiliki dua kromosom kelamin yang dilambangkan dengan XY. Individu betina dalam keadaan diploid memiliki dua kromosom kelamin X yang identik, disebut homozigot sedangkan individu jantan dalam keadaan diploid mempunyai kromosom XY yang disebut heterozigot. Gardner et al (1991) menyatakan bahwa konsekuensi dari hukum segregasi (pemisahan) Mendel dan adanya fertilisasi acak pada pasangan kromosom diramalkan akan menghasilkan nisbah kelamin 1 : 1. Mekanisme ekspresi kelamin D. *melanogaster* lebih tepat didasarkan pada teori perimbangan genetik, yaitu banyaknya kromosom X dibagi banyaknya autosom (X/A). Hasil perimbangan disebut indeks kelamin numerik. Rincian indeks kelamin numerik dan kaitannya dengan fenotipe jenis kelamin dijabarkan pada Tabel 15.

Tabel 15. Indeks Kelamin Numerik pada *D. melanogaster*

Jumlah Kromosom X	Jumlah A (Autosom) pada tiap pasang A	Rasio X/A	Fenotipe Kelamin
3	2	1,5	Betina super (*metafemale*)
4	3	1,33	Betina super (*metafemale*)
4	4	1	Betina normal (*tetraploid*)
3	3	1	Betina normal (*triploid*)
2	2	1	Betina normal (*diploid*)
1	1	1	Betina normal (*haploid*)
3	4	0,75	Intersex
2	3	0,67	Intersex
2	4	0,5	Jantan tetraploid
1	2	0,5	Jantan normal
1	3	0,33	Jantan super (*metamale*)

(Gardner et al., 1991)

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Nisbah kelamin merupakan jumlah individu jantan dan betina suatu populasi memiliki perbandingan yang sama, yaitu 1:1. Pada *D. melanogaster* sering terjadi penyimpangan nisbah (tidak 1:1) dapat disebabkan oleh beberapa faktor, diantaranya yaitu viabilitas, pautan gen resesif letal, karakteristik fisik dari spermatozoa, keberadaan dari gen tra (transformer), suhu, segregation distortion, umur jantan, faktor genetik, dan peristiwa non disjunction (Karmana, 2016).

2. Berdasarkan narasi tersebut, susunlah sebuah rumusan masalah yang berkaitan dengan nisbah kelamin pada organisme model *D. melanogaster*!

Merancang rencana untuk Proyek (*design a plan for the project*)

1. Berdasarkan daftar strain *D. melanogaster* yang tersedia di Laboratorium Genetika FMIPA UM. Pilihlah dua strain yang dapat digunakan untuk mengkaji peristiwa interaksi gen pada *D. melanogaster* kemudian identifikasi strain tersebut berdasarkan ciri morfologi (warna tubuh, warna mata, dan sayap)!
2. Jelaskan alasan memilih strain tersebut dengan mengkaji literatur!
3. Buatlah macam persilangan dan rekonstruksinya!
4. Rancanglah prosedur penelitian untuk mengkaji peristiwa interaksi gen pada D. *melanogaster*!
5. Tentukan jumlah perlakuan dan ulangan yang dilakukan serta cara menganalisis data yang diperoleh!

Alternatif Proyek Genetika pada Pembelajaran Daring

Kondisi saat ini tidak memungkinkan melaksanakan proyek secara langsung sehingga produk akhir dari kegiatan proyek Genetika 1 ini, yaitu proposal penelitian dan analisis kritis artikel dengan sistematika analisis kritis artikel pada Lampiran 1 dan kriteria penulisan proposal pada Lampiran 2. **Carilah artikel penelitian yang memiliki poin-poin penting sebagai berikut.**

- **Persilangan nisbah kelamin sampai generasi F7**
- **Faktor internal yang mempengaruhi penyimpangan nisbah kelamin**
- **Faktor eksternal yang mempengaruhi penyimpangan nisbah kelamin**

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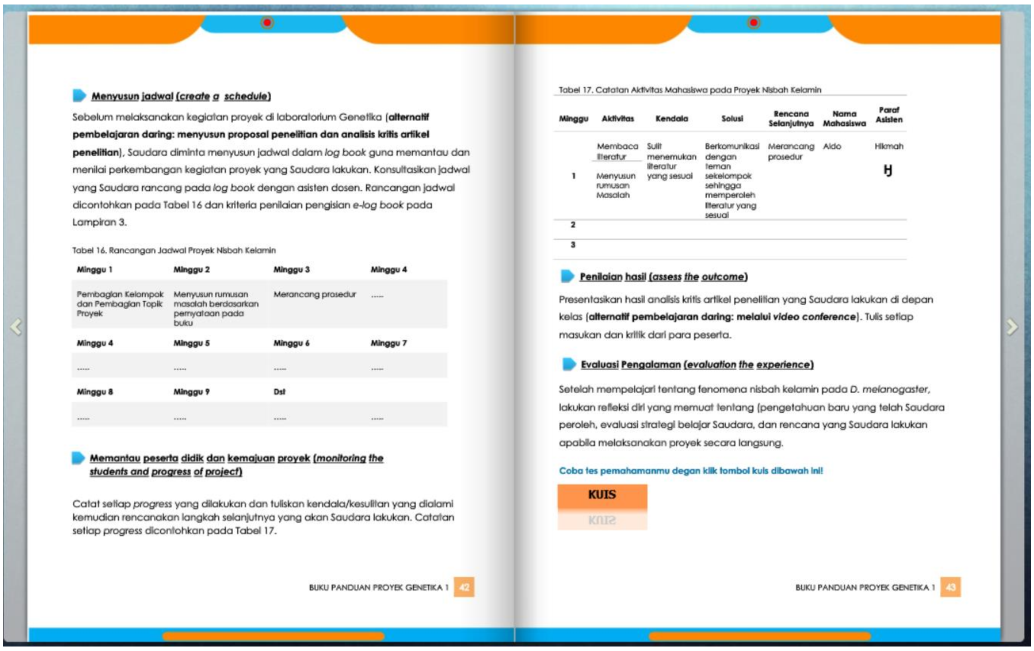
Figure 4. The phase of Determining Important Questions and Designing Research from the PBL-based Project Guide E-book for Genetic 1 Course



Menyusun jadwal (*create a schedule*)

Sebelum melaksanakan kegiatan proyek di laboratorium Genetika (**alternatif pembelajaran daring: menyusun proposal penelitian dan analisis kritis artikel penelitian**), Saudara diminta menyusun jadwal dalam *log book* guna memantau dan menilai perkembangan kegiatan proyek yang Saudara lakukan. Konsultasikan jadwal yang Saudara rancang pada *log book* dengan asisten dosen. Rancangan jadwal dicontohkan pada Tabel 16 dan kriteria penilaian pengisian *e-log book* pada Lampiran 3.

Tabel 16. Rancangan Jadwal Proyek Nisbah Kelamin

Minggu 1	Minggu 2	Minggu 3	Minggu 4
Pembagian Kelompok dan Pembagian Topik Proyek	Menyusun rumusan masalah berdasarkan pernyataan pada buku	Merancang prosedur	.....
Minggu 4	**Minggu 5**	**Minggu 6**	**Minggu 7**
.....	.....	.....	.....
Minggu 8	**Minggu 9**	**Dst**	
.....	.....	.....	.....

Memantau peserta didik dan kemajuan proyek (*monitoring the students and progress of project*)

Catat setiap *progress* yang dilakukan dan tuliskan kendala/kesulitan yang dialami kemudian rencanakan langkah selanjutnya yang akan Saudara lakukan. Catatan setiap *progress* dicontohkan pada Tabel 17.

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Tabel 17. Catatan Aktivitas Mahasiswa pada Proyek Nisbah Kelamin

Minggu	Aktivitas	Kendala	Solusi	Rencana Selanjutnya	Nama Mahasiswa	Paraf Asisten
1	Membaca literatur Menyusun rumusan Masalah	Sulit menemukan literatur yang sesuai	Berkomunikasi dengan teman sekelompok sehingga memperoleh literatur yang sesuai	Merancang prosedur	Aldo	Hikmah
2						
3						

Penilaian hasil (*assess the outcome*)

Presentasikan hasil analisis kritis artikel penelitian yang Saudara lakukan di depan kelas (**alternatif pembelajaran daring: melalui *video conference***). Tulis setiap masukan dan kritik dari para peserta.

Evaluasi Pengalaman (*evaluation the experience*)

Setelah mempelajari tentang fenomena nisbah kelamin pada *D. melanogaster*, lakukan refleksi diri yang memuat tentang (pengetahuan baru yang telah Saudara peroleh, evaluasi strategi belajar Saudara, dan rencana yang Saudara lakukan apabila melaksanakan proyek secara langsung.

Coba tes pemahamanmu degan klik tombol kuis dibawah ini!

KUIS

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Figure 5. Stage of Arranging Experience Evaluation Schedule from the PBL-based Project Guide E-book for Genetic 1 Course

In this study, students' accelerated metacognitive skills were characterized by their higher scores in the post-test than in their pretest. The pretest and posttest instruments used for measuring the participants' metacognitive skills were adopted from the academic achievement test developed by Corebima (2009). The participants' metacognitive skills were enhanced through the PBL syntax, starting from arranging important questions, designing the project plan, arranging the schedule, completing the project, evaluating the project results, and assessing the experience obtained during the projects, as illustrated in Figures 4-5. The learning activities in PBL-based learning encourage students to acquire information and correlate their new knowledge with their existing knowledge. This learning also allows students to present their work and exchange information with their peers. Further, through presentation and discussion, students can transfer information and communicate their meaningful findings obtained from the project (Fini et al., 2018). From this activity, students interpret, compare, and make a conclusion from the project (Indrawan & Jalinus, Nizwardi, 2018). Additionally, in the stage of experience evaluation, students are allowed to reflect deeply on their strategies and assumptions during the project completion (Hamidah et al., 2020). BEsdies, in this experience evaluation, students contemplate their new knowledge, analyze their lacking, and reflect on their enhancement for future learning (Afriana et al., 2016; Jumaat et al., 2017).

Students' enhanced metacognitive skills are also inseparable from the adoption of an interactive e-book that facilitates students in completing their projects. The features of the project guide e-book for the genetic 1 course assist students in improving their metacognitive skills, as the e-book contains a summary of materials, videos, and quizzes. With the features provided in the project guide e-book for the genetic 1 project, students can learn the fundamental concepts of a project, design a project, and evaluate the experience obtained from the project completion processes. The PBL-based learning with genetic 1 project guide e-book also helps students become interactive learners with great skills in exploring new knowledge (Indrawan & Jalinus, Nizwardi, 2018). Additionally, PBL-based learning with a project-guide e-book for the genetic 1 course also offers excellent flexibility, accessibility, and interactivity in establishing an independent learning environment (Kim & Jung, 2010). The comprehensive facilities provided by this interactive multimedia also help students realize independent learning and enhance their metacognitive skills (Ko et al., 2011). Lastly, this interactive e-book also expedites the syntax of PBL-based learning that promotes students' knowledge and skills to get involved directly during the learning process.

CONCLUSION

Results of our data analysis suggested that the PBL-based learning with project guide e-book for the genetic 1 course improves students' critical thinking and metacognitive skills. However, this study also has limitations, primarily on the usage of the pre-experiment design. Nevertheless, this PBL and project guide e-book for the genetic 1 course is still capable of empowering students' critical thinking and metacognitive skills.

RECOMMENDATION

Future studies are recommended to use a quasi-experiment design to ensure the accurate measurement of the effects of PBL-based learning with the project guide e-book in the genetic 1 course.

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REFERENCES

Afriana, J., Permanasari, A., & Fitriani, A. (2016). Project based learning integrated to stem to enhance elementary school's students scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 261–267. https://doi.org/10.15294/jpii.v5i2.5493

Aizikovitsh-Udi, E., & Cheng, D. (2015). Developing Critical Thinking Skills from Dispositions to Abilities: Mathematics Education from Early Childhood to High School. *Creative Education*, *06*(04), 455–462. https://doi.org/10.4236/ce.2015.64045

Alahmad, A., Stamenkovska, T., & Gyori, J. (2021). Preparing Pre-Service Teacher for 21st Century Skills Education: A Teacher Education Model. *GiLE Journal of Skills Development*, *1*(1).

Aldabbus, S. (2018). Project-Based Learning: Implementation & Challenges. *International Journal of Education, Learning and Development*, *6*(3), 71–79.

Ambarwati, D., Suyatna, A., & Ertikanto, C. (2019). The Effectiveness of Interactive E-Book for Self-Study and Increasing Students’ Critical Thinking Skills in Electromagnetic Radiation Topic. *Journal of Physics: Conference Series*, *1155*(1). https://doi.org/10.1088/1742-6596/1155/1/012050

Amin, A. M., Corebima, A. D., Zubaidah, S., & Mahanal, S. (2020). The correlation between metacognitive skills and critical thinking skills at the implementation of four different learning strategies in animal physiology lectures. *European Journal of Educational Research*, *9*(1), 143–163. https://doi.org/10.12973/eu-jer.9.1.143

Chartrand, J., & Flander, S. (2013). *Critical Thinking Means Business: Learn to Apply and Develop the NEW #1 Workplace Skill*.

Corebima, A. D. (2009). Metacognition Skill Measurement Integrated in Achievement Test. *Third International Conference on Science and Mathematics Education (CoSMEd)*. https://doi.org/10.1002/(SICI)1099-0518(199712)35:17<3683::AID-POLA7>3.0.CO;2-T

Corebima, A. D. (2016). Pembelajaran Biologi Indonesia Bukan Untuk Hidup. *Biology Education Conference*, 8–22.

Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). Promoting critical thinking in an online, project-based course. *Computers in Human Behavior*, *119*, 106705. https://doi.org/10.1016/J.CHB.2021.106705

Erlin, E., & Fitriani, A. (2019). Profile metacognitive awareness of biology education students in microbiology course. *Journal of Physics: Conference Series*, *1157*(2). https://doi.org/10.1088/1742-6596/1157/2/022066

Facione, P. (2015). *Critical Thinking: What It Is and Why It Counts*. https://www.researchgate.net/publication/251303244

Fauzi, A. (2017). *Analisis filogeni Tarsius tarsier form Buton dengan beberapa spesies tarsius dari Sulawesi Tengah, Sumatera-Kalimantan, dan Filipina atas dasar Gen MT-CO2 sebagai bahan pengembangan buku panduan penelitian Mata Kuliah Genetika II di Universitas Negeri Mal*. *June*.

Fini, E. H., Awadallah, F., Parast, M. M., & Abu-Lebdeh, T. (2018). The impact of project-based learning on improving student learning outcomes of sustainability concepts in transportation engineering courses. *European Journal of Engineering Education*, *43*(3), 473–488. https://doi.org/10.1080/03043797.2017.1393045

Finken, M., & Ennis, R. H. (2013). *Illinois Critical Thinking Essay Test*.

Hamidah, H., Rabbani, T. A. S., Fauziah, S., Puspita, R. A., Gasalba, R. A., & Nirwansyah. (2020). *HOTS-Oriented Module: Project Based Learning*. SEAMEO QITEP in Language Address:

Hartman, H. (1998). Metacognition in teaching and learning: An introduction. *Instructional Science*, *26*(1–2), 1–3. https://doi.org/10.1023/A:1003023628307

Hayati, M., & Syaikhu, A. (2020). Project-based learning in Media Learning Material Development for Early Childhood Education. *Al-Athfal : Jurnal Pendidikan Anak*, *6*(2), 147–160. https://doi.org/10.14421/al-athfal.2020.62-05

Heong, Y. M., Yunos, J. M., Othman, W., Hassan, R., Kiong, T. T., & Mohamad, M. M. (2012). The Needs Analysis of Learning Higher Order Thinking Skills for Generating Ideas. *Procedia - Social and Behavioral Sciences*, *59*, 197–203. https://doi.org/10.1016/j.sbspro.2012.09.265

Herlanti, Y., Zulfiani, Hutagalung, F. D., & Sigit, D. v. (2019). Metacognitive Attitude and Knowledge of Biology Teacher Candidates. *Advanced Science Letters*, *25*(1), 138–142. https://doi.org/10.1166/asl.2019.13204

Hilpert, J. C., Bernacki, M. L., & Cogliano, M. (2021). Coping with the transition to remote instruction: Patterns of self-regulated engagement in a large post-secondary biology course. *Journal of Research on Technology in Education*, 1–17. https://doi.org/10.1080/15391523.2021.1936702

Indrawan, E., & Jalinus, Nizwardi, S. (2018). Review Project Based Learning. *International Journal of Science and Research, 8*(4), 1014–1018.

Jumaat, N. F., Tasir, Z., Halim, N. D. A., & Ashari, Z. M. (2017). Project-based learning from constructivism point of view. *Advanced Science Letters*, *23*(8), 7904–7906. https://doi.org/10.1166/asl.2017.9605

Kim, J. H. Y., & Jung, H. Y. (2010). South Korean digital textbook project. *Computers in the Schools*, *27*(3–4), 247–265. https://doi.org/10.1080/07380569.2010.523887

King, F., Goodson, L., & Faranak Rohani, M. (n.d.). *Higher Order Thinking Skills*. www.cala.fsu.edu

Ko, C. C., Chiang, C. H., Lin, Y. L., & Chen, M. C. (2011). An individualized e-Reading system developed based on multirepresentations approach. *Educational Technology and Society*, *14*(4), 88–98.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kurniawati, Z. L., Zubaidah, S., & Mahanal, S. (2016). *Remap CS (Reading Concept Map Cooperative Script) Learning Model to Empower Student's Critical Thinking Skills*. *13*(1), 399–403.

Lestari, P., Ristanto, R. H., & Miarsyah, M. (2019). Analysis of conceptual understanding of botany and metacognitive skill in pre-service biology teacher in Indonesia. *Journal for the Education of Gifted Young Scientists*, *7*(2), 199–214. https://doi.org/10.17478/jegys.515978

Liana, L., Wiryokusumo, I., & Leksono, I. (2021). Pengembangan E-Book Berbasis Problem Based Learning Pada Pelajaran Bahasa Jawa Kelas IV Sekolah Dasar. *JINOTEP (Jurnal Inovasi Dan Teknologi Pembelajaran): Kajian Dan Riset Dalam Teknologi Pembelajaran*, *8*(3), 289–298. https://doi.org/10.17977/um031v8i32021p289

Lubis, N., Lubis, A., & Purba, N. B. (2020). Project-Based Learning Collaborated With Digital Media for Indonesian Efl Learners'Self-Confidence and Communication Skill. *Jurnal Pendidikan Dan Pembelajaran Terpadu*, *2*(1), 10–17.

Mahanal, S., Zubaidah, S., Sumiati, I. D., Sari, T. M., & Ismirawati, N. (2019). RICOSRE: A Learning Model to Develop Critical Thinking Skills for Students with Different Academic Abilities. *RICOSRE: A Learning Model to Develop Critical Thinking ... International Journal of Instruction*, *12*(2), 417–434. https://doi.org/10.29333/iji.2019.12227a

Ngurah, I. G., Saputra, H., Joyoatmojo, S., & Harini, H. (2018). International Journal of Multicultural and Multireligious Understanding The Implementation of Project-Based Learning Model and Audio Media Visual Can Increase Students ' Activities. *International Journal of Multicultural and Multireligious Understanding (IJMMU)*, *5*(4), 166–174. https://doi.org/http://dx.doi.org/10.18415/ijmmu.v5i4.224

Prihata, L., Suyatna, A., Rosidin, U., & Distrik, I. W. (2020). *Interactive Physics E-Book Design of Energy Resources to Optimize Self-Directed Learning and Critical Thinking Skill*. *422*(Icope 2019), 136–140. https://doi.org/10.2991/assehr.k.200323.106

Pulmones, R. (2008). Learning Chemistry in a Metacognitive Environment. *The Asia-Pacific Education Researcher*, *16*(2). https://doi.org/10.3860/taper.v16i2.258

Rahman, M. (2019). *21 st Century Skill " Problem Solving ": Defining the Concept*. *2*(1).

Rahmawati, Y., & Haryani, S. (2016). Penerapan Model Pembelajaran Berbasis Proyek Untuk Meningkatkan Keterampilan Metakognitif. *Jurnal Inovasi Pendidikan Kimia*, *9*(2), 1596–1606.

Saadé, R. G., Morin, D., & Thomas, J. D. E. (2012). Critical thinking in E-learning environments. *Computers in Human Behavior*, *28*(5), 1608–1617. https://doi.org/10.1016/j.chb.2012.03.025

Sianturi, M. K., Arwansyah, A., & Yusuf, M. (2021). Development of Student Worksheets (LKPD) Based on Problem Based Learning to Improve Learning Outcomes in Business Economics Subjects. *EDUTEC : Journal of Education And Technology*, *5*(1), 65–77. https://doi.org/10.29062/edu.v5i1.273

Stanton, J. D., Dye, K. M., & Johnson, M. (2019). Knowledge of learning makes a difference: a comparison of metacognition in introductory and senior-level biology students. *CBE Life Sciences Education*, *18*(2). https://doi.org/10.1187/cbe.18-12-0239

Sukmawati, I., Corebima, A., & Zubaidah, S. (2016). Fekunditas Dan Waktu Perkembangan D. Melanogaster Strain Wildtype, White, Dan Ebony Pada Lingkungan Bersuhu Tinggi Dan Pemanfaatannya Sebagai Sumber Belajar Perkuliahan Genetika. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *1*(5), 814–821. https://doi.org/10.17977/jp.v1i5.6261

Susanti, A., & Trisusana, A. (2018). *EFL Materials Development Based on Project Based Learning for Vocational High School*. *108*(SoSHEC 2017), 294–298. https://doi.org/10.2991/soshec-17.2018.60

Treffinger, D. J., & Isaksen, S. G. (2013). Teaching and Applying Creative Problem Solving: Implications for At-Risk Students. In *International Journal for Talent Development and Creativity* (Vol. 1, Issue 1). www.creativelearning.com.]

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1). https://doi.org/10.7771/1541-5015.1649

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2019). Determinants of 21st-century digital skills: A large-scale survey among working professionals. *Computers in Human Behavior*, *100*, 93–104. https://doi.org/10.1016/j.chb.2019.06.017

Vezzosi, M. (2004). *Critical thinking and reflective practice: The role of information literacy*. University of Northumbria.

Warni, Sunyono, S., & Rosidin, R. (2018). Measuring metacognitive ability based on science literacy in dynamic electricity topic. *Journal of Physics: Conference Series*, *948*(1). https://doi.org/10.1088/1742-6596/948/1/012041

Yalçin, S. A. (2017). The Effectiveness of Project Based Learning (PjBL) Worksheet to Improve Science Process Skill for Seven Graders of Junior High School in The Topic Of Environmental Pollution. *Unnes Science Education Journal*, *6*(3), 81–105. https://doi.org/10.15294/usej.v6i3.20359

Zubaidah, S. (2018). *Keterampilan Abad Ke-21: Bagaimana membelajarkab dan mengasesnya*. *April*.

Zubaidah, S., Corebima, A. D., Mahanal, S., & Mistianah. (2018). Revealing the relationship between reading interest and critical thinking skills through remap GI and remap jigsaw. *International Journal of Instruction*, *11*(2), 41–56. https://doi.org/10.12973/iji.2018.1124a