



Experimental College Student Worksheet-based on Critical Thinking Skills Training for Genetics and Evolution Course

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ABSTRACT

The study of genetics and evolution emphasizes the problem solving and processes that require critical thinking skills. For this reason, a college student experimental worksheet (CSEW) based on critical thinking skills is needed, so that students can be more active and have a meaningful learning experience. The purpose of this research is to develop the CSEW based on critical thinking skills which will be used at the Course Genetics and Evolution. This research was conducted at the Biology Education Campus, Faculty of Teacher Training and Education (FTTE), Universitas Riau. The research starts in the odd semester 2020-2021 from September 2020 to January 2021. The process of development referred to the ADDIE model. The results showed that the overall validation of the CSEW is 3.52 or very valid categories and based on the limited scale trials is 3.50 or very good categories. While the average student critical thinking is 79.00 or in a good category. Thus, it can be concluded that the CSEW is possible to be applied in genetics and evolution courses.

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Keywords: Critical thinking skills, experimental LKM, genetics and evolution

Introduction

Learning is an activity that has educational value and coloring the interaction between lecturers and students. Lecturers have a very important role in determining the quantity and quality of learning in the classroom. The quality of learning is strongly influenced by the learning atmosphere and the availability of facilities and learning resources. A democratic learning atmosphere will provide opportunities for achieving optimal learning outcomes, as opposed to authoritarian ones. In a democratic learning atmosphere, there is the freedom of students to learn, to express opinions, to have dialogue with classmates so that students can be more active.

University lecturers should be able to prepare well-design learning plan, which will cover learning tools, the right model or method for learning, teaching materials such as textbooks, learning media, student worksheets etc. Learning should be directed to student center learning instead of teaching center learning. To activate student in the learning process, lecturers must give assignments either in the form of theory or literature studies or tasks through practicum in accordance with the characteristics for each course.

The Course of Genetics and Evolution is a compulsory course (code KPK4130) which is a 4-credits course consisting of 3 credits for theory and 1 credit for practicum. The Genetics and Evolution course are offered in each odd semester. In this course, the learning strategy that requires students to be engaged intellectually and emotionally to obtain good learning opportunities. In accordance with the opinion of Khairil (2008) that learning genetics in higher education should focus on students, lecturers are as facilitators of learning process and teachers are not the main source of information.

The lecturers have provided the textbook, and student worksheet (CSW). However, the former CSW have not covered the training of high cognitive level and have not been validated yet. The questions that exist in the CSW have not provide the training for high-level thinking skills such as critical thinking. Thus, students perform these skills lower than expectation. The example of questions can be tracked from the questions given by lecturers during the learning process or through the fact that students performed low in responding the questions which lead to high cognitive levels or critical thinking such as analysis, synthesis, and evaluation. It seems the college students are only familiar with questions at a low cognitive level such as knowledge, understanding and application. In fact, the study of genetics and evolution emphasizes more on problem solving and other thinking process.

Keren (2006) argued critical thinking is a high-level of thinking with an active intellectual process and full of skills in understanding the concepts, applying, analyzing, synthesizing, and drawing conclusions. While critical thinking skills consist of the ability to analyze, synthesize, collect data, solve problems, and assess (Mustaji, 2012).

Therefore, it is necessary to improve the existing CSW (College Student Worksheet) to be CSEW by strengthening the aspects of critical thinking skills in doing the experiment on Genetics and Evolution courses, so that students can be more active and have a meaningful learning experience.

Methods

This research was conducted at the Campus of Biology Education FTTE Riau University. The research is conducted at the odd semester starts from September to January 2021. The CSEW was developed by following the Research and Development (R&D) of ADDIE model developed by Dick and Carey (2005). ADDIE model consists of stages of analyze, design, development, implementation and evaluate. But this paper will share the first stage to the stage of development.

The analysis stage is a process of defining what students will learn and what lecturers will need. The analysis conducted in this study was the analysis of the curriculum, which including SLP (Semester Learning Plan). SLP analysis is needed to find out the curriculum demands on learning competencies or learning outcomes that should be developed.

After the curriculum analysis, further analysis of student characteristics was carried out. The target students of this study were whom are at semester 3 of biology education with an age range of 20-22 years. According to Piaget's Theory at this age the individual is at the stage of formal operation, where they have been able to reason, generate hypotheses and determine which is most likely to occur based on analytical and logical thinking skills. Thus, the worksheet of students based on critical thinking skills is in line with the level of student thinking. Then, the analysis of student worksheets used by lecturers during this time and analysis of learning materials. The results of the analysis stage will be used to develop student worksheet.

After conducting the analysis, then the next stage is to design a product in the form of experimental worksheets. Before creating a student worksheet, the first step is to design a Learning Plan (LP) that will be used as a guideline in creating the student worksheet (Figure 1).

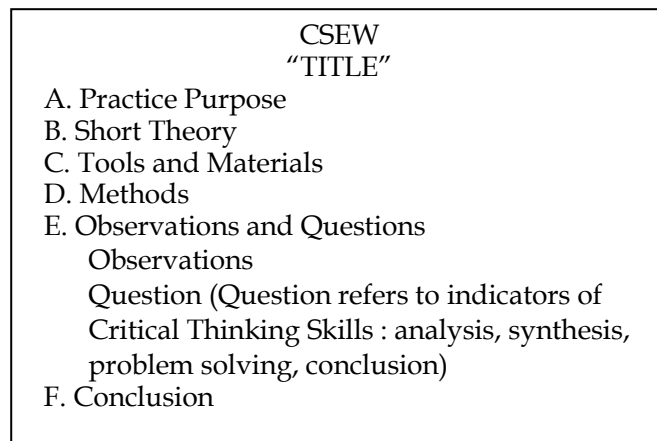


FIGURE 1. CSEW content design to promote critical thinking skill-based experiments

The Development stage is the stage where researchers construct what has been designed at the design stage. Researchers develop learning plans and assessments that have been set according to the design stage. Then, they also develop a student worksheet based on critical thinking skills as it has been designed.

The next step is to validate all instruments and products. Validation was run to validate the draft by 2 validators, i.e., one lecturer who has expertise in pedagogy and one lecturer who is expert in the concept of genetics and evolution. The results of the validation were revised by the researchers to be developed as worksheet of phase II.

The next step was to conduct a limited trial by disseminating student worksheet as well as questionnaire to students who take The Genetic and Evolution course. The limited trial was conducted to determine the level of approval of student worksheets in terms of structure, the readability, and the understandings of the content (Figure 2).

The instrument for validation is a sheet to review the product, which was designed with three aspects, namely the design, pedagogic, and content, as the criteria of validity. Questionnaire for limited trials were developed to determine the level of usability of the CSEW. For critical thinking skills, the data was taken from the limited trial of the CSEW.

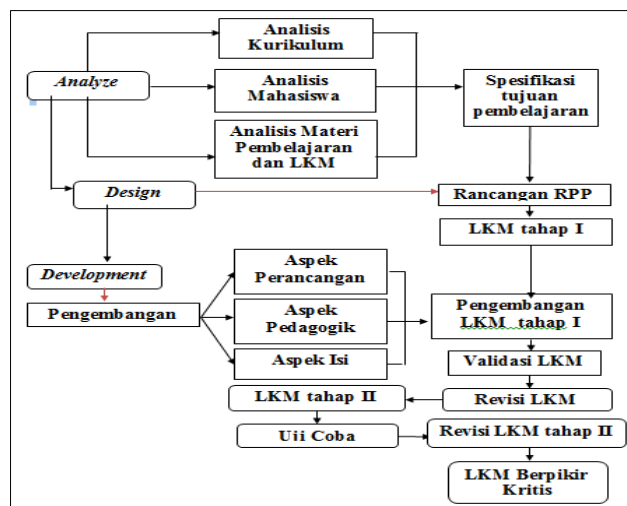


FIGURE 2. Flow of the Development of CSEW to Promote Critical Thinking Skills

The data was analyzed using the descriptive statistical analysis. The validation aspects assessed by validators and limited trial used the Likert scale with a score of 1-4 (disagree, disagree, agree, strongly agree). The result of validation, and limited trial were calculated using the following average score formula, with the criteria of validation as displayed in Table 1 and 2.

$$M = \frac{\sum FX}{N}$$

Description:

M = Average score

FX= Score earned

N = Number of components

Table 1. CSEW validation criteria are experiments based on critical thinking skills.

No	Average Score	Category
1	3.25 < x < 4	Very valid
2	2.5 ≤ x < 3.25	Valid
3	1.75 ≤ x < 2.5	Less valid
4	1 ≤ x < 1.75	Not valid

Table 2. The limited test criteria CSEW of critical thinking skills

No	Average Score	Category
1	3.25 < x < 4	Very good
2	2.5 ≤ x < 3.25	Good
3	1.75 ≤ x < 2.5	Poor
4	1 ≤ x < 1.75	Not good

(Source: Modification from Sugiyono, 2010)

Meanwhile, the critical thinking skills were calculated using the following formula, and using the criteria as shown in Table 3.

Critical thinking skills = (Gained score / Maximum score) x 100%

Table 3. Criteria for Critical Thinking Skills

No	Interval	Criteria
1	$X \geq 80$	Very good
2	$70 \leq X < 80$	Good
3	$60 \leq X < 70$	Fair
4	$50 \leq X < 60$	Poor
5	$X < 50$	Fail

Source: Rector UNRI Decree No. 5 year 2019

Result and Discussion

The CSEW Validation

The aspects of validation include the design, the pedagogical, and the content aspect. The design consists of indicators 1-6 (conformity of approach, practical purpose, use of language, systematics, presentation, suitability of questions), pedagogic aspect consists of indicators 7-12 (content according to LP, table image illustration display, material conformity, clear sentences, referring to critical thinking skills) and content aspect consists of indicators 13-15. (Conformity of observations and questions, suitability of student abilities, conformity of critical thinking skills level).

Table 4. The CSEW validation results by validators

CSW No	Aspect			Average (Category)
	Design	Pedago gical	Content	
1.	3,33	3,50	3,33	3,39 (VV)
2.	3,16	4,00	3,66	3,61 (VV)
3.	3,49	3,33	3,33	3,39 (VV)
4.	3,33	3,50	3,66	4,00 (VV)
5.	3,50	3,80	4,00	3,77 (VV)
6.	3,50	3,38	3,61	3,50 (VV)
Average	3,39 (VV)	3,59 (VV)	3,60 (VV)	3,52 (VV)

Description: VV = Very Valid

CSEW Number:

1. Chromosomes
2. Mendel's Law
3. Double Allele
4. Genes Expression Changed by Sex
5. Linking and Crossing
6. Chemical Structure of Genetic Materials

Table 4 shows that the average validation result against the design aspect is 3.39 with a very valid category. According to Sugiyono (2010), if the average validation result is in the range of $3.25 < x < 4$, the score would be categorized as very valid. Aspects of design serves

to measure the quality of CSEW that have been developed in terms of lay out or design, so that students are interested in working on the questions in the CSW. Based on Table 4, the lowest validation result average found in CSEW 2 (Mendel's Law), which was 3.16, but still in a valid category. There were some mistakes grammatically. The highest score of validation was found in CSEW 5 (linking and crossing). While the CSEW 6 (the chemical structure of genetic material) scored 3.50. According to the validation, the language used is acceptable, and the CSEW component has been suitable, in terms of systematic presentation, the questions have represented the content. According to the Ministry of Education (2008) the worksheet should be missed of mistakes on the sentences, phrases, vocabularies, word choices, easy-to-understand and grammatically correct. The correct language and systematic presentation can ease the students to understand the purpose of practicum activities. In addition, the sentences should be simple, non-convoluted, and far from double interpretation.

The pedagogic aspect is an aspect to measure the quality of CSEW in terms of pedagogic. Based on Table 3, the highest validation result was CSEW 2 (Mendel Law), which scored of 4.00 or a very valid category. According to the validator, CSEW 2 already referred to the ability to think critically, able to analyse, synthesis, know and solve problems, assess, and conclude. In accordance with the opinion of Jahro et al (2010) critical thinking must go through several stages or processes to conclude or assessment, namely the stages of analyzing, synthesizing, knowing, and solving problems, concluding, and evaluating.

The content aspect is to review the concepts and practicum activities presented in CSEW. Based on Table 3 the lowest validation result was found in CSEW 1 (chromosome) and CSEW 3 (gene expression) with a score of 3.33 each. This can be seen from the average level of critical thinking skills. According to the validator's comments, there were suggestions and inputs to improve CSEW 1 and 5, particularly the questions that do not meet the level of critical thinking. The problem of synthesizing has not fit with the level of critical thinking. The highest validation result was in CSEW 5 (linking and crossing) with a score of 4.

Based on the average results of the three aspects, the six CSEW scored as follows: the design aspect 3.39, pedagogical 3.59, and content aspect with a score of 3.60. Thus, the overall average was 3.52 with a very valid category. Therefore, the draft CSEWs are valid to be used in the Genetics and Evolution course.

Students Responses at the Limited Trial

The limited trial questionnaire was distributed to 35 students who attended the Genetics and Evolution course. This questionnaire also assessed three aspects, namely the design which covers indicators 1-4 (vocabularies, phrase sentences, clarity of images, attractive display, clarity of instructions), pedagogical aspects consisting of indicators 5-7 (suitability of topics of learning and the questions with the material, clear questions) and aspects of content consisting of indicators 8-10 (interesting questions, challenging questions, and concepts understanding)

Table 5. Limited test results

CSEW No	Aspect			Average (Category)
	Design	Pedagogical	Content	
1.	3,67	3,50	3,33	3,52 (VG)
2.	3,63	3,56	3,67	3,54 (VG)
3.	3,25	3,61	3,67	3,40 (VG)
4.	3,42	3,67	3,33	3,49 (VG)
5.	3,67	3,83	3,67	3,67 (VG)
6.	3,42	3,39	3,36	3,38 (VG)
Average	3,51 (VG)	3,59 (VG)	3,40 (VG)	3,50 (VG)

Description: VG = Very Good

Table 5 shows the average results of the overall limited trial of CSEWs. The design aspect scored 3.51 or excellent categories. The lowest was CSEW 3 with an average score of 3.25. Some of images in CSEW 3 was less interesting and in insufficient. The average test highest result was CSEW 1 and CSEW 5, which scored 3.67 and 3.63 respectively. This might be because students feel that the text, images, colors, layout, and languages used in CSEW 1 are very clear. Overall, the design aspect for CSEW 1 to 6 has a very good average score.

The average limited trial results for the whole pedagogic aspect were in the range of 3.39-3.83 with excellent categories. The lowest average test result was found in CSEW 6 with an average score of 3.39. According to students the material was difficult to understand also the given problem was difficult to solve, because students do not get used with the questions related to analysis and synthesis. The highest average test result was in CSEW 5 (linkage and crossing) with a score of 3.83 or an excellent category. Each indicator on the pedagogic aspect of CSEW 5 is in the category very well, this means that the pedagogic aspect of CSEW 5 shows the topic in the CSEW has been well presented.

The aspect of content asks students' perception, responses, and prediction to accomplish the tasks presented in the CSEW. The result of the overall CSEW for content aspect was 3.40 with excellent category. The lowest score is found in CSEW 1 (Chromosome) and 4 (genes expression) with a score of 3.33. The highest average test results were found in CSEW 2, 3 and 4 with a score of 3.67 each. According to students, the problems in the CSEW were very related to the material so challenging them in solving the problem. Overall, the content aspect has an average score of 3.40 with a very good category. In conclusion, the aspect of content in CSEW is worth. From Table 4 can be known that of the overall CSEW scored 3.50 or very good.

Limited Test on Completing CSEW

The limited trial conducted to check the abilities of college students to work with the CSEW and compete all tasks in. The result shown in Table 6.

Table 6. The results of the limited test on Completing the CSEW

CSEW No	Critical Thinking Skills				Average
	I	II	III	IV	
1.	75	72	72	84	76 (G)

CSEW No	Critical Thinking Skills				Average
	I	II	III	IV	
2.	69	69	69	80	72 (G)
3.	82	79	82	85	82 (VG)
4.	77	78	82	78	79 (G)
5.	76	78	79	84	79(G)
6.	84	85	84	87	85 (VG)
Average	77 (G)	77 (G)	78 (G)	83 (VG)	79 (G)

Description:

I. Analyzing II. Synthesizing III. Troubleshooting IV. Concluding. (G) Goof (VG) Very Good

From the limited trial of students in solving the question questions in the CSEW experiments seen in Table 6, showed that the results obtained on average critical thinking skills 79.00 categories well. In the indicator analyzing with a score of 77.00, students analyzed the problems contained in the CSEW containing tables or images that ask for answers in the form of descriptions or explanations using concepts that have been studied. Low analytical ability is due to most students being less able to identify or quickly reject strong and relevant counter arguments (Saputri, et al., 2017). Low analytical ability is also because some students have difficulty identifying known variables, questions, and strategies for solving given questions (Haryandi, et al., (2013). Solutions to improve the ability to analyze students by providing an integrated understanding of concepts, providing an interesting explanation of concepts so that students will continue to process them (Suryani, et al., 2016). Arini and Juliadi (2018) also stated the same solution to improve the ability to analyze that can be helped by familiarizing students to find equations by providing an integrated understanding of concepts. Example of an analysis from CSEW 2 Mendel’s Law.

Tanaman heterozigot bulat Merah (AaBb) disilangkan dengan tanaman homozigot keriput putih (aabb). Menghasilkan keturunan sebagai berikut : 62 bulat merah, 30 bulat putih, 30 keriput merah dan 66 keriput putih. Bagaimanakah hasil dari persilangan tanaman diatas. Apakah sesuai dengan hukum Mendel ? Beri alasan ! (Analisis)

<u>Perhitungan</u> X ²	<u>Bulat merah</u>	<u>Bulat putih</u>	<u>Keriput merah</u>	<u>Keriput putih</u>	<u>Jumlah</u>
A	45	30	30	55	160
H	40	40	40	40	160
(A-H)	5	-10	-10	15	0
(A-H) ²	25	100	100	225	
<u>(A-H)²</u>	0.625	2.5	2.5	5.625	11.25
H					



FIGURE 3. Example of an analysis from CSEW 2 Mendel’s Law

For the synthesis skill, a score of 77.00 was obtained, the answers to the synthesis questions given by the students were incomplete and the reasons given by the students were inaccurate, while the synthesis question required a skill to combine parts into a formation.

Synthesis questions require the reader to integrate all the information obtained from the reading material. Example of a synthesis question from CSEW 2 (Mendel's Law).

Buatlah tabel chi square (χ^2) dari data kelompok tabel 2, 4 dan 6. Untuk daftar nilai χ^2 tabel terlampir (sintesis).

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FIGURE 3. Example of a synthesis question from CSEW 2 Mendel's Law

Problems should be case based to ease students to come with some solutions. Keren (2006) said that to solve a problem must use a basic thought process, gather related facts, and look for other necessary information. As for the example of problem-solving problems from CSW 4 (Gene expression changed by sex).

Seorang gadis sangat khawatir akan kehilangan rambutnya dan menjadi botak, sebab ia adalah seorang foto model iklan suatu produk shampo. Pada suatu hari ia pergi ke dokter untuk meminta penjelasan karena kakak laki-lakinya yang dulunya tidak botak sekarang sudah botak. Ayahnya tidak botak, tetapi ibunya botak. Andaikata saudara yang menjadi dokter itu, bagaimanakah jawaban saudara? Buktikan dengan bagan perkawinan !.(Memecahkan Masalah)



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FIGURE 4. Example of problem-solving problems from CSEW 4

To nurture the university students in generating the conclusion, students can already work on it because the CSEWs are equipped with cases so that students have knowledge, able to decipher, connect between concepts with each other in solving problems, students understand various aspects gradually, so that students are easy in making conclusions. According to Uno (2008), Skill concludes is the activity of the human mind based on its knowledge or truth. This skill requires the reader to be able to decipher and understand various aspects gradually to come to a new formula. An example of the question concludes from CSW 1. Chromosome.

Thinking skills are very important for biology teacher candidates because critical thinking skills will greatly help prospective teachers to prepare 21st century generations with optimal solving problems abilities ranging from simple to the most complex (Synder&Synder, 2008). According to Paul &Elder (2005), critical thinking is a way for one to improve the quality of the results of thinking using systematic techniques of thinking and generating intellectual thinking power. Criteria in this critical thinking process are clarity, accuracy, precision, relevance, logic, breadth, depth, honesty, completeness of information and how the implications of the solution are needed, it is necessary to teach a course so that there is an increase in the ability to think critically of students.

Conclusion

The results of the study concluded that the result of CSEW validation is 3.52 or very valid and the limited trials of student responses is 3.50 or excellent, and the limited trials of the accomplishment of the tasks in the CSEWs scored 79 or good. Thus, the CSEW to nurture the critical thinking skills is valid to be used in the Course Genetics and Evolution. Further research should be done on effectiveness of the CSEWs.

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