Scaffolding as an effort for thinking process optimization on heredity

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Abstract. Thinking is an activity and process of manipulating and transforming data or information into memory. Thinking process is different between one and other person. Thinking process can be developed by interaction between student and their environment, such as scaffolding. Given scaffolding is based on each student necessity. There are 2 level on scaffolding such as explaining, reviewing, and restructuring; and developing conceptual thinking. This research is aimed to describe student’s thinking process on heredity especially on inheritance that is before and after scaffolding. This research used descriptive qualitative method. There were three kinds of subject degree such as the students with high, middle, and low achieving students. The result showed that subjects had some difficulty in dihybrid inheritance question in different place. Most difficulty was on determining the number of different characteristic, parental genotype, gamete, and ratio of genotype and phenotype F2. Based on discussed during scaffolding showed that the subjects have some misunderstanding terms and difficulty to determine parental, gamete, genotype, and phenotype. Final result in this research showed that the subjects develop thinking process higher after scaffolding. Therefore the subjects can solve question properly.

1. Introduction
Learning is a process or activity to gain knowledge, improve skills, behavior, attitudes, and strengthen the personality, as a result of student’s own experience in interaction with the environment [1,2]. Change and development of knowledge can improve students' thinking process. According to Wragg in Jihad & Haris [3] effective learning can allow students to learn concepts, skills, values, and attitudes or learning outcomes. Biology has essential two objectives such as to help students developing skills in using common reasoning patterns and to help students acquire scientific concepts [4]. Therefore, learning, especially biology, should be done with a process that makes students active and facilitate students in achieving learning outcomes.

Heredity, especially inheritance, is the one of material Biology in Junior High School. It is basic material of Genetics and important as the provision to study more complex Genetics in High School. This material has some characteristic on terms and crossing models of Mendel. Therefore, this material is very important and every student must be understood. However, in fact, the students' achievement on Inheritance is still low. The results of the national examination of Junior High School on 2015 in Surakarta City on the inheritance concept shows the percentage of completeness at the City level, that is 47.02%, the Province level 39.19%, and the National level 46.76% [5]. Based on some student interview, that are many students have difficulty in this material because it has lot of new terms and in crossing models of Mendel. Learning process is teacher centered so that students still to memorize the material and they will found difficulty in different question or condition. In addition, based on researchs
that many student had some Genetics’s misconception in High School, especially on inheritance concept [6].

Based on these problems, it can be seen that students have not been able to study inheritance material properly. Students are still on actual development level. Therefore, that is need to develop their potential to a potential level which students can do something outside the actual zone with the help of others who are more capable. In Vigotsky's theory, Zone of Proximal Development (ZPD), that is the distance between actual development levels i.e things that can be done independently and the level of potential development is something that can be done with the help of adults or more capable people [7-9]. Scaffolding is the direction of the learner process in the acquiring knowledge process, firstly the teacher has more responsibility then it move on to students when learning takes place [10,8]. According to Wood, scaffolding is used as a way of adult to support the child to learn that has been adjusted and will be eliminated when the child can learn on his own [11-14]. According to Bruning et al, and Puntambekar & Hübscher in Schunk [7], Larkin [15], and Duffy [16] that scaffolding refers to sections that are beyond the basic skills of students, so that students can understand and complete the task effectively. According to Stone in Yamin [24] that students can develop to higher thinking skills level when getting scaffolding from someone who more expert. Scaffolding also effective to enhance self-regulation [16,13]. Self-regulation is one of critical thinking aspect [17]. Suggestions for scaffolding are to look for situations where scaffolding is possible in the classroom, seek to provide the right amount of assistance, avoid assistance on what the student can do on their own, and monitor the student process and provide the necessary support and assistance [18]. There are three level in scaffolding such as environmental provisions; explaining, reviewing, and restructuring; and developing conceptual thinking [11].

Thinking is an activity of manipulating and transforming data or information into memory. Thinking goals are for concept formation, reasoning, critical thinking, creative thinking, problem solving, and decision making [18]. Thinking process is the thinking steps to achieve a certain goal [19]. In this research is solving problem steps on inheritance question. Intellectual development based on Piaget occurred through two processes: organization and adaptation [20]. Organizational process is organizes activities and integrates structure to be a physically and psychologically coherent system. Adaptation process is an activity to adjust in environment. Adaptation consists of assimilation and accommodation [20,21].

Assimilation is a cognitive process to integrate perception, concept, or new experience in schema or pattern which already inside person’s mind. Assimilation is incorporation new stimulus inside an existing schema so that one’s understands can be developed. According to Wadsworth, assimilation did not cause schema changes, but it led to schema development. Accommodation is a personal cognitive process which occurs when a person faces stimulus or new experience, but it is not suitable with existing schema. Therefore, it is necessary to establish new schema or change (modify) existing schema so that it fits on new stimulus [20,22,23].

Piaget’s cognitive development theory stated that there is a need to make a balance between assimilation process and accommodation of a person called as Equilibrium. Assimilation process and accommodation occurs continuously inside a person [20]. When someone gets new stimulus cannot do assimilation, so there will be an imbalance (disequilibrium) and cause accommodation, therefore the existing schema changes or the new schema raise and create equilibrium [19,23].

The purpose of this research is to describe students’ thinking process on inheritance material and effort to optimize the process with scaffolding. In this research, the data obtained will be about the thinking process structure in doing exercises before and after scaffolding, therefore it is expected to be useful for students in acquiring difficulties in this material, gives input to teachers in giving scaffolding for students and alternative to make learning tools which are using scaffolding method so that students can learn effectively.
2. Research method
This research was conducted in 2nd State High School of Surakarta in first semester on 2017/2018. Used 30 students of X IPA-1 who had studied heredity on Junior High School. Chose the class with random technique. Students given question of dihybrid question that must be completed based on their ability. The questions instrument has been validated very good and relevant by two lecturers.

Students write down the stages of problem solving, then researcher examine answers from each students and mapped out the common problems experienced by most students inside that class in problem-solving stages. Students who answer less correctly were chosen as subject research candidate who were also based on their level cognitive ability and good communication skill. Then, the three categorization of students’ cognitive skill were determined based on score from Junior High School National Examination using norm reference benchmark. The three subjects are student with high academic achievement, student with medium academic achievement, and student with low academic achievement. The next step, students were invited to discuss their answers. This discussion aimed to know the thinking process of students in solving question and the researcher could provide direction and guidance (scaffolding) so students can improve the answer. Teacher’s scaffolding with explaining, reviewing, and restructuring; and developing conceptual thinking. In this step, students were asked to Think Out Louds the process of solving the problem.

The mapping (scheme) thinking process of subject in solving problem before scaffolding can be known by comparing ideal thinking map structure with subject’s thinking map structure. Then, the final structure of student completion after given scaffolding was made and describe kind of scaffolding on each subject. Then finally analysis the scheme to classified intellectual development on each subject that are assimilation and accommodation process.

3. Result and discussion
The result of this research is description of student’s thinking process in generally on X-IPA1 as the steps of solve the question which most students less able to did it and then describe the subject thinking process. The thinking process of subjects was described before and after scaffolding, then made mapping result of intelectual development such as assimilation and accommodation process for each subject.

The common problems shown by most students in solving the problem of dihybrid inheritance i.e on the determination of total different traits, the determination of genotype and the determination of parental 1,2, the determination of gamete 1,2, and the determination of genotype and phenotype in F2 ratio. The determination of total different traits in the crossing (hybridization), most students have not been able to explain it. Determination genotype and parental 1 still results in error. Meanwhile, most students were unable to answer correctly on the determination of gamete 1. In the determination of gamete 2, the errors made by students on determining two different traits as seen on their answers on table above that the top side (column) and left side (row) is not written a male and female gamete, but a combination of a different trait. Students had difficulty in distinguishing genotype and phenotype in F2. Student errors were not only caused by lack of comprehension of subject but also inaccuracies in determining the phenotype, genotype, parental and gamete ratio, and there were concept errors. This following description was the thinking process of subjects before and after scaffolding.

| Code | Meaning |
|------|---------|
| S    | Question |
| A1   | Is known A long beans trait is circle seed (BB) |
| A2   | Is known A long beans trait is chocolate colour (CC) |
| A3   | Is known B long beans trait is wrinkled seed (bb) |
| A4   | Is known B long beans trait is grey colour (cc) |
| A5   | Is known both of them are dihybrid crossed |
| A6   | Is known circle trait is dominan then wrinkled trait |
| A7   | Is known chocolate colour is more dominant than grey colour (resessive) |
| Code | Meaning |
|------|---------|
| S    | Question |
| A1   | Is known A long beans trait is circle seed (BB) |
| B1   | Determining A long bean genotype (BBCC) |
| B2   | Determining B long bean genotype (bbcc) |
| C1   | Crossing BBCC with bbcc |
| D1   | Determining Parental 1 (P₁) |
| D2   | Determining Gamete 1 (G₁) |
| D3   | Determining Filial 1 (F₁) |
| C2   | Crossing F1 with another (BbCc with BbCc) |
| E1   | Determining Parental 2 (P₂) |
| E2   | Determining Gamete 2 (G₂) |
| E3   | Determining Filial 2 (F₂) |
| F1   | Determining genotype F₂ ratio |
| F2   | Determining phenotype F₂ ratio |
| G    | Determining percentage of genotype BbCC i.e 2/16 x 100% = 12.5% |

This following description is the thinking process of subjects before and after scaffolding.

3.1. Scheme and description S1 thinking process

![Figure 1. Structure thinking process of S1. The shades show that S1 make error.](image)

![Figure 2. Ideal Structure.](image)

![Figure 3. Result after Scaffolding on S1. The shades show after scaffolding (true answer).](image)
### Table 2. Describe scaffolding on S1.

| Code | Error Type on S1 | Scaffolding Type |
|------|------------------|-----------------|
| Scaf 1 | No determining number of hybrid | Prompting and probing (ask to S1), then Looking, touching, and verbalizing (reunderstand the question) |
| Scaf 2 | Determining two long beans genotype | Prompting and probing (ask to S1), then Students explaining and justifying (on his answer), then Making connection (between number of hybrid and trait gene symbols are known) |
| Scaf 3 | Determining parental 1 and no determining gamete 1 | Prompting and probing (ask to S1), then Explaining (the definition of gamete). |
| Scaf 4 | Determining crossing to produce F₂ and not determining parental 2 (P₂) | Prompting and probing (ask to S1) and Prompting and probing (ask to S1) |
| Scaf 5 | Determining gamete 2 and filial 2 (F₂) | Prompting and probing (ask to S1), then paralel modelling (to determining gamete), Students explaining and justifying. |
| Scaf 6 | Make genotype F₂ ratio | Prompting and probing (ask to S1), then Explaining (example determining genotype ratio F₂) |
| Scaf 7 | Make phenotype F₂ ratio | Prompting and probing (ask to S1), then Making connection (between trait dominant and ressive gene) |

### 3.2. Scheme and description S2 thinking process.

![Figure 4](image1.png) **Figure 4.** Structure thinking process of S2. The shades show that S2 make error.

![Figure 5](image2.png) **Figure 5.** Ideal Structure.

![Figure 6](image3.png) **Figure 6.** Result after Scaffolding on S2. The shades show after scaffolding (true answer).
Table 3. Discribe scaffolding on S2.

| Code  | Error Type on S2                          | Scaffolding Type                                                                                                                                                                                                 |
|-------|------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Scaf 1| No determining number of hybrid          | Prompting and probing (ask to S2), then looking, touching, and verbalizing (reunderstand question)                                                                                                            |
| Scaf 2| Determining two long beans genotype and parental 1 | Prompting and probing (ask to S2), explaining (about determining parental), then Making connection (between number of hybrid and trait gene symbols are known), then reprashing student’s talk (genotype correct writing) |
| Scaf 3| No determining gamete 1                  | Prompting and probing (ask to S2), then Explaining (determining gamete).                                                                                                                                          |
| Scaf 4| Determining gamete 2 and filial 2        | Prompting and probing (ask to S2), then Looking, touching, and verbalizing (re-check and revise gamete 2 and F<sub>2</sub>), then explaining (determining gamete 2)                                                   |
| Scaf 5| Make genotype F<sub>2</sub> ratio         | Prompting and probing (ask to S2), then Looking, touching, and verbalizing, then Explaining (the definition of genotype and example determining genotype ratio F<sub>2</sub>)                      |
| Scaf 6| Make phenotype F<sub>2</sub> ratio        | Prompting and probing (ask to S2), then Looking, touching, and verbalizing, then explaining (the characteristic of phenotype)                                                                                     |

3.3. Scheme and description S3 thinking process

Figure 7. Structure thinking process of S3. The shade boxs show that S3 make error.

Figure 8. Ideal Structure.

Figure 9. Result after Scaffolding on S3. The shades show after scaffolding (true answer).
Table 4. Describe scaffolding on S3

| Code | Type Error of S3 | Scaffolding Type |
|------|------------------|------------------|
| Scaf 1 | No determining number of hybrid | Prompting and probing (ask to S3), then Looking, touching, and verbalizing (reunderstand question), then explaining (about hybrid) |
| Scaf 2 | Determining genotype two long beans and parental 1 | Prompting and probing (ask to S3), then Looking, touching, and verbalizing (reunderstand question), then Making connection (between number of hybrid and trait gene symbols are known) |
| Scaf 3 | No Determining gamete 1 and filial 1 | Prompting and probing (ask to S3), then Looking, touching, and verbalizing (reunderstand question), then Explaining (definition of gamete and determining F1) |
| Scaf 4 | Determining crossing to produce F2 and no determining parental 2 | Prompting and probing (ask to S3) |
| Scaf 5 | Determining phenotype F2 ratio | Prompting and probing (ask to S3), then explaining (definition of phenotype and dominant trait), then Looking, touching, and verbalizing, then Making connection (between trait dominant and recessive gene) |
| Scaf 6 | Determining percentage of BbCC genotype | Prompting and probing (ask to S3), then Looking, touching, and verbalizing, explaining (make percentage on genotype), then Students explaining and justifying (on his answer), then explaining (to multiply the ratio with 100%) |

Based on data analysis, show that the students’ develop thinking process higher after scaffolding. Scaffolding effectively help each student toward potential zone based on each student’s necessity. Scaffolding given to students is level 2 (explaining and reviewing) and level 3 (developing conceptual thinking) that have the characteristics of a direct interaction between students and teacher or students who are more capable. The three subjects show that have differences in number and scaffolding types depend on each subjects difficulty in solve the problem. Subject 3 (S3) doesn’t perform some thinking process more than S1 and S2. This indicates that the S3 has a less accurate character in solve the problem. Siswono study [25] also revealed the same thing that low achieving students have no or less accurate thinking features in solving math problems. Because of this, showed that low achieving students need more scaffolding to help difficulty in solving the problem. This is consistent with research on the effectiveness of the learning model that has the characteristics of a scaffolding on it stages showed that the low achieving students need more help to understand the lesson, so it cause a significant effect on students’s science process skills [26] and learning outcomes [27].

Therefore, it show that giving scaffolding are proofed can develop students thinking process with developing student’s skills toward ZPD, so the students can solve the problem properly. In addition, on this process, we can see assimilation and accommodation process, it shows there are intellectual development on students can be optimized.

4. Conclusion
Based on the results and discussions, it can be found that the thinking process of most students and the subjects before scaffolding have different structures. In general, most students’ and subjects’ problem are the determination of total different traits, genotype long beans and parental, gamete, and genotype and phenotype in F2 ratio. After scaffolding, the result showed that all subjects could solve the problem well. Thus, it is concluded that scaffolding can be used as a method or tool to optimize students’ thinking processes. Some suggestions are given as follows: the researchers or teachers need to understand the thinking process and the structure of students’ thinking in a learning material, so that they can do scaffolding based on their needs. The errors made by most students are on the determination of parental
genotypes and gametes, so that teachers need to emphasize the concept and immediately clarifying that. Using scaffolding can optimizing thinking process, so learning method or model in class should using method that make student with higher academic can share and help another low academic students, so all of students can complete their study. The research of students’ thinking process that focus on the material of inheritance is instead still limited, thus it needs to be a more in-depth study, for example in revealing the type of misconception on the students.

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