Developing a Learning Continuum of the Pedagogic Materials of Genetics Aspects from Elementary School to Senior High School Level Based on the Opinions of Biology Education Experts

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Abstract. Learning continuum is a set of competencies mutually related from one concept to the others. The competencies are ordered from the easy ones to the difficult and specific ones at all levels sustainably from the elementary to the secondary level. This study aims to reveal the opinions of biology education experts on the learning continuum of genetics materials viewed from the competency level and material characteristics and also to reveal the learning continuum of the specific pedagogic materials of the genetics aspects according to experts. The expert respondents were selected by considering their educational background, namely their expertise in the field of biology education, with regard to their bachelor, masters, and doctoral programs. This study is a survey with a sample of 85 biology education experts, established using the convenience technique, i.e. those who are easy to find. The result of this study shows that 25% of the respondents agree that genetics is taught to grade 9 students at the cognitive level of C2 (comprehension), on the sub-aspect of character inheritance, while 75% have the opinion that genetics is taught to grade 12 students at the cognitive level of C2 (comprehension). However, 100% of the participants of the Forum Grup Discussion have the opinion that genetics is taught to grade 12 students at the cognitive levels of C2 and C3. Therefore, it can be concluded that the genetics aspect is taught to grade 9 students of junior high school and it is taught again to high school students for the different cognitive level and the learning materials are different and more complex.

1. Introduction
A good teaching and learning system is the one that refers to a current curriculum, and of course the curriculum becomes a very important consideration. A curriculum is a set of plans and arrangement containing instructional goals[1]. The structure of a curriculum is determined based on the National Standard of Education, which aims to manage every competency aspect which contains teaching materials in an educational program. The structure of a curriculum consists the goal, content (teaching materials), strategies, learning resources, time allocation, and infrastructure, all of which support the teaching and learning activities[2]. A curriculum is improved in order to adapt to the current development. Developing a curriculum is not an easy matter, because it has to refer to a various types of needs analyses, one of which is the content aspect (teaching materials)[3].
Teaching materials (Content Knowledge) are specific pedagogic materials which, if combined with competencies and teaching strategies, will enable to determine the curriculum well and will determine the materials and cognitive levels that have to be developed in the students. However, in the year-to-year curriculum development, there has not been an explanation concerning the description which shows the degrees of complexity and abstraction of Content Knowledge or specific pedagogic materials (SPM) from elementary school level to high school level, and therefore, there needs to be orderly graded competencies which then become a Learning Continuum (LC) or Learning Trajectory (LT) for a good curriculum, one of which is that the curriculum is in line with current advancement and with students’ needs.

The principal use of a learning continuum is to facilitate the teachers’ understanding of general and specific instructional objectives, teachers’ references in teaching easy materials to difficult materials, monitoring different students’ learning achievement, and teachers’ references in using teaching strategies suitable with the students’ characteristics[4]. Determining a continuum in one aspect refers to the difficulty level of learning materials and the student cognitive development[5]. According to Knowles learning continuum can be revealed through the teaching materials taught to the students, including simple (easy) concepts to complex (difficult) ones[6]. This is in line with the dimension of both knowledge and skill which are developed and it is adjusted to the students’ level of cognitive development. For example, in elementary school (at the ages of 7 to 11 years old) the students learn simple concepts with the cognitive domain to achieve being to remember and to understand[7].

One of the reasons for using a learning continuum is that the materials taught to the students are in accordance with their competence and cognitive development. A learning continuum is highly related to the curriculum, while the curriculum used in schools and practised by teachers contains overlapping materials and is not in line with their students’ cognitive development, i.e. it is not developed from the easy competency, and it makes teaching ineffective. A curriculum which is developed and used by referring to a learning continuum will be better, because it has really been adjusted to the students’ competence and cognitive development. That is why a learning continuum needs to be used in the education in Indonesia.

Genetics is one of the aspects in biology materials which is quite important in the analysis of the content (teaching materials). This is due to the fact that genetics is an essential part of biology materials, and that there have not been studies on the learning continuum which deals with the genetics aspect up to the level of experts’ opinions.

The study of genetics aspect materials involves practitioners consisting of supervisors, teachers, and school principals. Practitioners (supervisors, teachers, and school principals), the people who are very close to students, give different opinions about the content of genetics material aspects. Most teachers refer only to the available curriculum[8],[9],[10],[11]. The problem is, if the materials of the genetics aspect are not suitable with the students’ cognitive development, the students do not develop following the continuum in their study.

2. Method
This research is a descriptive study using the survey method to reveal the data on the biology education experts’ opinions about the students’ competence level and specific pedagogic materials of the genetics aspects for elementary and secondary school students. It was conducted in five provinces, including West Java, Jakarta, Central Java, and West Java Provinces, and Yogyakarta Special Territory, from early 2018 to end of 2019. The biology education experts are lecturers of biology education who became the sample respondents from the afore-mentioned provinces. The number of the respondents is 85 lecturers spread in universities – state and private universities. They were selected by considering their educational background, i.e. expertise in biology education in their bachelor, masters, and doctoral programs. The sample was established using the convenience sampling technique, i.e. those who are easy to find[12]. The research variables include the percentage of learning continuum of specific pedagogic materials and competency level. This research uses a non-
test instrument in the form of a questionnaire. The data were collected using the questionnaire on students’ competency level and specific pedagogic materials of the Aspect of Life in Nature, Science and Biology Subject written by Bambang Subali and Team in 2018. The questionnaire was validated through a forum grup discussion (FGD) of a team of validators consisting of three lecturers of UNY and five lecturers of UNS[13]. In addition to the experts’ opinions, the result of the FGD was used as the supporting data in mapping out the grid of the learning continuum of the genetics aspects.

In the FGD, the lecturers were asked to decide whether or not the aspects were logical to teach in the classroom and to decide the cognitive level chosen by the experts. If the experts’ opinions are illogical, then in the FGD the lecturers had to decide the material aspect suitable to teach in class and the appropriate cognitive level according to the analysis of a variety of considerations.

The result of the FGD on experts’ opinions is used to consider a number of things, including the difficulty level of materials, depth of materials, cognitive levels, and students’ cognitive development. The calculation of scores in the process of obtaining percentages is as follows: if an expert chooses a certain sub-topic to be taught, for example to grade 10 students at the cognitive level of C2, then he/she is given a score of 1, but if he/she does not suggest that it is taught to grade 10 students, for example: kelas X; cognitive level C2, then he/she is given a score of 0. The percentage is obtained by summing up the scores and then converting them in the form of percentage.

Each genetics aspect has a variety of sub-aspects, and thus, the percentage is presented in a range of percentages, for example, in the crossing aspect, the percentage of experts’ opinions ranges from 28% to 36%, which means that for the available material sub-aspect in the crossing aspect, 28 to 36% of the experts suggest that the materials should be taught to grade 12 students at the cognitive level of C2 (comprehension). The collected opinions of the experts were analysed in FGD in order to determine the straight line of the learning continuum of specific pedagogic materials of the genetics aspects. The learning continuum is chosen by analyzing every opinion of each expert by considering the cognitive level, scope, depth of specific pedagogic materials of the genetics aspect, and the students’ cognitive development.

3. Result and Discussion

Based on the scope of BSCS Biology A Molecular Approach 9th Edition, genetics materials are taught starting from the easy to the difficult materials, from a concrete objects including animals and vegetation with the level of biome organization up to individuals and then followed by the abstract objects and the level of organ system organization up to abstract molecules[14]. The experts’ opinions vary. The opinion most frequently appears will become the mode of each genetics sub-aspect. The result shows that the mode of each genetics sub-aspects varies.

As many as 44 – 45% of the experts’ opinions are in the mode of character inheritance through fission and genetics materials taught to grade 12 students at the cognitive level of C2. As many as 59% of the experts suggest that the genetics materials of the sub-aspect of DNA replication should be taught to grade 12 students at the cognitive level of C2. As many as 42% of the experts suggest that the genetics materials of the sub-aspect of genotype and phenotype should be taught to grade 12 students at the cognitive level of C2. As many as 41% of the experts suggest that the genetics materials of the sub-aspect of gene characteristics: dominant, recessive, and intermediate, should be taught to grade 12 students at the cognitive level of C2. As many as 53% of the experts suggest that the genetics materials of the sub-aspect of allele and multiple allele should be taught to grade 12 students at the cognitive level of C2. For sub-aspect 1 up to sub-aspect 5, the result of the FGD shows that the experts have the opinions that genetics materials are suitable/logical to be taught to grade 12 students at the cognitive level of C2 (understanding) because they have considered the cognitive development of the students. The following are the experts’ modes and the result of the FGD.
Table 1. The percentages of biology education experts’ opinions and the result of Forum Grup Discussion.

| Genetics Aspects                                      | Biology Education Experts’ Opinions | FGD          |
|-------------------------------------------------------|------------------------------------|--------------|
|                                                       | Modes     | %            | Logical     | Illogical |
| Character inheritance through fission and genetics materials | XII/C2    | 44-45        | √           | -         |
| DNA replication                                       | XII/C2    | 59           | √           | -         |
| Genotype and phenotype                                | XII/C2    | 42           | √           | -         |
| Gene characteristics: dominant, recessive, and intermediate | XII/C2    | 41           | √           | -         |
| Allele and multiple allele                            | XII/C2    | 53           | √           | -         |
| Crossing                                              | XII/C2    | 28-36        | -           | √ (replaced by XII/C3) |
| Law of character inheritance                          | XII/C2    | 28-33        | -           | √ (replaced by XII/C3) |
| Character inheritance in human, animal and vegetation | IX/C2; XII/C2 | 25-44       | -           | √ (replaced by XII/C3) |
| Mutation                                              | XII/C2    | 51-66        | √           |           |

As many as 28 – 36% of the experts suggest that the genetics materials of the sub-aspect of crossing should be taught to grade 12 students at the cognitive level of C2. As many as 28 – 33% of the experts suggest that the genetics materials of the sub-aspect of the law of character inheritance should be taught to grade 12 students at the cognitive level of C2. As many as 25 – 44% of the experts suggest that the genetics materials of the sub-aspect of the character inheritance in human, animal and vegetation should be taught to grade 12 students at the cognitive level of C2. The result the FGD for sub-aspects 6 and 8 shows that the experts think that it is illogical that those materials are taught to students of grades 9 and 12 at the cognitive level of C2 (comprehension) but it will be logical that the materials are taught to grade 12 students at the cognitive level of C3 (application). This is due to the fact that the students are expected not only to understand the materials but also to do exercises and solve problems related to the materials so that the cognitive level is raised to C3 (application). For the sub-aspect of mutation, 51-66% of the experts suggest that the materials should be taught to grade 12 students at the cognitive level of C2. The result of the FGD on the experts opinions is logical that the materials are taught to grade 12 students at the cognitive level of C2 (comprehension) because it has considered the students’ cognitive development.

Viewed holistically, all sub-aspects, from the sub-aspect of characteristic inheritance to the sub-aspect of mutation, the mode of biology education experts’ opinions shows that the genetics materials are taught to grade 9 or grade 12 students. The differences in the biology education experts’ opinions are affected by the factors of ideology, competence, and teaching experience as well as insight into the curriculum[8]. Some of the experts suggest that genetics materials should be taught to grade 9 students at the cognitive level of C2 (comprehension). This is in line with the Decree of the Minister of Education and Culture of the Republic of Indonesia, No. 37, Year 2018 that in junior high school, genetics materials begin to be taught to grade 9 students[15]. The result of the FGD (Forum Grup Discussion) was obtained from observing biology education experts’ opinions by considering students’ cognitive development.

Indonesia has applied the spiral model curriculum, in which teaching materials in the lower level educational institution will be continued in the next level[8],[16]. Burner states “If the understanding of amount, size, and probability is considered very important in science, then instruction in school subjects must begin intellectually with honesty and as early as possible consistent with students’ way of thinking. Let it be developed in the following class”[17]. Of course, this also applies to the biology subject of the genetics aspect, in which if genetics materials are considered important then they are introduced as early as possible to the students by consistently considering the students’ cognitive
development. In delivering the teaching materials, the teacher has to fully understand which materials can be understood and which materials cannot be understood by the students. Of course, the teacher has to understand his/her students’ cognitive development. The genetics materials are taught starting from the simple to the complex, from concrete to abstract, and of course it develops in accordance with the education level. The higher the education level, the wider the scope and depth of the materials, and the concepts developed by the students also improve because the initial materials become the basis for the students in finding the following concept[18],[19].

Table 1 shows that all sub-topics of genetics materials, from character inheritance to mutation are suggested to be taught to grade 12 students at the cognitive level of C2 (comprehension) and up to C3 (application). This is in line with the Decree of the Minister of Education and Culture of the Republic of Indonesia, No. 37, Year 2018 that in senior high school, genetics materials begin to be taught to grade 12 students[15]. The genetics materials for grades 9 and 12 are basically repeated materials, with a deeper and higher complexity in grade 12[20],[21], [22], [23]. In its implementation, the application of a learning continuum in genetics materials is a solution to the making of students’ more focus on understanding the lesson. The following is the table of learning continuum of the genetics aspect.

| Genetics aspects                                      | SD (I-VI) | SMP (VII-IX) | SMA X | XI | XII | C1 | C2 | C3 | C4 | C5 | C6 |
|------------------------------------------------------|-----------|--------------|-------|----|-----|----|----|----|----|----|----|
| Character inheritance through fission and genetics materials | -         | -            | -    | -  | √   | -  | -  | -  | -  | -  | -  |
| DNA replication                                      | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |
| Genotype and phenotype                              | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |
| Genetic characteristics: dominant, recessive, and intermediate | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |
| Allele and multiple allele                          | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |
| Crossing                                             | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |
| Law of character inheritance                        | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |
| Character inheritance in human, animal and vegetation | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |
| Mutation                                             | -         | -            | -    | -  | √   | -  | √  | -  | -  | -  | -  |

In accordance with Table 2 above, a line of learning continuum can be drawn based on biology education experts’ opinions and the result of the FGD. A teacher as one of the practitioners in the field can apply the grid of learning continuum in teaching specific pedagogic materials of the genetics aspect starting from character inheritance to mutation. In the aspect of genetics materials, the students’ cognitive process achieves the level of C3 or application. This does not necessarily mean that all materials presented in the lesson focus only on the cognitive process of C3 (application); they also
include the cognitive process of C1 (knowledge) and C2 (comprehension). When a student has achieved a high cognitive level, automatically he/she has achieved the cognitive level below it. For example for the sub-aspect of crossing material which has been taught to grade 12 students at the cognitive level of C3 (application), the students who have learned it at the cognitive level of C3 (application) automatically have also been able to understand and to do the work on it at the cognitive level of C2 (to understand) and C1 (to remember). Overall, the result of this study is a grid of learning continuum which is formed using the biology education experts’ opinions expressed in focus group discussions. As practitioners, teachers can apply the developed grid of learning continuum in the field for try-outs in the form of classroom action research, so that they can see the differences in their student’s mastery of genetics materials.

4. Conclusion
The learning continuum of specific-pedagogic materials of the genetics aspect is the end result of this study. Based on the entire discussion of biology education experts, the grid of the learning continuum containing the aspect of genetics materials which is taught to grade 9 students of junior high schools at the cognitive level of C2 (comprehension), and C3 (application). The higher the students’ education level, the higher the cognitive level they have to reach.

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