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What Should be Mastered by Elementary, Junior and Senior High School Teachers Related to the Concept of Evolution?

Susanti Wulandari[1*], Nuryani Y. Rustaman[2], Ari Widodo[2], I Nyoman Pugeg Aryantha[3]
[1] Department of Science Education, School of Postgraduate Studies, Universitas Pendidikan Indonesia, Bandung, Indonesia; [2] Department of Biology Education, Universitas Pendidikan Indonesia, Bandung, Indonesia; [3] School of Life Sciences and Technology, Institut Teknologi Bandung, Indonesia
[*]E-mail: susantiwulandari@upi.edu

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Abstract

Content knowledge is one of the competencies to be mastered by a teacher. Teachers who master content thoroughly and understand the limitations in teaching content to students at different levels are professionals. Online interviews were conducted, and questionnaires were distributed to 9 partici-pants consisting of 3 elementary school teachers, 3 junior high school science teachers, and 3 senior high school biology teachers. This qualitative research aimed to investigate the depth of evolution content that must be mastered by teachers at every level of elementary, junior, and senior high schools. The answers from the participants were analyzed qualitatively using a grounded theory re-search design. It is known that the three kinds of teachers have different depths of the evolution ma-terial from one to the others. Elementary school teachers should master the concept of evolution in the form of signs of an evolutionary process that can be found by students in everyday life. In addi-tion to being required to master elementary school materials, junior high school teachers should master the theories of evolution as well. For senior high school teachers, they are required to have a wider and deeper mastery of the material that includes the meaning, theories, clues, and mechanism of evolution.

Keywords: biology content knowledge, evolution concept, curriculum, professional teacher

Introduction

Shulman (1987) stated that a professional teacher must have good knowledge and ability on pedagogical content knowledge (PCK). Shulman & Skyes (1986) formulated seven basic teaching knowledge that a teacher must possess, namely subject matter knowledge, general pedagogical knowledge, pedagogical content knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational ends, purposes, and values, and knowledge of educational context. Furthermore, Tamir (1988) distinguished between general and special pedagogical knowledge. Shulman & Sykes (1986) used the term *content knowledge* while Tamir (1988) used *subject-matter knowledge* to refer to the components of content knowledge and syntax. Content knowledge is one of the absolute competencies that a teacher must have (Shulman, 1987; Grosman, 1990; Marks, 1990; Cochran, DeRuiter, and King, 1993; Fernandes-Balboa & Stiehl, 1995; Gess-Newsome & Loderman, 1999; Morine -Dhersimer & Kent, 1999; Carlsen, 1999; Loughran, Gustone, Berry, Milroy, and Mulhall, 2000; Pierson, 2001; Rollnick, Bennett, Rhemtula, and Ndlovu, 2008; and Helm & Stokes, 2013).

Loughran *et al.,* (2001) developed a PCK articulation and depiction approach called Content Representation (CoRe) to represent certain content or topics of science teaching. Previous research

has succeeded in grouping PCK teacher abilities into three levels of pre-PCK, growing-PCK, and maturing-PCK (Anwar *et al.*, 2014). The research of Anwar *et al.* (2014) also stated that the development of PCK occurs as the knowledge and ability to integrate content and pedagogy in teaching increases. This is as in the research results of (Putra *et al.*, 2017) which stated that to teach with an integrated approach, a teacher must have a balanced PCK. Concerning the increase in PCK, Widodo (2017) stated that systematic and planned efforts are needed to facilitate the improvement of the teacher's PCK. PCK research is generally carried out by involving pre-service teachers as the subjects (Putra *et al*., 2017; Anwar, Rustaman and Widodo, 2012; Anwar *et al*., 2014; Anwar *et al*., 2017; Rochintaniawati *et al.*, 2018) and experienced teachers (Widodo, 2017; Sukardi *et al.*, 2016; and Destiansari *et al.*, 2016).

Referring to the National Science Teacher Association (NSTA) in 2003 about the content standards that must be possessed by science teachers, especially in biology materials, it is known that there are different levels of content knowledge to be possessed by teachers who teach science (including biology) at the elementary, junior, and senior high school levels. At the elementary school level, science should be linked to developing an interdisciplinary perspective. Junior high school science teachers must be prepared to master content by emphasizing collaborative inquiry, mastering integrated approaches, and having an interdisciplinary and thematic perspective on science. Meanwhile, senior high school teachers, in general, are prepared with more in-depth content than elementary and junior high school teachers. In addition to the core competencies to be mastered by senior high school teachers, they should have advanced and supporting competencies to guide their students to master the material more deeply and holistically.

Based on the results of the reference analyzes carried out on the biology content, there are some discussions found, one of which is Evolution (KOBI, 2015; KOBI, 2017; Augutter & Wheathly, 2008; Sarkar & Plutynksi, 2008; Sober, 2018; Rosenberg & McShea, 2008; Wilkins, 2014; Mayr, 1988; O'Malley & Dupre, 2007; and Cohen & Wartofsky, 1976). Evolution discusses the core of Darwin's theory and the theory of Neo-Darwinism. Darwin based his theory on two fundamental ideas, namely random mutations and natural selection. Meanwhile, the theory of Neo-Darwinism considers evolutionary variations because of random mutations followed by natural selection (Capra, 2002). The novelty of this research is it comprehensively explores how deep (vertical dimension) the mastery of evolution content which should be mastered by teachers who teach at different levels (elementary, junior, and senior high school) is. Because the horizontal dimension that states the breadth of the biology material at different levels for both pre-service, beginner teachers, and professional teachers has been stated in both the national curriculum document, NSTA, and the biology consortium document. However, related to the depth of the evolution material, it has not been clearly described the differences in the mastery of content to be mastered by teachers at different levels. The researcher formulates the research questions as follows:

RQ1: How deep should elementary school teachers master the evolution content?

RQ2: How deep should junior high school science teachers master the evolution content?

RQ3: How deep should senior high school biology teachers master the evolution content?

Methodology

This research involved 9 participants consisting of 3 elementary school teachers, 3 junior high school science teachers, and 3 senior high school biology teachers. The elementary school teachers interviewed teach in different schools, all of whom had a bachelor-degree educational qualification with different teaching experiences (8 years, 21 years, and 30 years). The three junior high school teachers interviewed have a bachelor-degree educational background in the biology educa-

tion department, two of whom had graduated from the master's degree. They have varied teaching experiences (5 years, 15 years, and 25 years). Meanwhile, senior high school teachers interviewed have different educational backgrounds. One teacher has a bachelor's degree in biology education, another has a master's degree in management education with a bachelor's degree in pure biology, while the other one has a master's degree in management education with a bachelor's degree in biology education. They have different teaching experiences (6 years, 20 years, and 30 years).

The researcher collected the data using direct interviews (in-depth interviews), telephone interviews, and written interviews via social-media. The interviews with elementary, junior, and senior high school teachers were conducted by asking what kind of evolution material should be taught to students. The material in question is determined by Basic Competence (KD) at each level in the current curriculum. The current curriculum applied in Indonesia (revised 2013 curriculum) and foreign curriculum documents, such as Next Generation Science Standard (NGSS) and NSTA, were also analyzed to be compared with the responses of the interviews with the teachers.

A grounded theory design was employed to analyze the data. The data analysis began when the interview took place. During the interview, the researcher took important notes, recorded the entire process of direct and telephone interviews, and then transcribed and encoded all the data obtained. The interview was carried out in 6 months until there had been no new data found from the results of the analysis. In other words, it was carried out until the data obtained was saturated (Creswell & Clark, 2007; Noble & Mitchell, 2016).

In the coding process, the first thing to do was to read the entire text data before assigning them into information segments. Then, the segments were labelled by code, and if there are overlapping codes, they will be reduced to create descriptions and themes. The final step in the data analysis process was to represent and report findings. The representation can be in the form of tables, diagrams, pictures, or maps. The findings were interpreted by summarizing them, conveying personal reflection, making comparisons with the literature, and offering limitations and suggestions for further research (Creswell & Clark, 2007; Noble & Mitchell, 2016).

Results

The findings of the research are divided into three parts, namely the depth of evolution content to be mastered by elementary teachers, the depth of evolution content to be mastered by junior high school science teachers, and the depth of evolution content to be mastered by senior high school biology teachers.

1. The depth of evolution content to be mastered by elementary teachers

Evolution is one of the materials that need to be mastered by a teacher or a pre-service teacher. In both the revised 2013 curriculum and the previous curriculum that had been in effect in Indonesia, the material for evolution at the junior and senior high levels is contained in a certain chapter. Based on the current curriculum, evolution material is taught to the ninth-grade students in the second semester. Likewise, at the senior high school level, evolution material is taught to the twelfth-grade students in the second semester.

Based on the results of the analyses of interviews with elementary school teachers, it is known that there is one basic concept of evolution material, namely adaptation. Adaptation at the elementary level is given to students through observable examples in everyday life, for example, the concept of camouflage in squid, mimicry in chameleons, and auto-tomy in lizards. The following are the illustrations of the researcher's interviews with the elementary school teachers.

Researcher: *"In your opinion, how detailed are the concepts that underlie evolution taught to elementary students?"*

Teacher A: *"Students are taught about the notion of adaptation, in which adaptation is the ability of living things to adapt to their environment and how they adjust to their environment."*

Teacher B: *"Students are taught the concept of adaptation by getting them to think about how living things can survive. They are asked to mention the examples of adaptations done by humans, animals, and plants, for example, by asking them why roses have thorns while others do not."*

Teacher C: *"Students are reminded about the characteristics of living things and directed to adaptation. They were then told that the adaptation is to adjust to the environment. For example, students go to school in uniform. They adapt to their fellow friends, older people, and others. The next is the efforts of living things to defend themselves; for example, a lizard will detach its tail if run after by its enemy. The chameleon changes its body color according to the object it inhabits."*

All the elementary school teachers interviewed have a bachelor-degree educational background with different years of service. Two of them have been working as a teacher for more than 20 years while the other has been working for less than 10 years. Although there are different perspectives in the application of teacher pedagogy in teaching the concept of adaptation, the concepts that are important to be mastered by teachers based on the results of interviews with elementary school teachers in general include:

a. the meaning of adaptation (both in general and in specific),
b. examples of living thing adaptation (humans, animals, and plants),
c. ways in which living things adapt to their environment (autotomy, mimicry, and camouflage), and
d. the efforts of living things to defend themselves.

2. The depth of evolution content to be mastered by junior high school science teachers

To get complete information related to the depth of evolution content to be mastered by junior high school teachers, interviews were conducted with three junior high school teachers. The three teachers teach in different schools. One teacher has a bachelor-degree educational background while two others have a master-degree educational background, and all of them come from the biology education major. Based on the results of the researcher's interviews with the junior high school teachers, it was found that there are several concepts taught to junior high school students, namely Lamarck's Theory, Darwin's Theory, and types of adaptation. The following are the illustrations of the researcher's interviews with the teachers.

Researcher: *"How detailed are the concepts of evolution taught to your students?"*

Teacher A: *"The evolution I taught to my students is about Lamarck's Theory, Darwin's Theory, and examples of natural selection. I teach my students based on the Graduates Competency Standards of National Examination (SKL UN) because they are commonly asked in exam questions."*

Teacher B: *"The evolution materials I taught are, among others, the notion of evolution, Lamarck's theory of 'use and disuse' along with examples of giraffes, and Darwin's theory and its relation to adaptation and natural selection. I also explain the types of adaptation along with examples to the students."*

Teacher C: *"Explaining Darwin's theory, other evolution theories with the examples of long- and short-necked giraffes and the examples of adaptations in humans, animals, and plants."*

In general, based on the results of the interviews with junior high school teachers, evolution is conveyed through theories of evolution and adaptation. Although the order of the evolution content delivery is different, the point is that they are entirely guided by the applicable curriculum and do not neglect the graduates competency standards contained. In more detail, the evolution material taught to students is as follows.

a. Definition of evolution.

b. Lamarck's theory of 'use and disuse' through the example of giraffes.

c. Darwin's theory of variations in the beaks of birds and their relationship to the type of food.

d. Darwin's theory of natural selection that living things that can adapt to their environment will survive while those who cannot will disappear.

e. Definitions of adaptation and types of adaptation (morphology, physiology, and behavior) along with the examples in both humans, animals, and plants.

3. The depth of evolution content to be mastered by senior high school science teachers

At the senior high school level, evolution material is taught to the twelfth-grade students in the second semester. It is also taught at the second semester in junior high school. This shows that evolution is one material that requires other concepts as a basic concept to understand. Interviews were conducted with three senior high school teachers who taught evolution material, each of whom has a different educational background.

Based on the results of the interviews, it is known that there are several important concepts that teachers must master in teaching evolution material, namely the meaning of evolution, revolution, Darwin's Theory, Lamarck's Theory, Weismann's Theory, clues to evolution, and evolution mechanisms. The following are the illustrations of the researcher's interviews with senior high school teachers.

Researcher: “How detailed are the concepts of evolution taught to your students?”

Teacher A: “*At first, I give my students an understanding of the differences between evolution and revolution and ask them to set an example. This is to form an understanding that evolution lasts a long time. Then, I explain the theories of the evolution of Darwin, Weismann, and Lamarck and compare the three. Then, I relate the theories with the origin of life: pre-naturalist, abiogenesis, biogenesis, cosmozoa theory, and naturalist. I explain that one advantage of Darwin's is the fact or evidence of evolution that can be found to date. The evidence for evolution is in the form of horse fossils because these fossils are the most complete and can explain the evolution of various aspects of the body (jaw shape, size, type of teeth, toes, etc.). The latter is the use of mathematical equations or opportunities concerning Hardy-Weinberg's Law”*.

Teacher B: “*The notion of evolution, theories of evolution by Darwin, Lamarck, and Weismann, evidence of evolution, clues to evolution, and the mechanism of evolution which is closely related to genetic understanding. Because learning the Hardy Weinberg equation requires a correct understanding of genetics, mutations, etc., then I think that is the reason why evolution is given to the twelfth grade and at the end.*”

Teacher C: “*The notion of evolution, the development of the theory of evolution, the comparison of the theory of evolution according to Darwin, Lamarck and Weismann, examples of phenomena related to the theory of evolution (environmental influences, adaptation, natural*

selection), evidence of evolution, evolution mechanism, Hardy Weinberg's law, new species formation, and theories of the origin of life (biogenesis, abiogenesis, and modern biological theories). The theory learning in the second semester is usually accelerated, so it is not too detailed. The discussions of the issue of school exams, national-based school exams, and national exams often appear. It is the most repeated material during intensive learning".

There are different repetitions and depths of evolution material taught to students from elementary, junior, to senior high school levels. The detailed evolution materials taught to senior high school students based on the results of the interview are as follows.

a. Definition of evolution

b. Weismann's theory of evolution: changes in body cells due to the environment will not be passed on to one's offspring.

c. Lamarck's theory of evolution about "use and disuse" that parts of the body that are often used will develop and get stronger while those not used will disappear. The second principle is about the inheritance of acquired characteristics.

d. Darwin's theory of evolution about variation and natural selection.

e. The evidence for evolution can be seen from individual variations and examples.

f. Fossils as evidence of evolution (human fossils, horse fossils, and Saurus). Horse fossils are the most complete fossils found in almost every geological period so that they can adequately explain the evolution seen from their body size, legs, molars, neck, head, and the number of fingernails.

g. Homology tools of various living things (upper limbs on whales, frogs, horses, tigers, humans, and birds) that show the common ancestry.

h. Comparative embryos as evidence of evolution are seen from the development of embryos of various types of animals (fish, salamanders, turtles, birds, rabbits, humans).

i. Biochemical comparisons: all living things have the same genetic code in putting together proteins (amino acids).

j. Comparison of physiology and instructions for the remaining organs and examples.

k. Evolution mechanism: (1) Gene mutation, (2) Hardy-Weinberg's law regarding changes in the ratio of gene frequencies in populations, and (3) emergence of new species.

Discussion

In teaching the evolution material to elementary school students, the development of thinking of elementary school students who are still at a concrete level (Dahar, 1996) must be considered. This is as stated by Eshach & Fried (2005) that explaining the full concept of evolution is still not feasible to convey to elementary school students because it is too abstract. This statement is based on Piaget's framework of cognitive development. This is in line with Geake (2004) stating that learning consists of four stages, namely concrete experience, reflective observation, making hypotheses, and testing hypotheses.

The evolution material to be mastered by junior high school teachers, according to the interviews, covers the materials taught to elementary school students added with the theories of evolution and the comparison of these theories. Theories of evolution that need to be understood include Darwin's and Lamarck's theories. For the senior high school level, senior high school teachers and pre-service teachers to understand evolution more deeply, namely microevolution and macroevolution, the mechanism of evolution, and genetic understanding of gene mutations. According previous research (Nedelson *et al.*, 2009), understanding fully about evolution requires

prior knowledge of the concepts of mutation, adaptation, and opportunity (Gould, 2002; Miller, 1999). However, the concept of evolution can only be understood by elementary school students by simplifying the concepts and components taught (Eshach & Fried, 2005; NRC, 1999, 2007).

Based on the interviews with the elementary school teachers, it is known that the evolution material taught to elementary school students is the concept of adaptation of living things. This is in line with the research of Nedelson *et al.* (2009) who applied the teaching of the concept of evolution about adaptation and speciation to kindergarten and elementary school students. In the research conducted by Nedelson *et al.* (2009), the concept of evolution taught to kindergarten students is observing and describing the similarities and differences between several types of plants and animals, while the concept of evolution taught to elementary school students is an introduction to some organisms that lived in the past and seeing their similarities with the living organisms today, some of which have been destroyed.

Based on the results of interview, there are repetition concepts from elementary to senior high school level. Elementary students taught the basic concept of evolution that is about adaptation concept. Then, junior high school students taught about kinds of adaptation and theories of evolution. While for senior high school students taught the more complex and depth materials including clues of evolution and the mechanisms of evolution. According to Goswami (2008), the brain mechanism learns to extract structures from inputs. The children's brain builds detailed conceptual frameworks through watching and listening to the surrounding environment. When we learn languages and label concepts in observed objects, the brain tissue will be more complex. As we learn new information through language, neural connections form responses that encode information that is more abstract and becomes an abstract concept. Learning is a process that is embedded in individual experience, and one of the goals of education is to help individuals to extract a structure of knowledge (body of knowledge) at a higher level.

Teachers who teach the evolution material often experience obstacles in conveying the idea of evolution. This happens because there is a misconception or incomplete understanding that the teacher has about evolution. The teacher understands the phenomena such as "humans are originated from apes" as part of Darwin's theory. In fact, in Darwin's book entitled "The origin of the species", he never mentioned that humans are originated from apes. This raises an error if it is also conveyed by the teacher to students. According to the interview with the teacher, as a middle way, the teacher said that students could believe or not about Darwin's theory, and the teacher merely conveyed it. Curriculum about evolution in biology is found in several Muslim countries, such as in Pakistan, Iran, Turkey, Indonesia, and Egypt (Hameed, 2008). The message of evolution in the Islamic world needs to be framed in a way that emphasizes practical application and shows that it is the main foundation of modern biology (Nisbet & Mooney, 2007).

The evolution material taught to students is given in stages. For each level of education, new concepts and new learning experiences are increasing. This is supported by Goswami (2008) stating that learning is incremental and experience-based. The importance of incremental environmental input shows that the learning environment created in schools by teachers can have a cumulative effect. The growth of new neuron connections in the brain will always occur in response to new inputs known as 'neuroplasticity'. This will lead to the 'conception change' process. Many neural networks develop over time and do not suddenly undergo restructuring with only one learning experience (Goswami, 2008).

The success of learning also depends on the curriculum and teacher, the context provided by the classroom and family, and the context of the school and, further, the community. All of these factors play a role in interactions with individual brain characteristics (Goswami, 2004). Therefore,

teachers need to provide content with scope and depth that is appropriate to the stage and thinking ability of their students.

Conclusion

When viewed from the curriculum, teachers deliver the students the material in textbooks. At the senior high school level, there is a deeper development related to evolution material. If at the elementary level the teacher only provides the basic concept of adaptation, at the junior high school level the Darwin and Lamarck theories are added. Thus, at the senior high school level, the evolution material provided is quite complex. This is assumed as a vertical spiral curriculum.

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