RESEARCH ARTICLE

Ability to compose concept maps and student cognitive learning outcomes in animal embryology and reproduction courses

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Abstract: One of the learning outcomes of learning Animal Embryology and Reproduction is that students can explain concepts about reproduction or embryology theory. Since concept map-based learning can improve students' critical thinking skills and analysis, and support their interest in learning, this study analysed the ability of students enrolled in the 2019/2020 Animal Embryology and Reproduction course to construct concept maps and students' cognitive learning outcomes through assignments and tests. This descriptive study involved 127 students in semester VI enrolled in the Embryology and Animal Reproduction programme at the Department of Biology Education, FTTE at the Universitas Muhammadiyah Malang. The sampling technique was saturated sampling and the data were collected through the task of compiling concept maps and learning outcomes with tests. The drafting of concept maps was assessed by the concepts and ideas, relationships between concepts, hierarchies, propositions, and spelling, with cognitive learning assessed by tests. The results showed that most students had sufficient ability to compose a concept map and very good learning outcomes, indicating that concept maps can be used to learn biology in Animal Embryology and Reproduction courses.

Keywords: cognitive learning outcomes; concept map; embryology and reproduction

Introduction

Professional teacher candidates must have 21st-century abilities, specifically 4C and digital literacy (Kim, 2019). According to the Assessment and Teaching of 21st Century Skills, skills, knowledge, 21st-century attitudes, values, and ethics are organised into four categories: ways of thinking including creativity and innovation, critical thinking, problem-solving, decision making, and learning about learning (metacognition); working style which involves communication, collaboration, and teamwork skills; work tools including general communication and information technology skills and literacy; global living involving citizenship, life and career, personal and societal responsibility, as well as competency and cultural awareness (Saavedra & Opfer, 2012). The National Education Association identified 21st-century skills as "The 4Cs" including creativity, communication, collaboration, and critical thinking

(Rhedana, 2019).

Critical thinking is one of the Higher-Order Thinking Skills (HOTS) in addition to creative thinking, problem-solving, and reflective thinking (Lu et al., 2021). Critical thinking can be interpreted as a student's skill in analysing an argument, drawing conclusions through reasoning, assessing or evaluating, and decision-making or problem-solving (Fatmawati et al., 2014). It encompasses various analyses, assessments, evaluations, reconstructions, and decision making which leads to rational and logical action (Septiani et al., 2019). Analysis, assessment, and reconstruction activities are used to perform thinking activities regarding the subject, content, and problems (Gallenstein, 2013; Papp et al., 2014). Critical thinking in learning can be provided by distributing independent assignments or projects in the form of concept maps.

A concept map is a visual technique to show the information structure of how the concepts in a particular domain are related. It is an alternative way to holistically, interrelate, and comprehensively organise material in the form of maps (images). Moreover, concept maps are also useful for refining thinking to be more creative and critical (Rahman, 2016; Rosa et al., 2021), as well as provide students with an overview of the depth and breadth of a concept that needs to be taught to create a series of concepts and organise learning systematically (Kinchin et al., 2019; Vodovozov & Raud, 2015). In composing a concept map, the students can improve their metacognitive by negotiating their ideas, controlling their learning, and monitoring their learning improvement (Zubaidah & Pangestuti, 2016).

One of the learning outcomes in the Animal Embryology and Reproduction Course is to explain concepts and theories of reproduction and embryogenesis and to conduct an observation and analyse reproductive organ data according to academic norms and ethics. The course characteristics based on the learning outcomes emphasise conceptual understanding and observation skills in the laboratory. Generating concept maps is expected to increase students' cognitive learning outcomes as well as their thinking skills. Concept map tasks construct the idea and students' creativity, thus, are closely related to thinking ability and cognitive learning outcomes. The process of studying science using concept maps is still linked to academic accomplishment (Kusumadewi & Kusmaryono, 2022; Singh & Moono, 2015). For example, concept maps can improve learning outcomes in physics (Taufiq, 2013), and natural sciences material (Hwang et al., 2011; Romero et al., 2017). Another study showed that there was a difference in the effect of using mind map and concept map strategies on the learning achievement of class X students (Redhana et al., 2021). Concept maps also help facilitate meaningful learning for students (Bressington et al., 2018; Carr-Lopez et al., 2014) and develop college-level student learning outcomes in speaking skills (Alhomaidan, 2015). However, none of these studies has investigated the task of making concept maps and learning outcomes in embryology lectures.

To better prepare professional Biology teacher candidates, the quality of graduates should be improved in terms of their knowledge of biology and their ability for continuing professional growth. This can be achieved by familiarising innovative learning activities in lectures, such as concept maps. This study analysed the ability to compose concept maps and cognitive learning outcomes of Biology Education students at Universitas Muhammadiyah Malang. The study findings contribute to the existence of recommended alternatives to improve higher-order thinking skills in students (biology teacher candidates) who need to be trained regularly and consistently.

Method

This descriptive study was conducted for one semester and involved 127 6th-semester students enrolled in the Animal Embryology and Reproduction Course in the Faculty of Teacher Training and Education (FTTE) Universitas Muhammadiyah Malang-Indonesia during the 2019/2020 academic year. The data regarding the students' ability to compose concept maps were collected via assignments to read relevant scientific articles and textbooks regarding the material discussed in the course. The aspects assessed to compose concept maps were: (1) concepts and ideas, (2) relationship between concepts, (3) hierarchy, (4) proposition, and (5) spelling. The data regarding cognitive learning outcomes were obtained by responding essay questions or items which contained five items of C2 and C4. The criteria for cognitive learning outcomes were (1) very good (score: 80−100), (2) good (score: 70−80), and (3) average (score: 60−70). The selection of three criteria was based on the Minimum Completeness Criteria for the Animal Embryology and Reproduction course which was 70. Data were analyzed descriptively using percentages and averages (mean). The concept map assessment criteria were those of Kinchin et al., (2019).

Results and Discussion

The assessment of the ability of the students to compose concept maps is provided in Figure 1 showing that 10% of students were very good, 34% were good, 48% were sufficient, and 8% needed to improve concepts and ideas. In terms of the relationship between concepts, most students (65%) were sufficient but 13% of students required improvement. Regarding the hierarchy, most students (62%) were adequate but 20% needed improvement. Similarly, most students (55%) were sufficient in proposition but 17% of students required improvement, whereas most students (44%) were good at spelling with only 3% requiring improvement.

In general, it is critical to pay close attention to the components that exist in a concept map because a concept map can describe the breadth and depth of comprehension of the learning material. According to Novak (1990), a concept map is composed of several components: (1) a proposition, which is a statement regarding the relationship between one concept (information) and another; (2) hierarchy is the level of a concept that is organised from the most general concept to the least broad concept to the most detailed concept; (3) proportion which connects concepts on the concept map that are in different segments or domains. Kinchin et al., (2019) reported three categories or types of concept maps, namely: (1) network tree/listing net or radial structure in which all related aspects of the topic are directly related to the core concept but not directly related to each other; (2) chain or a sequence of linear understanding that only exists linked to the one just above and below. Although there is a logical order from start to finish, the implied hierarchical nature of multiple links is invalid; (3) a network or dominant network that is highly integrated and hierarchical and shows the depth of understanding of the topic. In this cohort, most students (69%) prepared concept maps based on network tree/listing net (Figure 2). Examples of the student's work are provided in Figures 3, Figure 4, and Figure 5.

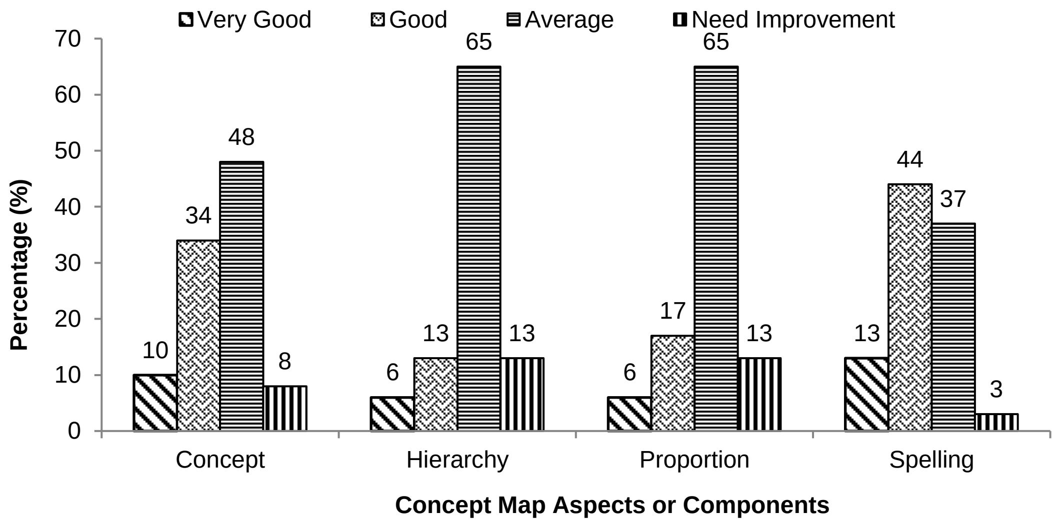

Figure 1. Assessment of the students' ability to compose concept maps

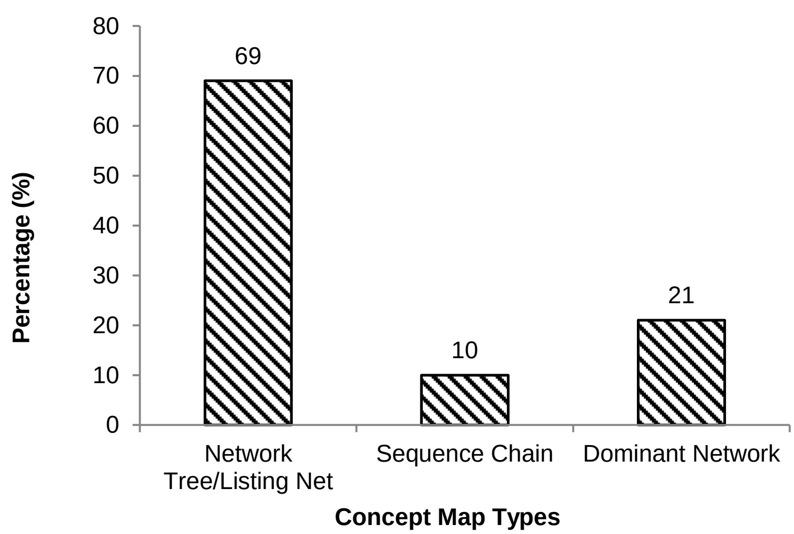

Figure 2. The concept map types used by students

Figure 3 illustrates the dominant components of a network tree concept map in which the students noted the Embryology and Reproductive course material to be discussed. Sub-chapters containing material coverage such as comprehension, types of reproduction, examples, and numerous types accompany the material on animal reproduction and fertilisation. The reproductive cycle material includes stages and cycle sub-chapters, with reproductive organs anatomy material including sub-sections of several reproductive organs as well as differences between males and females, accompanied by a representative animal example. This series tends to involve list-making rather than showing the interrelationships between concepts and is classified as a form of net to assist the cognitive process. Words on the connecting lines provide relationships between the primary concepts (Khasanah, 2019).

Figure 3. An example of the network tree/listing net concept map

Figure 4 shows the sequence chain concept map in which the students try to outline the concept of the material but there is no picture of the relationship between the chapters or the material discussed. The material understanding of the stages of embryogenesis is written in outline like a plot. The stages of embryogenesis, the reproductive cycle, and the reproductive organs are arranged separately and there is no connection between the three. Khasanah (2019) postulates that the sequence chain concept map can be used to sequence an event.

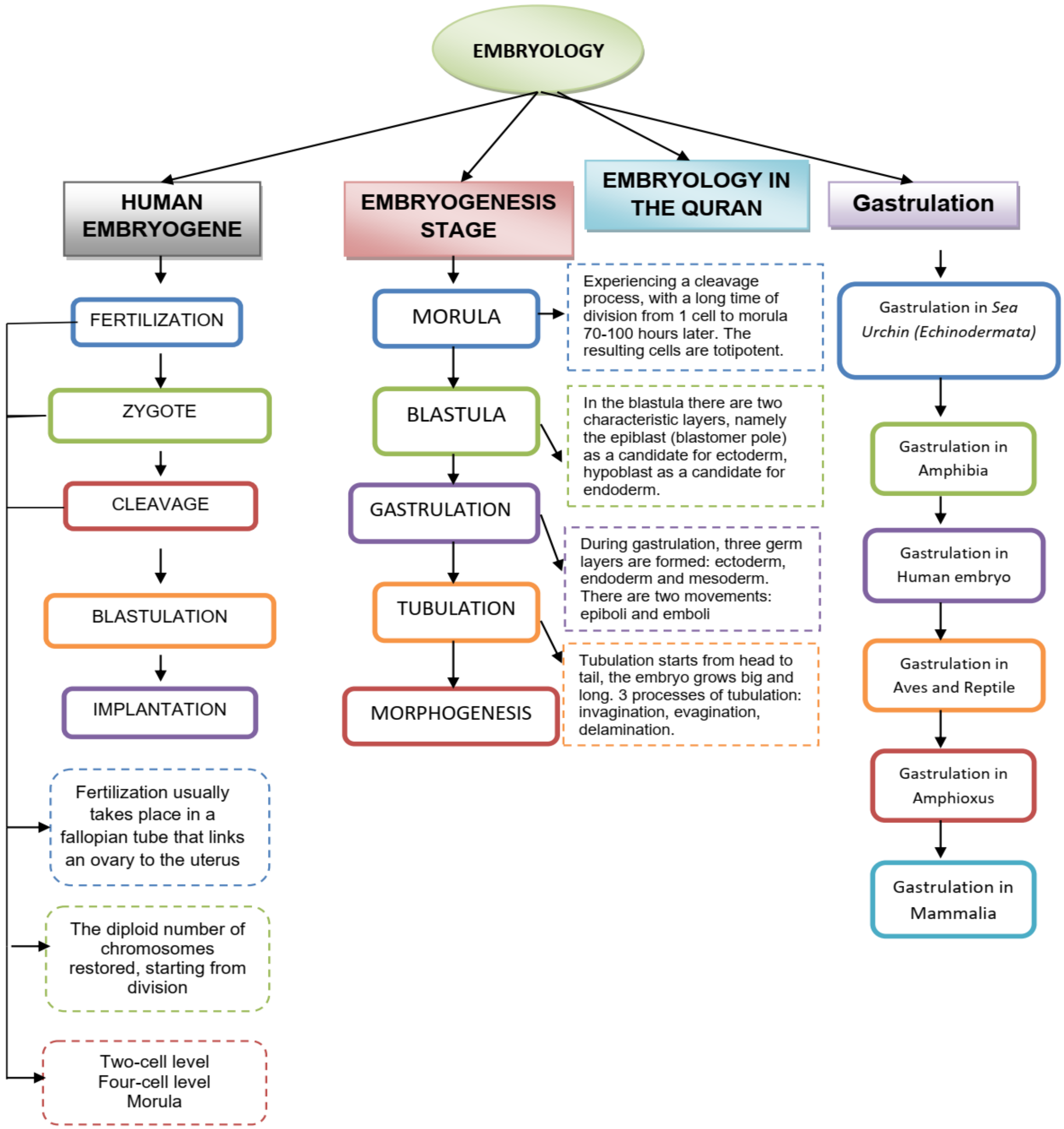

Figure 4. An example of a sequence chain concept map

Figure 5 provides an example of a dominant concept map which describes all the information and demonstrates the range of the student's cognitive abilities and their ability to remember previously taught concepts. Students connect three different concepts—animal reproduction and fertilisation, reproductive cycles and stages, and reproductive anatomical organs—that are related to the material to be examined. These three concepts are distinguished by their relationship to each other. This concept map can begin with terms being divided and grouped according to specific links, making the terms more useful by writing them outside the core concept (Khasanah, 2019).

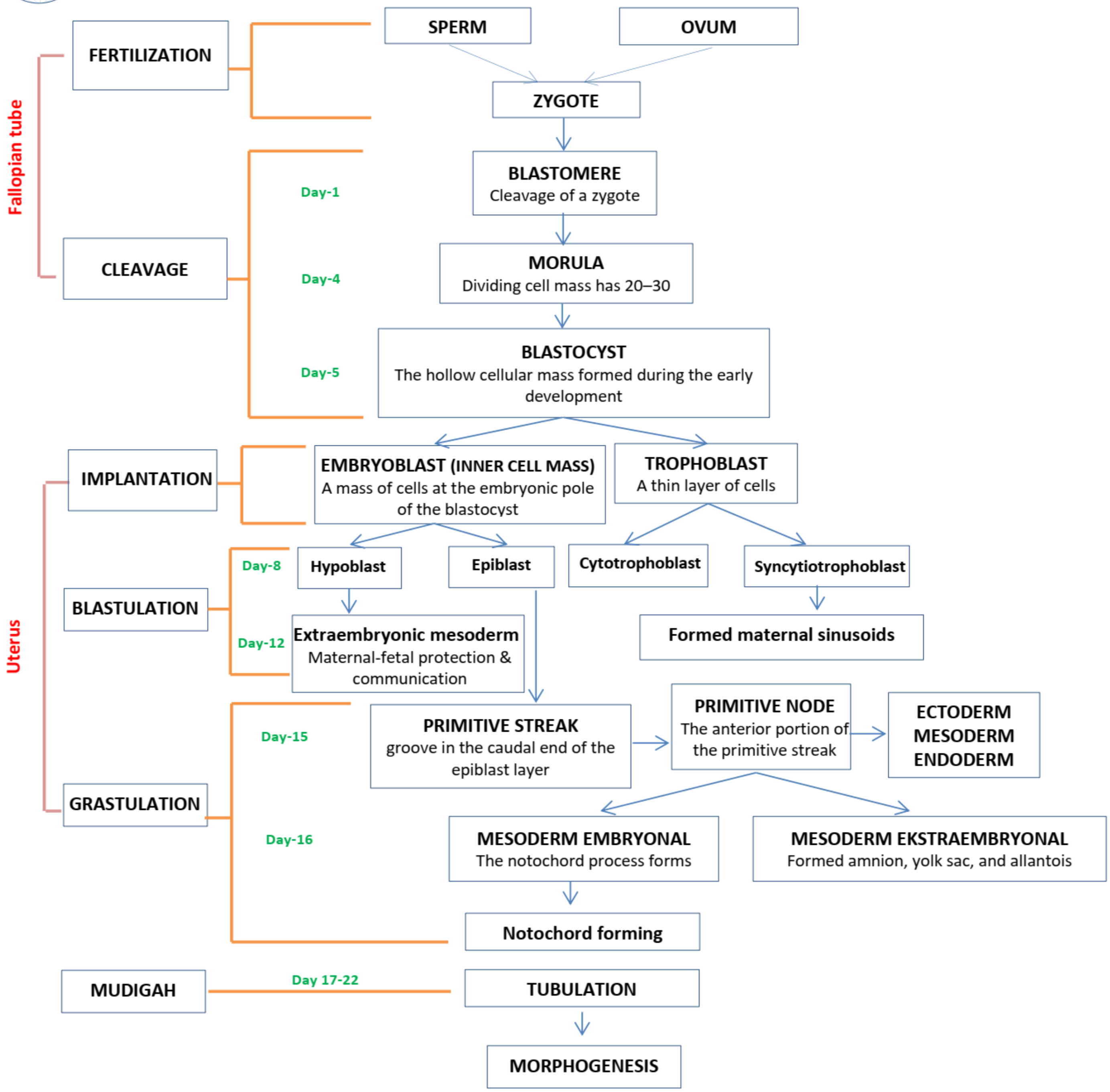

Figure 5. An example of a dominant network concept map

A study about concept maps has developed from the learning media development to the effect on student learning achievement (Kinchin et al., 2019). Experts describe the benefits of concept maps, namely: (1) to assist in the development of meaningful learning to strengthen critical thinking, (2) to investigate what students already know, and (3) as a tool for evaluating learning outcomes (Eshuis et al., 2022; Musyrifah & Ismail, 2014). Concept maps can be utilised in learning activities as a method to measure concept comprehension and identify student misconceptions (Zubaidah & Pangestuti, 2016). Figure 6 indicates that most students (65%) had very good cognitive learning outcomes. It has been suggested that the concept map-based learning model can improve students' achievement and cognitive learning outcomes, as there is a correlation between concept map creation and students' learning achievement. The learning process utilising concept maps can increase students' interest in learning, resulting in higher learning outcomes and more rapid mastery of the material (Zulva & Hidayati, 2016). There is a significant relationship between the ability to create concept maps and learning outcomes (Carr-Lopez et al., 2014; Maurisa & Herkules, 2016). Furthermore, learning via concept maps can help independent learning, improve critical thinking skills, analysis, and support interest in learning (Biniecki & Conceição, 2016; Jamaludin, 2017; Maryam et al., 2021).

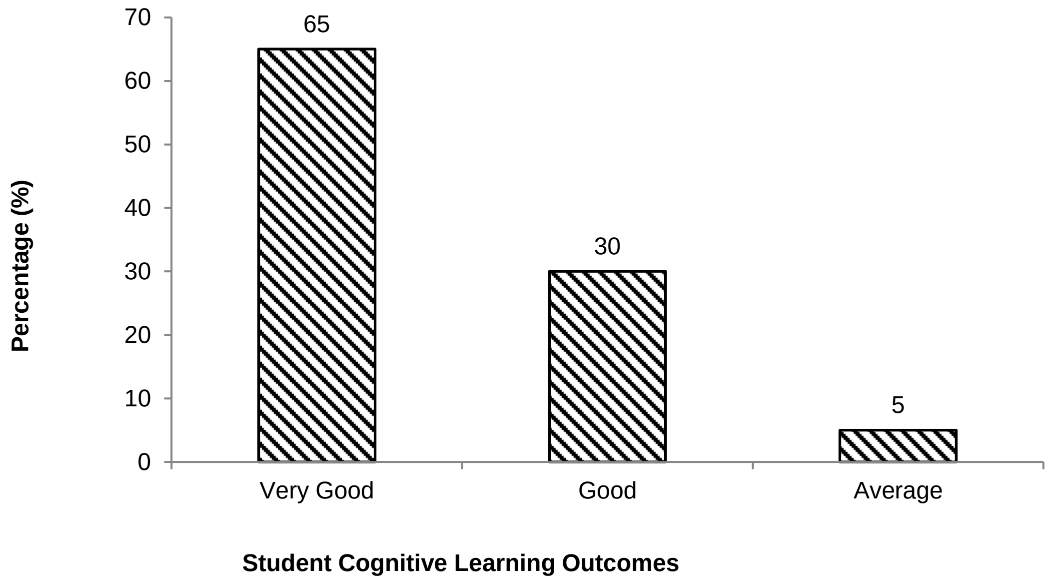

Figure 6. Classification of the students' cognitive learning outcomes

The very good students' cognitive learning outcomes cannot be separated from the functions, advantages, and benefits of concept map learning. The use of learning concept maps becomes significant since new information and knowledge that students already have are connected, making it easier for them to absorb and giving them the freedom to be creative, thereby improving student learning outcomes (Khasanah, 2019). Project-based learning has advantages including increasing learning outcomes and motivation and encouraging creativity and independence in producing a product (Adinugraha, 2018; Almulla, 2020). The functions of using tasks to compose concept maps are: (1) to develop meaningful learning to improve understanding and memory; (2) to improve activeness and creative thinking; and (3) for a more comprehensive understanding of the subject matter (Dong et al., 2020; Khasanah, 2019), and connecting previously learned concepts with newly learned concepts (Gallenstein, 2013). Concept maps also increase student involvement, thereby impacting students' understanding and can improve student learning outcomes (Pribadi & Delfy, 2015; Sari et al., 2022).

Conclusion

In summary, these findings show that there are numerous forms of concept maps, a range of aspects and components of concept maps generated by students, and the student's ability to compose concept maps in the Animal Embryology and Reproduction Course. Most students had good cognitive learning outcomes but some need regular training to prepare concept maps. This study only focused on the ability to compose concept maps and student cognitive learning outcomes, so further research is required to focus on various abilities or the 21st-century skills of biology teacher candidates.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

E. Susetyarini: Data analysis; Writing ─ original draft**;** Writing ─ review and editing. **E. Nurrohman:** Writing ─ original draft. **D. Sharafie:** Writing ─ review and editing. **D. Fatmawati:** Writing ─ review and editing.

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