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Utilizing Concept Maps to Uncover Misconceptions in Biology

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Abstract

Misconceptions in Biology learning can hinder students' ability to assimilate new knowledge and negatively affect their academic performance. This study aimed to uncover students' misconceptions regarding the human reproductive system using concept maps and clarification interviews. Conducted in October 2022 at MAN 1 South Tangerang, this qualitative descriptive study involved 12 purposively selected students from different achievement levels. Data were collected through concept map worksheets and follow-up interviews. The results revealed that 92% of students experienced misconceptions in the concept of fertilization, while only 8% understood it correctly. Misconceptions were also found in the concepts of reproductive organs (75%), gametogenesis (67%), and menstruation (75%). These findings highlight the effectiveness of concept maps as a diagnostic tool for revealing deep-seated misconceptions and informing targeted instructional strategies.

Keywords: concept maps, human reproductive system, misconceptions

INTRODUCTION

Education is considered successful when it achieves its learning objectives. In practice, educational goals also emphasize planned behavioural changes in the learning process, encompassing changes in knowledge, attitudes, and skills. Learning outcomes are measured to determine the achievement of educational goals. Learning outcomes refer to the demonstrable changes in students’ knowledge, skills, and attitudes that result from a learning experience (Orr et al., 2022). Low student learning outcomes can indicate a low understanding of the subject matter. Biology learning itself aims at a deep understanding of concepts. For students to describe and link one biological concept to another, they must first establish a coherent conceptual framework. Such an integrative understanding enables deeper learning and supports mastery of subsequent topics (Anderson & Schönborn, 2021; Lenski et al., 2022).

The human reproductive system is one of the subjects in Biology learning that contains a significant amount of abstract material due to its strong connection to physiological processes within the body. In the human reproductive system material, students are also required to be able to analyze the relationship between the structure of tissues forming reproductive organs and their functions (Permendikbud No. 37, 2018). The concepts within this material have many interrelated sub-concepts. Therefore, students need to understand every concept in the human reproductive system material. If students' understanding of a sub-concept in the human reproductive system material is incomplete, they are susceptible to misconceptions in subsequent sub-concepts (Yusi & Marsah, 2017). Misconceptions in science are understood as individual knowledge acquired from educational experiences or informal events that are irrelevant or meaningless according to scientific concepts

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(Soeharto, 2019). Misconceptions can hinder students from connecting new information into their cognitive structure, potentially leading to weak understanding or conceptual misunderstandings (Nakhleh, 1992). Recent studies confirm that misconceptions hinder the integration of new knowledge into students' cognitive structures. Weis and Schreiber (2022) showed that tools like refutation texts help align misconceptions with correct concepts, improving understanding. Similarly, Gartmeier et al. (2022) found that addressing misconceptions directly enables students to restructure their thinking more effectively.

One measurement tool that can be used to identify misconceptions in students is concept maps (Zulfiani, 2009). Concept maps can illustrate the expression of externalized concept propositions because they are an explicit and open representation of a person's concepts and propositions. This also makes it easier for teachers and students to know and exchange information about the proportional relationship between certain concepts, whether good and valid, or to recognize missing relationships between concepts; thus, concept maps are called an effective tool for showing misconceptions. Misconceptions are usually characterized either by a relationship between two concepts leading to a clearly false proposition or by a relationship that misses a key idea (Joseph D. Novak & D. Bob Gowin, 2006). Recent studies have confirmed the value of concept maps in science education. For instance, a meta-analysis by Adesope et al. (2025) showed that concept mapping significantly improves students' understanding and helps reveal persistent misconceptions in biology and other STEM disciplines. Similarly, Sarwar et al. (2024) demonstrated that combining concept maps with conceptual change texts helped reveal and address misconceptions in nanoscale science.

Building on traditional concept map diagnostics, qualitative research has also explored the integration of co-constructed concept mapping with diagnostic interviews. For example, Kinchin, Streatfield, and Hay (2010) demonstrated that collaboratively generating concept maps during the interview process enhances the quality of participant responses, revealing deeper insights into learners' mental models and underlying misconceptions. More recently, Bielik et al. (2023) combined concept map analysis with semi-structured interviews to examine how preservice biology teachers conceptualize complex phenomena, highlighting how interviews can help interpret and validate the structures observed in students' concept maps.

Observations conducted at MAN 1 Tangerang Selatan showed that Biology learning for the human reproductive system in Class XI used the Biology textbook by Irnaningtyas and the Human Reproductive System E-Module Integrated with Islamic Values by Nadya as teaching materials. This was done to realize the mission of scientific integration mandated to all educators in the Madrasah. To achieve this mission, the development of science in Madrasah aims for students to know the Creator and believe in Him, and to study humans from various sides, not only as mere objects of study, but as creations of Allah SWT (M. Hamdar Arraiyyah, 2019).

Learning modules are one of the communication components in learning and are used as independent learning materials for students (Depdiknas, 2008). Learning modules can lead to misconceptions in students if the language is difficult or the explanations provided are inaccurate (Paul Suparno, 2005). This is also affirmed by David F Treagust and Reinders Duit that textbook authors can build students' internal representations through the textbooks they write. Along with advances in information technology, the presentation of teaching materials has shifted from print to digital format, known as electronic modules (Wirayasa et al., 2020). Electronic modules are learning media presented in digital form to support the learning process, and typically include important components such as

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competencies and learning outcomes, usage instructions, required tools or materials, material summaries, and exercises and assignments (Delita et al., 2022). Previous studies have explored misconceptions in various biological concepts, yet limited research has focused specifically on the use of concept maps to uncover misconceptions related to the human reproductive system among high school students. Most existing research has not integrated diagnostic tools such as concept maps with in-depth clarification interviews to validate students' conceptual understanding. Therefore, this study aims to investigate specific misconceptions held by Grade XI students regarding the human reproductive system using concept maps and clarification interviews. The findings are expected to provide insights for educators to design more effective learning strategies and materials in biology education.

Based on the background described above, the problem formulated is "What misconceptions occur in class XI students in understanding the human reproductive system concept as measured using a concept map creation test?" The use of concept maps is expected to identify student misconceptions in the human reproductive system material.

RESEARCH METHOD

This research is a qualitative descriptive study that aims to explore student misconceptions using concept maps on the human reproductive system material. The research was conducted at MAN 1 Tangerang Selatan. The research subjects consisted of 12 students from two different classes, selected based on their daily assessment scores at the end of the human reproductive system chapter, with varying score levels: high, medium, and low, provided they had studied the human reproductive system material from the Biology Human Reproductive System E-Module.

The selection of 12 students followed purposive sampling to ensure representation across academic performance levels—high, medium, and low—so that a range of misconceptions could be explored in depth. In qualitative research, such sample sizes are considered sufficient when the goal is to gain rich, contextual understanding rather than statistical generalization (Vasileiou et al., 2018). Recent literature also supports that data saturation in qualitative studies is often achieved with samples of 10 to 15 participants (Hennink & Kaiser, 2022). To ensure ethical integrity, all participants provided informed consent, and participation was voluntary. Confidentiality and anonymity were strictly maintained to protect the identities and personal data of the students, aligning with ethical standards in educational research (Sarwar et al., 2024).

The research instruments used were the Student Worksheet for Concept Map Creation and Compilation and interviews. This worksheet contained instructions for creating concept maps, beginning with an explanation of concept maps, their characteristics, steps for creating them, as well as a reference concept map created by the researcher on the reproductive system material, which served as a model (reference) for assessing student responses and identifying misconceptions. This worksheet also presents several examples of concept maps in Biology topics and concept map creation test questions. These test questions were given to students to obtain data in the form of student misconceptions, which were then clarified through interviews.

The development of this research flow was adopted from Lina Komala Sari's (2017) research, consisting of 4 stages: concept map creation training, concept map creation test, clarification interview and analysis, and conclusion. These four research flows used in this study were packaged into three stages: planning, implementation, and conclusion. The activities conducted in the planning

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stage involved preliminary studies to obtain information that would serve as the basis for the research. Subsequently, the activities conducted in the implementation stage involved students completing the concept map creation test questions in the concept map compilation and creation worksheet, and finally, processing the data obtained from the research results. The concept maps created by the students were then interpreted, with each relationship between concepts analyzed according to each student's case. Student answers were differentiated based on the following criteria:

a. **Knowing Concept (KC) criterion**: given if concepts are connected by appropriate linking words forming propositions and/or hierarchies and/or cross-links that demonstrate meaningfulness and align with scientific community views, leading to meaningful understanding (Novak & Gowin, 2006).
b. **Misconception (M) criterion**: given if there are inappropriate propositions, missing or incorrect relationships between two or more concepts (Djanette & Fouad, 2014), missing relevant concepts (Novak & Gowin, 2006), incorrect concept usage, incorrect classifications, incorrect examples, confusion of concepts, and incorrect hierarchical relationships of concepts (Fowler & Jaoude, 1987).
c. **Not Knowing Concept (NKC) criterion**: given if the concept is not listed in the concept map (Lina, 2016) or if there are no propositions/hierarchies/cross-links accompanied by linking words (Lidyawati, 2014).

RESULTS AND DISCUSSION

The misconceptions identified from each student's concept map are summarized in Table 1. Based on Table 1, it is evident that students experienced misconceptions in eight concepts: human reproductive system, conceptual biological knowledge, human reproductive organs, gametogenesis, fertilization, pregnancy, breastfeeding, menstruation, and reproductive health.

Table 1. Total Students with Concept Understanding, Misconceptions, and No Concept Understanding

No	Concept	Knowing Concept		Misconception		Not Knowing Concept	
		Number of Students	Percentage	Number of Students	Persentase	Number of Students	Percentage
1	Human reproductive organs	3	25%	9	75%	0	0%
2	Gametogenesis	4	33%	8	67%	0	0%
3	Fertilization	1	8%	11	92%	0	0%
4	Pregnancy	11	92%	1	8%	0	0%
5	Menstruation	1	8%	9	75%	2	17%
6	Breastfeeding	10	83%	0	0%	2	17%
7	Family Planning Program	9	75%	0	0%	3	25%
8	Reproductive Health	8	67%	0	0%	4	33%
	Average	49%		40%		11%	

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From this data, it can be seen that 40% of students experienced misconceptions, 49% understood the concepts, and 11% did not understand the concepts. A more detailed explanation of the specific misconceptions will be provided in the following table.

Table 2. Student Misconceptions in Human Reproductive System Material.

No	Concept	Misconception	Number of Students
1.	Human reproductive organs	Internal male reproductive organs include the epididymis, testes, vas deferens, and ejaculatory ducts	2
		Internal reproductive organs include the epidermis, testes, vas deferens, and ejaculatory ducts	1
		Internal male reproductive organs consist of the bulbourethral gland, testes, epididymis, urethra, ejaculatory duct, vas deferens, seminal vesicles, and prostate gland	1
		Internal reproductive organs consist of the epididymis, vas deferens, seminal vesicles, prostate gland, and testes	1
		The scrotum is an internal male organ	1
		Penis, scrotum, testes, epididymis, vas deferens, and ejaculatory ducts can undergo spermatogenesis	1
		Testes are the site of spermatogenesis	7
		Internal female reproductive organs consist only of the ovaries	1
		Internal female reproductive organs consist of the ovaries, uterus, and vagina	1
		The labium contains the labium major	1
		The clitoris consists of the labium minor, because the clitoris is close to the labium minor	1
		Vulva, ovaries, uterus, and vagina can undergo oogenesis	1
2.	Gametogenesis	Testes produce spermatogenesis, because spermatogenesis is the male sex cell	1
		In humans, there are 23 pairs of chromosomes, 22 somatic chromosomes, and one sex chromosome. The female sex chromosome is called an oogonium	1
3.	Fertilization	Fertilization occurs if sperm and an ovum meet	12
		Sperm meets ovum, produces a zygote, and then fertilization occurs	1
		After fertilization, it will become a zygote and then a baby	3
		Fertilization is the initial process of pregnancy	2
		After fertilization occurs, it will cause pregnancy	12
4.	Pregnancy	During pregnancy, the ovum and sperm that meet during fertilization develop into a zygote	1
5.	Menstruation	If the ovum is not fertilized, menstruation occurs	6

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		The menstrual cycle includes the menstrual phase and the secretory phase	1
		Menstruation occurs in the external female reproductive organs, precisely in the vulva	1
6.	Breastfeeding	Hormones that influence breast milk production also influence the mother's immune system	1

As shown in Figure 1, the concept of fertilization had the highest frequency of misconceptions, experienced by 92% of students. Misunderstandings were also prevalent in the topics of menstruation and human reproductive organs.

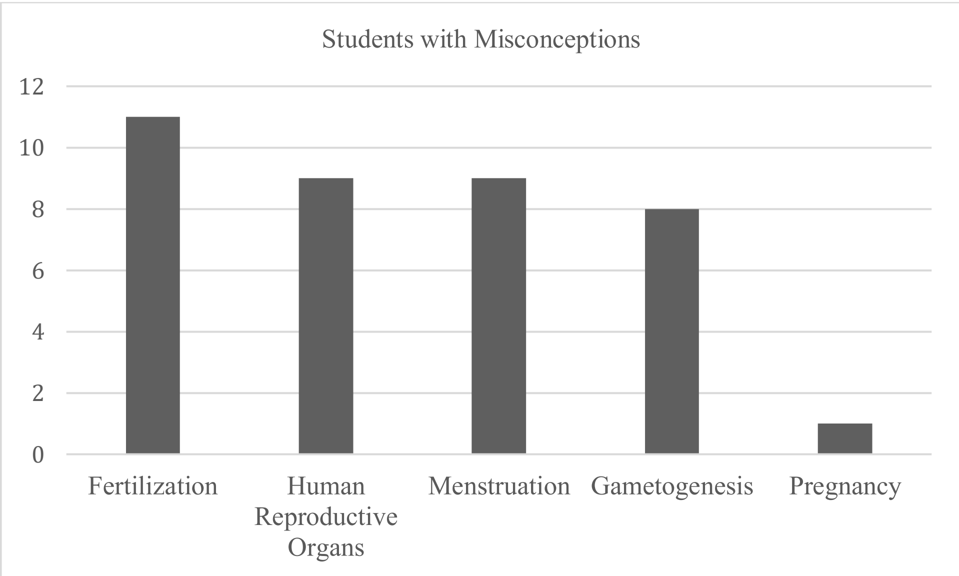

Figure 1. Number of students experiencing misconceptions in each concept of the human reproductive system.

To improve clarity and coherence, the discussion has been structured into specific subsections, each representing a conceptual domain in the human reproductive system. Misconceptions are supported by student responses and connected to relevant literature.

Misconceptions on Human Reproductive Organs

Many students misclassified internal male reproductive organs. For instance, several students listed scrotum and penis as internal organs or failed to differentiate between reproductive ducts and accessory glands. This type of error reflects conceptual confusion and incorrect classification, which aligns with Fowler & Jaoude (1987), who identified similar structural misunderstandings in biology.

Furthermore, some students inaccurately associated multiple organs (e.g., epididymis, vas deferens) as sites for spermatogenesis. Clarification interviews revealed that students misunderstood the specific location of sperm formation, which only occurs in the seminiferous tubules (Campbell, 2010). Similar misconceptions regarding the functional roles of organs were also identified in studies by Djanette & Fouad (2014).

Misconceptions in Gametogenesis

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Several students misidentified spermatogenesis and oogenesis processes. For example, student responses showed confusion between female sex cells (oogonia) and sex chromosomes. This indicates conceptual overlap and incorrect assimilation of prior knowledge, especially from cell division topics. Misconceptions in gametogenesis may also stem from recent learning experiences that are not yet conceptually integrated (Paul, 2005).

Misconceptions in Fertilization

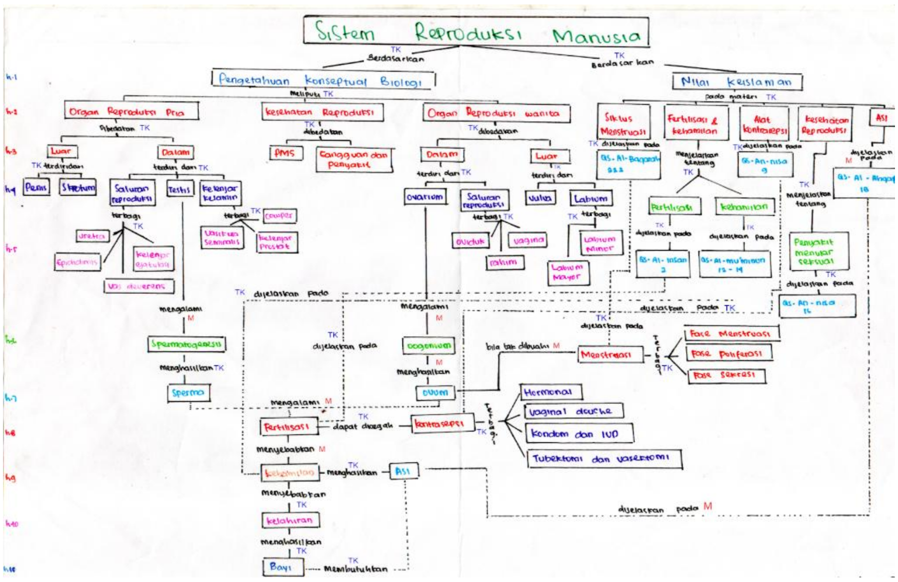

Figure 2. Sample Student Concept Map on Fertilization (Student A).
This concept map shows a common misconception where fertilization is represented as a mere meeting of sperm and ovum, with no reference to nuclear fusion or meiosis completion.

This was the most frequent misconception. Many students believed fertilization occurs simply when sperm meets the ovum, rather than understanding it as the fusion of haploid nuclei (Campbell, 2010). Similar misconceptions were reported by Djanette & Fouad (2014), indicating that misunderstanding fertilization as mere contact of gametes is a common issue. Furthermore, students assumed that fertilization directly leads to pregnancy, which is scientifically inaccurate. Pregnancy begins only after successful implantation in the uterus (Johnson, 2018).

Misconceptions in Menstruation

Misconceptions regarding menstruation were influenced by faulty logic derived from misunderstandings about fertilization. Some students believed menstruation happens due to an unfertilized ovum being discharged. In reality, menstruation occurs due to hormonal changes and the breakdown of the endometrial lining (Marieb, 2018; Campbell, 2010). Student 10's belief that menstruation occurs in external organs like the vulva suggests a lack of understanding of anatomical structures.

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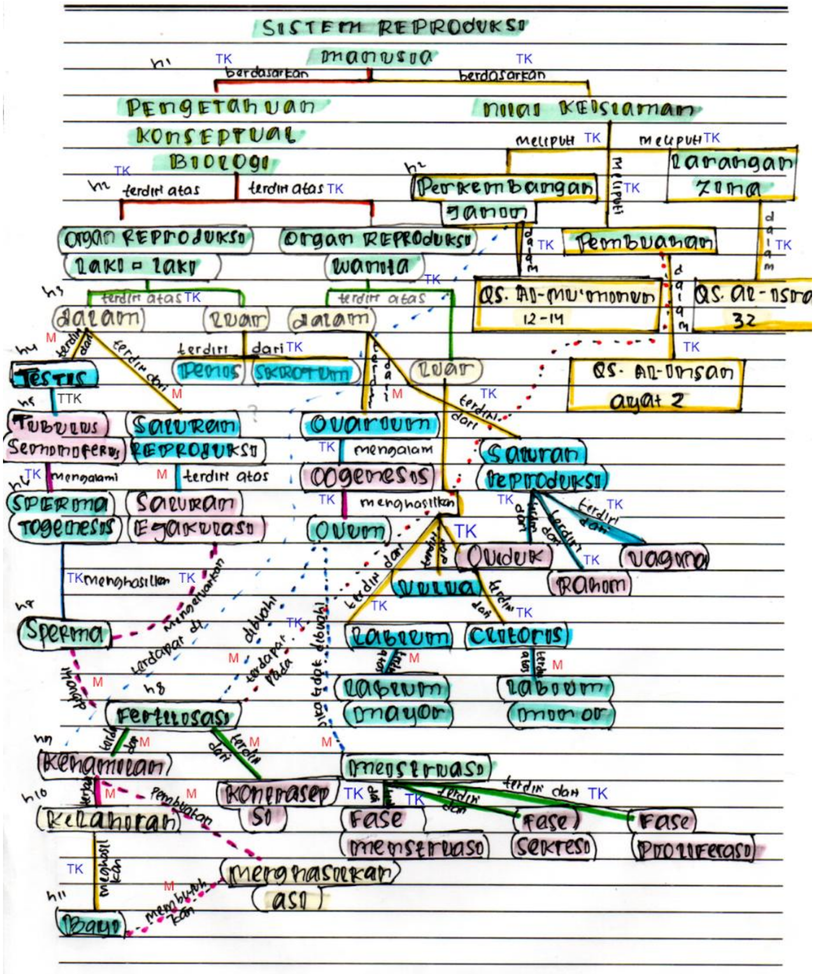

Figure 3. Sample Student Concept Map on Menstruation (Student B).
Student B incorrectly links menstruation directly to the ovum not being fertilized, and places menstruation as occurring in the vulva, showing confusion between internal and external reproductive anatomy

Misconceptions in Pregnancy and Embryo Development

Some students were confused about the sequence and location of events post-fertilization. For instance, several believed that zygote development occurs during or after pregnancy, while in fact it precedes pregnancy and begins with fertilization and ends with implantation (Johnson, 2018). This shows how a misconception in one area (fertilization) can cascade into related topics like embryo development.

Misconceptions in Breastfeeding

Student 1 believed that hormones regulating breast milk production enhance maternal immunity. This reflects a misattribution of function. While oxytocin aids postpartum recovery, it is not directly linked to immune enhancement (Boeck et al., 2018). This misconception possibly arose from unverified internet sources, highlighting how informal learning can introduce scientifically inaccurate ideas.

Overall, these results emphasize that interconnected biological concepts require a strong foundational understanding. Students' inability to distinguish between related yet distinct processes and structures often leads to chain misconceptions. These findings reinforce previous research by Novak & Gowin (2006) and underscore the value of using concept maps as diagnostic and instructional tools.

CONCLUSION

This study revealed significant misconceptions held by students regarding the human reproductive system, particularly in concepts such as fertilization, gametogenesis, and menstruation. The most prevalent misconception occurred in the concept of fertilization, where 92% of students misunderstood the process. The use of concept maps combined with clarification interviews proved effective in identifying and clarifying these misconceptions. In conclusion, the use of concept maps in biology education holds significant potential, not only as a diagnostic tool but also as a means for students to reflect on and reorganize their understanding of biological concepts. By encouraging deeper connections between ideas, concept maps can support meaningful learning and knowledge restructuring. Future research should expand on this by examining the comparative effectiveness of alternative diagnostic instruments, such as three-tier tests or digital learning modules, across various biological topics to enhance both teaching practices and student learning outcomes.

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