The Influence of Discovery Learning on Serotonin Hormones and Student Learning Achievements

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Abstract: Discovery learning is a model designed to tackle the issue of low learning achievement. However, typically, research on discovery learning mainly focuses on outcomes to enhance specific abilities partially. Yet, discovery learning is also associated with physiological aspects. This study aims to determine the discovery of learning influence on learning achievement and serotonin. This is an experimental study. The independent variable (x) is discovery learning, whereas the dependent variables (y) are student achievement and serotonin. The statistical test used the paired sample t-test. Other data related to students' learning skills in the classroom using discovery learning were observed and analyzed with the descriptive qualitative method. There were significant differences in learning achievement and serotonin levels before and after the implementation of discovery learning. The average scores before and after the implementation of discovery learning were 46.75 and 78.55, respectively. The average hormone levels before and after the implementation of discovery learning were 719.25 and 1420.59 ng/mL, respectively. The implementation of discovery learning increases serotonin levels, thus optimizing student learning achievement. Following this research finding, research on how to increase serotonin levels through other learning methods needs to be conducted to explore many best practices that affect students' achievement.

Keywords: Discovery learning, learning achievement, serotonin levels, elementary school

INTRODUCTION

Low learning achievement is a serious problem that has been widely studied by experts. To overcome this problem, a breakthrough involving various strategies has been made. The common methods used include a self-assessment approach (Yan, 2020), gamified e-quizzes (Zainuddin et al., 2020), metacognitive scaffolding (Huertas et al., 2017), problem-based and project-based learning (Özdemir, 2017), inquiry-based learning (Jerrim et al., 2022), mobile learning (Criollo-C et al., 2021), cooperative learning (Eymur & Geban, 2017), and discovery learning. Among the various methods or learning models mentioned, discovery learning stands out as an interesting model deserving further examination. Discovery learning offers a student-centered approach, allowing learners the freedom to explore their environment and interests (Alimuddin et al., 2021). It enables students to be independent and adopt a constructivist approach, integrating learning focused on 'learning how to learn' and 'learning by doing' (Ozdem-Yilmaz & Bilican, 2020). In general, learners collaborate to understand challenging concepts and retain information in the long term (Purwaningsih et al., 2020). Importantly, it promotes active, innovative, effective, and enjoyable learning, ultimately optimizing student abilities (Subagis, 2021). Discovery learning also proves effective in problem-solving and improving self-efficacy abilities (Simamora et al., 2018).

Despite appearing ideal, the discovery learning model is not without its shortcomings. Various studies have highlighted some drawbacks, including the reliance on additional tools and the need for preparation time in implementing the discovery learning model (Chusni et al., 2020). Setyaningrum et al. (2020) added that not all students can abstract or think to express relationships between concepts in discovery learning. Moreover, the model is less effective when dealing with a large number of students. Hariyanto et al. (2023) further emphasized that every learning activity is linked to students' learning styles; unfortunately, not all learning styles are suitable and adaptable to the discovery learning model. A crucial point to note is that the essence of this learning model is geared toward conditioning students to learn through their own activities and observations (Zahara et al., 2020). The discovery learning model aims to spark students' curiosity, providing them with a satisfying experience as they discover things through the process of discovery learning (Sugiarti & Husain, 2021). On the flip side, discovery learning targets intuitive thought patterns, conceptual understanding, and the ability to make intrinsic decisions (Hajian et al., 2021). From this description, it can be inferred that discovery

learning is closely intertwined with physiological mechanisms. This is because elements like intuitive thought patterns, as mentioned earlier, are facets of internal cognitive abilities involving the functioning of the central nervous system (Guy & Byrne, 2013).

Assumptions about learning models are intricately tied to physiological mechanisms, ultimately leading to the further assumption that the success of a learning model is also influenced by biological factors. Guy and Byrne (2013) elucidated that the central nervous system, peripheral nervous system, receptors, hormones, and various other components, indeed exert influence on learning activities. Numerous studies have been conducted to determine the neuroscience approach that helps in the development of several learning models. These studies are also based on glucocorticoid and oxytocin hormones which have different effects on the learning process and memory. Ideally, they determine whether the memory is damaged or increased (Wirth, 2015). Also, serotonin, commonly known as the "happy hormone," can influence the success of a learning process. This hormone is produced by the gut and helps to regulate human mood as well as sleep, appetite, digestion, learning ability, and memory (Meneses & Liy-Salmeron, 2012).

The objective of this research was to determine the influence of discovery learning on learning achievement and serotonin levels. The assumption is that effective discovery learning can simultaneously enhance learning achievement and serotonin levels. This research was conducted at an elementary school because the learning process at this level forms the foundation of future life (Gürbüztürk, 2018). Usually, the success of the subsequent stages of student learning depends on the achievement at this level. It is crucial to provide a learning approach that is in line with the student's needs and characteristics (Ozen & Topal, 2019). Therefore, schools should prepare students to effectively face the future (Coffey et al., 2015). Elementary school is the basis for the three development aspects, namely; knowledge, attitudes, and skills. These three aspects are the prerequisites of success at higher learning levels (Cassell & Symon, 2004).

The results of the research above support the policy of education through the Law of the Republic of Indonesia Number 20 of 2003 on the National Education System article 1, paragraph one. The law states that education is a conscious and planned effort to realize the atmosphere and process of learning, and therefore, students actively develop their potential for spiritual strength, self-control, personality, intelligence, noble character, and the skills needed by themselves, the society, the nation, and the state. It is also in line with UNICEF's stipulation that elementary school education is a kind of formal education. Children at this level have the right to receive good, child-friendly, and anti-bullying services. This is because trauma greatly impacts their life. Therefore, schools should develop a happy and child-friendly environment within learning and habituation.

This research provides fresh insights into the discovery learning model associated with biological aspects, specifically the happiness hormone. In general, studies on the discovery learning model typically focus on learning outcomes such as enhancing problem-solving skills (Purwaningsih et al., 2020), critical thinking skills (Indah, 2020), metacognition skills (Junina et al., 2020), and others. Additionally, some research attempts to integrate this discovery learning model with other learning models, such as game-based learning (Aldalur & Perez, 2023), problem-based learning (Mardi et al., 2021), or project-based learning (Ashfahani et al., 2020).

METHODS

This is an experimental study focusing on the implementation of discovery learning participated by students. It uses serotonin levels to trigger an improvement in student achievement. The samples were 20 third-grade students at "X" Islamic Elementary School in Indonesia who were selected based on inclusion criteria such as gender and average learning ability. The independent variable (x) is discovery learning, whereas the dependent variables (y) are student achievement and serotonin. To determine the improvement in the learning outcome, this study also used in-depth interviews with the teacher. Therefore, to reduce the bias of natural growth, a robustness check is conducted by comparing the student learning outcomes both at the beginning and at the end of this research. This study is considered as natural growth, whereas the differences are considered as an outcome contributed by the intervention of variable x. Student learning outcomes are then measured using pretest and post-test in the form of multiple choice and essay.

Serotonin levels were measured before and after the implementation of discovery learning. Data from the test results were then taken to the Tropical Disease Diagnostic Center (TDDC) for analysis. Serotonin levels were tested using the urine samples of the students before and after the implementation of discovery learning. The samples were analyzed using the Human Serotonin Enzyme-Linked Immunosorbent Assay Kit MBS494377. Each student's urine sample was collected and placed in a 50 mL urine pot and stored in a freezer at $-20°C$, whereas the serotonin hormone kit was stored at $2–8°C$. Analysis was conducted to determine the effect of discovery learning on improving learning achievement and happy hormone levels. This statistical test uses the paired sample t-test. Other data related to students' learning skills in the classroom using discovery learning were observed and analyzed with the descriptive qualitative method based on Miles et al. (2014).

Research limitations or drawbacks are covered in the research process. Researchers realize that in a study, there are many obstacles. One of the obstacles in this research is the time and place of research. Limited time adjustment and limited availability of supervisors and instructors could prolong the research duration. However, these obstacles can be overcome by the existence of good communication among the school principal, supervisors, teachers, and students who participate in this research so that the process of sampling can be carried out well.

RESULT AND DISCUSSION

From the results of the study, the test scores and serotonin levels of the students increased after the implementation of discovery learning. The results are presented in Figure 1.
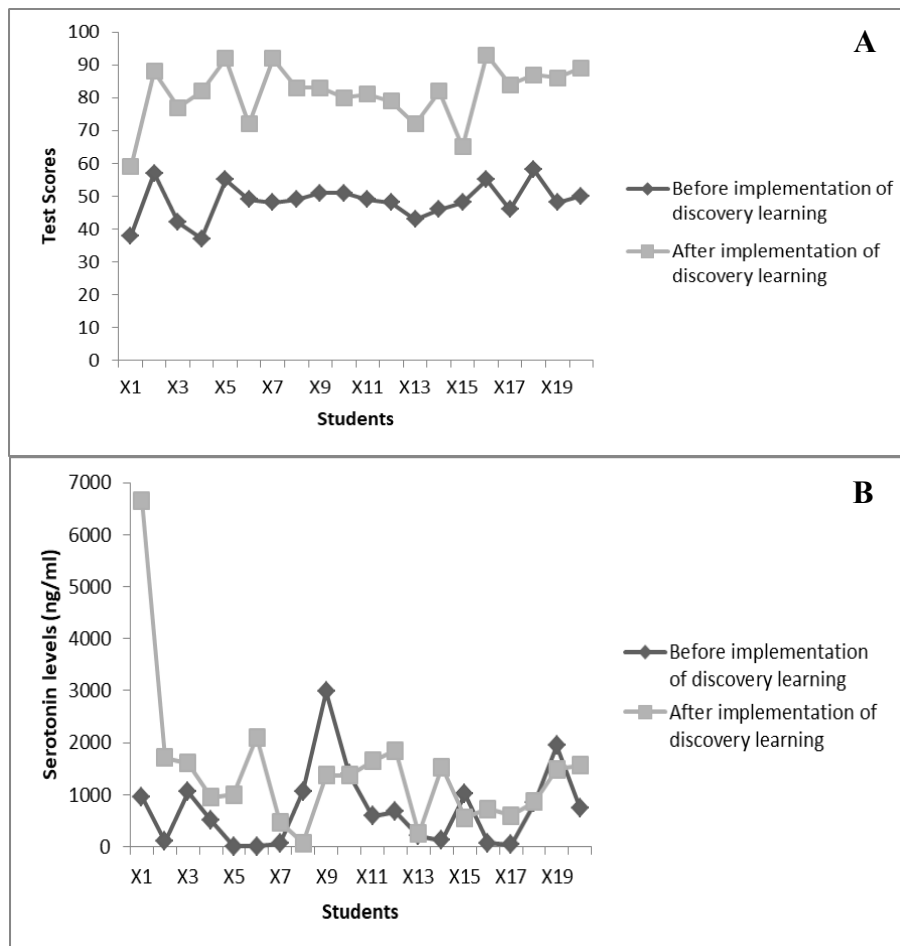

Figure 1. The test scores and serotonin levels of the students

As can be seen from Figure 1, both the test scores and hormone levels of the third-grade students after the implementation of discovery learning are higher. From the results of the statistical test using the t-test (Table 1), the student's score was P-value 0.000 < 0.005, whereas the serotonin level was P-value 0.046 < 0.05. From the results of the statistical test, P-values < 0.05 were obtained. Therefore, discovery learning affects the scores and hormone levels of the students.

Table 1. Statistical test results using the t-test

Parameter	P-*value*
Scores	0.000
Serotonin Hormone	0.046

The average serotonin levels before and after the implementation of discovery learning were 719.25 and 1420.59 ng/mL, with an increase of 1.98 times. The average student scores before and after the implementation of discovery learning were 46.75 and 78.55. Based on the average of student test scores, learning outcomes increased by 1.68 times (Table 2). This value has exceeded the KKM (Minimum Completeness

Standard) set by the school. Therefore, this study indicated that the implementation of discovery learning increases serotonin levels, thus optimizing learning outcomes.

Table 2. The average results of student scores and hormone levels before and after the implementation of discovery learning

	Before Learning	After Learning	Increase
Average of the student test scores	46.75	78.55	1.68 times
Average of serotonin levels (ng/mL)	719.25	1420.59	1.98 times

Improved student learning outcomes are indicated by the increased levels of participation during the learning process. Based on the results of in-depth interviews with the teacher, students' learning responses are very good. Most of them are actively involved in the discussion because they already have enough material to share the results based on their observations and experiments. This condition is different from learning with conventional approaches, such as the lecturing method. During learning, the teacher uses a one-way learning model that does not encourage students to be actively involved, such as discussion, project, etc. Also, students tend to have difficulty answering questions that require reasoning. This is shown by the following expression from the principal.

"*Students, especially in the third grade, are very happy when teachers place their roles as student-centered learning. Students-centered learning places teachers as facilitators and motivators then the children are often more eager to reach the inquiry stage and enthusiastic to complete the challenging assignment with the various available sources.*"

Based on the information above, the implementation of discovery learning enhances students' motivation to learn. Students are happy when the teachers design learning in a way that encourages them to be active. Discovery learning is one of the models focusing on student activities. It is widely used by researchers to determine the influence of learning success. For example, it has been used in mathematics (Yurniwati & Hanum, 2017), chemistry (Ott et al., 2018), problem-solving ability and self-efficacy (Simamora et al., 2018), English (Singaravelu, 2012), academic success (Suphi & Yaratan, 2016), science misconception (Tompo et al., 2016), writing a research proposal (Arifani, 2016), education management (Druckman & Ebner, 2018), listening and social attitude (Hanafi, 2016), and APA-style writing (Skeen & Zafonte, 2015).

Several other studies were conducted in three categories, namely, attitudes, knowledge, and skills. The attitude category includes the studies by Simamora et al. (2018) on the implementation of guided discovery in problem-solving ability and self-efficacy, by Suphi and Yaratan (2016) on discovery learning and academic success, and by Hanafi (2016) on listening and social attitude. The knowledge category includes the study by Yurnita and Hanum (2017) on mathematics; Ott et al. (2018) on chemistry; Singaravelu (2012) on English; and Tompo et al. (2016) on completing science misconceptions. Furthermore, the skill category includes the studies by Suphi and Yaratan (2016) on academic success, by Arifani (2016) on writing the research proposal, by Druckman and Ebner (2018) on educational management, by Hanafi (2016) on listening and social attitude, and by Skeen and Zafonte (2015) on APA-style writing skills.

Research-based on attitude aspects, such as those of Simamora et al. (2018), established that learning with guided discovery materials significantly improves students' problem-solving abilities in mathematics and enhances self-efficacy. Skeen and Zafonte (2015) established that discovery learning leads to success in teaching reference management.

This study examined the interventions of discovery learning that affect serotonin, which is a happy hormone, and student achievement. Research on happy hormones using discovery learning has not been widely conducted. Happiness is an important human right for every individual. Students' interactions in class or school should guarantee happiness. Although schools aim at knowledge transfer, they are also essential aspects of human life (Shrimal & Sharma, 2012). According to UNESCO, education has four pillars: learning to know, learning to do, learning to be, and learning to live together (Pigozzi, 2006).

These pillars indicate that the learning process in the class aims to impart knowledge, skills, and life goals, as well as prepare students to live together. In a classroom context, the success of the four pillars depends on their interaction. Individual behaviors, including those of teachers and students, in influencing others need attention (Kuran et al., 2017). When teachers make students happy during class, learning is comfortable and fun (Sundari, 2017). This condition stimulates their emotions in the alpha zone, which positively affects the long-term memory sensor (Iftanti & Madayani, 2019). Teachers' cheerfulness, openness, and personality determine classroom conditions and facilitate learning in the alpha zone (Khuluqiyah & Arif, 2012). The similarity of this research to the previous works lies in the aspect of student achievement. However, hormones are the

novelty of this study. Learning achievement in this research has similarities to that in previous research. The difference only involves the determination of the learning achievements of children in "X" Islamic elementary school. Their growth period is in the golden age, which is the foundation of their development (Ozen & Topal, 2019).

This study revealed that classroom interventions using discovery learning improved student achievement and increased serotonin levels by 1.68 and 1.98 times, respectively. It may have been due to the positive effect of discovery learning on the serotonin level and eventually the influence of hormones on the improvement in student achievement. So, it can be indicated that the improvement in student achievement is related to the increase in serotonin levels. It is probably related to the role of serotonin in affecting emotion and mood in the learning process, thus also affecting the learning outcome. Bradbury et al. (2014) stated that serotonin is a hormone that influences human emotions and moods. Perreau-Linck et al. (2007) established that remembering pleasant events increases serotonin production in the anterior cingulate, and vice-versa. Several studies indicated that a decrease in serotonin levels is related to negative moods (Mitchell & Phillips, 2007). A method commonly employed to temporarily lower the concentration of serotonin during circulation is acute tryptophan depletion, where tryptophan is the precursor in serotonin synthesis (Neumeister, 2003). The studies conducted by Carpenter et al. (1998) and Salomon et al. (2003) revealed that psychiatrically normal participants typically exhibit a transient worsening of mood due to the depletion of tryptophan, although this never amounts to clinical depression.

Besides affecting emotions and moods, several studies revealed that serotonin significantly influences memory and learning (Meneses & Lily-Salmeron, 2012). Generally, normal serotonin levels in the body range from 101 to 283 ng/mL. Low serotonin level causes poor memory, depressed moods, and cognitive impairment, including a decrease in verbal reasoning, episodic, and memory. Conversely, tryptophan supplementation has a positive effect on concentration and memory (Jenkins et al., 2016). Moreover, some studies stated that mood is correlated with cognitive skills. Ashby et al. (1999) argued that positive mood tends to improve word fluency due to enhanced flexibility in seeing novel ways to categorize and think about words. Bartolic et al. (1999) studied the effects of positive and negative mood inductions on a letter fluency task. The results revealed that verbal fluency was better in the positive mood group compared with the negative mood group. Therefore, serotonin plays a significant role in the learning process because it can affect mood, emotion, memory, and cognitive skills, so it is important to find the best learning methods that can improve student achievement related to the role of the hormone. Discovery learning is one of the best learning methods that make students feel comfortable and enjoy, thus creating a good and positive mood and increasing serotonin levels, so it can eventually increase student achievement.

CONCLUSION

This research indicates that the implementation of discovery learning increases serotonin levels, thus optimizing student learning achievement. There were significant differences in learning achievement and serotonin levels before and after the implementation of discovery learning. The average scores before and after the implementation of discovery learning were 46.75 and 78.55, respectively. The average hormone levels before and after the implementation of discovery learning were 719.25 and 1420.59 ng/mL, respectively. Following this research finding, research on how to increase serotonin levels through other learning methods needs to be conducted to explore many best practices that affect students' achievement.

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