RESEARCH ARTICLE

Enhancing student's conceptual understanding on the patterns of Mendelian genetics through task-based learning

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Abstract: Mendelian genetics are essential for students seeking to comprehend the complexities of inheritance; although fundamental, these biology concepts are difficult for students to understand. This study examined the effectiveness of task-based learning (TBL) in enhancing the students' conceptual understanding of the Patterns of Mendelian Genetics. A pretest and posttest quasi-experimental research design involved an experimental and a control group. An Intrinsic Motivation Inventory questionnaire was utilized to assess the level of intrinsic motivation for task evaluation for the experimental group. Paired t-test was used to compare the pretest and post-test results. Before the intervention, both groups had a low conceptual understanding of the topic. At the end of the intervention, both groups had significantly increased their performances from pretest to posttest scores. The study revealed that TBL is more effective than Traditional Lecture-Based Instruction (TLI), as seen in their enhanced student performance, implying the effectiveness of the TBL as an innovative instructional approach. Participants from the experimental group expressed enjoyment, competence, and ownership of their task activities, and they did not feel nervous and anxious about doing the tasks. Pearson r-correlation was used to establish a relationship among the variables. Perceived choice, pressure/tension, and student performance in the experimental group have low positive correlations, and perceived choice, interest/enjoyment, and performance have a negligible correlation. This approach is highly commendable for biology instruction. By illuminating the effectiveness of active learning in improving student's conceptual understanding, this study bridges the gap between theoretical-practical gap in genetics via active learning effectiveness.

Keywords: biology education; conceptual understanding; Mendelian genetics; task-based learning; traditional lecture-based instruction

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Introduction

Mendelian genetics patterns are crucial for students aiming to unravel the intricacies of inheritance. The topic delineated the patterns of inheritance for traits governed by discrete units or genes (Bamshad et al., 2019; Schacherer & Muller, 2016; Zschocke et al., 2023). While foundational, these patterns can be conceptually demanding for students due to their abstract nature. However, traditional teaching methods often need to catch up in engaging students and facilitating a deep comprehension of these patterns. To address this challenge, educators increasingly turn to innovative instructional approaches such as task-based learning, prioritizing active participation, problem-solving, and practical application in the learning process. Task-based learning, on the other hand, capitalizes on active engagement, promoting critical thinking and linking theoretical knowledge to real-world scenarios (Khoshsima & Shokri, 2016; Mäkiö & Mäkiö, 2023; Marashi & Mirghafari, 2019; Rodríguez et al., 2014). Students may better grasp Mendelian genetics patterns by incorporating innovative teaching approaches that simulate genetic crosses, phenotypic outcomes, and inheritance probabilities.
Previous research by eminent authors has acknowledged the importance of Mendelian genetics education(Awang-kanak et al., 2016; Boboňová et al., 2019; Çakir & Dogan, 2015; Hagiwara, 2017; Price et al., 2018; Westerlund & Chapman, 2017; Wilk et al., 2018). These authors have identified students'

challenges in grasping complex genetic concepts and proposed various teaching strategies. Hagiwara, (2017) and Westerlund & Chapman, (2017) emphasized the need for active learning, while Price et al., (2018) and Wilk et al., (2018) emphasized the role of hands-on activities. Awang-kanak et al., (2016) highlighted the significance of visual aids, and Çakir & Dogan, (2015) explored technology integration. On the other hand, Boboňová et al., (2019) emphasized the need for interdisciplinary approaches. While their contributions are valuable, there is still room for an in-depth examination of the effectiveness of task-based learning.

Despite the insights provided by existing literature, there remains a significant gap in our understanding of how task-based learning specifically impacts students' conceptual understanding of Mendelian genetics. There is a need for more context-specific research to understand its efficacy, particularly in diverse educational settings (Hillmayr et al., 2020; Jung et al., 2017). Moreover, previous studies often need an evaluation of long-term retention and practical application of the knowledge gained through these innovative approaches. These gaps in knowledge warrant an empirical investigation.

To bridge the identified gap in knowledge, this study plans to design and implement a task-based learning approach tailored to the specific educational context. This study will carefully assess how these approaches influence students' conceptual understanding of Mendelian genetics. This study aims to provide evidence of the effectiveness of task-based learning and identify the specific aspects of this approach that contribute to enhanced comprehension.

The expected outputs of this study include a comprehensive analysis of the impact of task-based learning on students' conceptual understanding of Mendelian genetics. The research will provide insights into the effectiveness of this innovative approach, enabling educators to make informed decisions about its integration into the curriculum. Ultimately, this research improves science education and fosters a deeper understanding of fundamental biological concepts among students.

Method

Research Design

The study employed the pretest and posttest quasi-experimental research design (Fraenkel et al., 2012) with a control group to determine the effectiveness of task-based learning approach in enhancing the conceptual understanding to the students on the patterns of Mendelian genetics. The quasi-experimental design has the rigors of true experimental designs (Rogers & Révész, 2019). This design evaluates the association between an intervention and an outcome using experiments in which the intervention is not randomly assigned (Dafouz et al., 2014; Shadish et al., 2002).

Context and Participants

Two groups of 30 randomly selected 8th-grade students from a secondary school in Cebu City, Philippines, participated in the study. These participants were selected through a simple random sampling technique using fish-bowl randomization. The demographic profiles of the participants are presented in Table 1. In the control group, most participants were female and aged fourteen. For the experimental group, most participants were male and aged thirteen.

Table 1. Demographic Profile of the Participants

Variables	Profile	Control group		Experimental Group	
		F	%	f	%
Sex	Male	13	43.33	16	53.33
	Female	17	56.67	14	46.67
Age	12 years old	6	20.00	4	13.33
	13 years old	10	33.33	13	43.33
	14 years old	12	40.00	10	33.33
	15 years old	2	6.67	3	10.00

Research Instrument

A researcher-made 30 item pretest–post-test questionnaire structured based on Bloom's Taxonomy framework was utilized. The questionnaire went through validity by the panel of experts in Biology education and reliability test of Cronbach's alpha value of 0.79. An Intrinsic Motivation Inventory (IMI) instrument was adapted from the Center for Self-Determination Theory. It was utilized to assess the level of intrinsic motivation for task evaluation for their interest/enjoyment, perceived competence, perceived choice, and pressure/tension. The 22-item questionnaire was used in previous research (Ryan, 1982; Ryan et al., 1983). The survey instrument was rated on a seven-point Likert scale ranging from *"not at all true"* to *"very true".* For the scoring procedure, the researchers begin by reverse scoring items # 2, 9, 11, 14, 19, 21. In other words, the researcher subtract the item response from 8, and use the result as the item score for that item. This way, a higher score will indicate more of the concept described in the subscale name. Thus, a higher score on pressure/tension means the person felt more pressured and tenser; a higher score on perceived competence means the person felt more competent; and so on. Then calculate subscale scores by averaging the items scores for each subscale. They are as follows. The (R) after an item number is just a reminder that the item score is the reverse of the participant's response to that item.

Procedure

In the experimental group, the teacher utilized a lesson plan using the task-based learning approach in teaching the patterns of Mendelian genetics that was taught to explore how traits are inherited through discrete units called genes, which follow predictable patterns of inheritance from one generation to the next. These patterns encompass principles such as dominance, segregation, and independent assortment, forming the foundation of the modern understanding of heredity. The teacher introduced the lesson by asking some questions about inheritance and traits and explained what happened when a trait can be passed on from generation to generation in the pre-task stage. In the while-task stage, the teacher demonstrated some concepts of explaining the basics of inheritance, dominant and recessive traits, and the Punnett square method. Then, he presented the task to students where he guided them to make a group of four members and asked them to analyze the principles of Mendelian genetics. Each member was assigned the group's role, like the planner, the information collector, the data organizer, and the presenter. A fixed group leader was not set, and each member had to serve as the leader by turns to make each group member actively involved in the task. In this stage, the teacher's role was to help learners set instructions to follow and facilitate (guide) them while doing the task by moving from one group to another to ensure guidelines are followed and give clarifications, if needed, about the decision taken by any group. Before harmonizing the work from different groups, two minutes were given to each group to present their work. Lastly, they were asked to describe the parental traits, clearly indicating which traits are dominant and recessive, predict the outcome of a cross between two parents with different traits, and determine the possible genotypes and phenotypes of the offspring. Finally, the teacher helped learners summarize what they had discussed in the post-task stage.

In the control group, the teacher utilized lectures consisting of classroom discussion and used the chalk-and-talk method, where the teacher took most of the part explaining the patterns of Mendelian genetics. The teacher imparted information, explanations, and insights through verbal communication and visual aids. Students listen, take notes, and may ask questions for clarification, but the interaction is generally limited, making it primarily a one-way flow of information from the instructor to the students.

Data Analysis

To determine whether there is a significant difference between the pretest and posttest performances, a t-test for correlated samples was used. This was employed to test the hypothesis that there is no significant difference before and after traditional lecture-based instruction and task-based learning, and no significant difference between the control and experimental group. All tests were used at a level of significance, $\alpha=0.05$. Mean and standard deviation were utilized to determine the level of intrinsic motivation in terms of task evaluation. Pearson Moment correlation was applied to determine the correlation between the experimental group performance and the intrinsic motivation in terms of task evaluation.

Ethical Considerations

A permit from the school principal was secured before the conduct of the study. Upon approval, informed consent was given to the participants with the consideration of the freedom to participate in the study. All names remained anonymous, while data obtained from the study were kept private and confidential. The pretest tool was administered to the two groups before the intervention to establish baseline knowledge. After pretesting, the two groups of 8th-grade students underwent the experimentation phase. The first group was exposed to TLI, while the other was exposed to TBL. After two weeks of experimentation, the two groups were given the posttest to measure knowledge gain. The TBI group was assigned the IMI survey to assess their level of intrinsic motivation in terms of task evaluation.

Results and Discussion

Pretest and Posttest Performance Levels of Students

The performance level in Patterns of Mendelian Genetics from Traditional Lecture-Based Instruction (TLI) and Task-Based Instruction (TBI) is presented in Table 1. It can be gleaned that both groups had low performance in the pretest, which means there have significantly lower than the standard set by the Department of Education. This low performance implies that the students had low knowledge of the topics shown in the pretest, understandably because the lesson on Ecological Interactions still needed to be introduced.

In the posttest, the TLI group performed very satisfactorily, while the TBI group had an outstanding performance. This performance was supported by Pietri, (2015) that exposure to the task-based learning approach produced highly positive results. The activities and tasks designed by the researcher attempted to assess the students in real-world scenarios (Bachelor, 2022; Bunmak, 2017). The task was designed to draw upon the students' course structure and previous experience while at the same time encouraging them to put those skills to practical use in a variety of tasks that were not necessarily familiar. The assignments were tailored to prompt students to actively engage with Mendelian genetics concepts through hands-on tasks, problem-solving activities, and collaborative projects. Students were asked to analyze Punnett squares and conduct genetic crosses. Given these assignments, students actively participate in discussions, applying theoretical concepts to real-world scenarios, seeking clarification on challenging topics, and demonstrating their understanding through written explanations, diagrams, or presentations. Task-based learning encouraged students to take ownership of their learning, fostering curiosity, critical thinking, and a deeper conceptual understanding of Mendelian genetics principles. In addition, Han, (2018) found TBL shows a tangible gain on the performance of the students. Students' Pretest and Posttest Performance Levels presented in the Table 2.

Table 2. Students' Pretest and Posttest Performance Levels

Group	Pretest Mean±SD	Posttest Mean±SD	Mean Paired Difference	t	p-value
Control	9.60±2.39	17.50±3.34	7.90	-13.177	0.00
Experimental	10.77±4.25	25.27±2.80	14.50	-23.349	0.00

$p<0.05$ Significant

Comparison of the Mean Gains in the Patterns of Mendelian Genetics between TLI and TBL Groups

As compared in Table 3, there was a highly significant difference between the mean gains of TLI and TBL. TBL was more effective in improving students' performance in teaching the patterns of Mendelian genetics than those taught using the TLI. This implies the potential benefits of employing active learning approaches like TBL in teaching biology. It suggests that TBL provided students with a more engaging and interactive learning experience, which led to a deeper understanding and retention of the topic. Additionally, TBL's collaborative nature could have fostered peer-to-peer interaction, critical thinking, and problem-solving skills among students. These results supported Azlan et al., (2019) and Musengimana et al., (2022) study that task-based learning positively impacts students' self-confidence to deliver their ideas and broader engagement in the learning process, namely focusing on speaking skills. In addition, students are scaffolding their knowledge and skills during experience task assignments (Al Kandari & Al Qattan, 2020). Thus, the goal was to shape student's foundation skills, which included basic academic skills, thinking skills, and personal quality (Loveland, 2017).

Table 3. Comparison of the Mean Gains between TLI and TBL Groups

Groups	Mean Gain	Difference Between Means	t-value	p-value
TLI	7.90	7.10	-9.53	0.00
TBL	14.50			

$p<0.05$ Significant

Level of Intrinsic Motivation in terms of Task Evaluation

The level of intrinsic motivation in terms of task evaluation with four components: interest/enjoyment, perceived choice, perceived competence, and pressure/tension, is presented in Table 2. The student motivation tends to be positive in carrying out assignments such as Punnett squares and conducting genetic crosses. Throughout the process, students encountered obstacles such as correctly identifying alleles, determining genotype combinations, and comprehending the probabilities of different genetic outcomes. These obstacles were resolved by the students with minimal guidance from the teacher.

In terms of interest/enjoyment, students perceived it as very true, implying that they enjoyed the task and found it very interesting. This suggests that this teaching method fosters a dynamic and engaging learning environment. The heightened enthusiasm among students could lead to enhanced participation, active exploration, and a deeper connection with the subject matter. Such positive experiences improve immediate learning outcomes and cultivate a lifelong love for learning and a proactive approach to education. According to Lin et al., (2017), immediate feedback on achieving the goals can increase enjoyment and make learning more interesting and challenging. Thus, understanding how students develop biology interests and the roles interest plays in biology contexts could help teachers increase students' motivation and persistence (Rowland et al., 2019).

As for the perceived competence, the students felt more competent in doing the teacher's tasks. This underscores the positive impact of effective instructional strategies on their self-confidence and skill development. This perception of increased competence may contribute to greater motivation and engagement in learning, potentially leading to improved overall academic performance. This is supported by Marshik et al., (2017), who found that students' competence is positively related to their achievement. However, educators must maintain a balanced task challenge level to ensure students' confidence is aligned with their abilities.

In terms of perceived choice, the students perceived it as very true. This implies that the teacher allows students more choice in completing tasks and empowers learners to take ownership of their activities. This autonomy over task selection could increase motivation, as students can align their choices with their interests and strengths, resulting in a more personalized and engaging learning experience. Hanewicz et al., (2017) found that when students are allowed to have more choice in completing tasks, they completed a range of assignments and activities and showed mastery of the lesson. Additionally, this approach nurtures essential skills like decision-making and critical thinking, which are valuable beyond the classroom, promoting holistic development. In terms of pressure/tension to the task, students perceived that they did not feel nervous and anxious about doing it. This suggests a potential alignment between their confidence levels and the perceived demands of the assignment. This could indicate a positive impact of adequate preparation or a conducive learning environment on their task engagement. Because this kind of atmosphere offers the best conditions for the development of knowledge, Cayubit, (2022) stressed that favorable learning environments among students result in an increase in their enthusiasm to learn. Summary of the Level of Student's Intrinsic Motivation in terms of Task Evaluation presented in Table 4.

Table 4**.** Summary of the Level of Student's Intrinsic Motivation in terms of Task Evaluation

Component	MeanSD	*Qualitative Description
Interest/Enjoyment	6.25±0.28	Very True
Perceived Competence	6.33±0.75	Very True
Perceived Choice	6.31±0.74	Very True
Pressure/Tension	1.34±0.54	Not At All True

***Legend:** *1:00-1.85 (Not At All True); 1.86-2.71 (Rarely True); 2.72-3.57 (Sometimes but Infrequently True);3.58-4.43 (Neutral); 4.44-5.29 (Sometimes True); 5.30-6.15 (Usually True); 6.16-7.00 (Very True)*

Correlation on the Student Performance using TLB and Intrinsic Motivation in terms of Task Evaluation

The four variables (i.e., interest/enjoyment, perceived competence, perceived choice, and pressure/tension) were further investigated as to their relationship with the experimental group performance through Pearson (r) moment correlation (refer to Table 4). Interest/enjoyment and student performance were negligibly correlated to each other. These two factors are mainly independent. Academic success may be influenced by factors other than personal interest/enjoyment, and it highlights the importance of considering diverse aspects of a student's learning experience when aiming to improve their performance (Milner, 2020). The findings also show that the perceived competence and performance of the students had a low positive correlation, which implies that students who feel more competent in a subject tend to have slightly better academic performance (Dafouz et al., 2014; Pekrun et al., 2017). However, the relationship is not very strong, indicating that other factors likely play a significant role in determining a student's overall performance, and self-perceived competence.

Furthermore, perceived choice and students' performance have negligible correlation, which suggests that the sense of autonomy or choice a student feels in their learning process has little to no impact on their academic performance. This implies that, in terms of academic success, the degree of control students feel over their learning experience may not be a significant factor, and other aspects of education and motivation likely play a more crucial role. Meanwhile, pressure/tension and students' performance have a low positive correlation, which suggests that there is a weak association between feeling pressured or tense and achieving better academic results. While some levels of pressure/tension might drive students to perform slightly better, the relationship is not very strong, indicating that excessive pressure or tension can also have detrimental effects on performance, highlighting the importance of a balanced and manageable level of stress for optimal academic outcomes.

The p-values, which are greater than 0.05, imply that there is not enough statistical evidence to support a significant relationship between these variables. In other words, the data does not indicate a statistically significant correlation or association between a student's performance in task-based learning and their intrinsic motivation related to task evaluation, summary presented in Table 5.

Table 5. Summary of the Level of Student's Intrinsic Motivation in terms of Task Evaluation

Intrinsic Motivation	Student Performance using TBL		
	r value	*p value**	Remarks
Interest/Enjoyment	0.00	0.99	Negligible correlation
Perceived Competence	0.33	0.86	Low positive correlation
Perceived Choice	0.05	0.79	Negligible correlation
Pressure/Tension	0.33	0.07	Low positive correlation

**Correlation at the level of 0.05 (Two-tailed)*

This suggests that any observed link between these factors may be due to random chance or other unaccounted-for variables, and it does not provide robust support for a meaningful connection between performance and intrinsic motivation in this context. The findings highlighted the need for educators to consider a multifaceted approach to enhancing academic success. The lack of a significant correlation between intrinsic motivation and performance underscores the complexity of factors affecting student achievement in task-based learning contexts. Therefore, biology educators should focus on comprehensive strategies encompassing various motivational factors beyond intrinsic motivation to support student learning and success effectively.

Conclusion

In conclusion, this quasi-experimental study illuminates the potential of task-based learning in advancing students' conceptual understanding on the patterns of Mendelian genetics. By distinguishing between the control and experimental groups, it was confirmed that task-based learning is an effective tool for enhancing student's conceptual understanding. The results consistently showcased that student engaged in task-based learning outperformed their peers in the control group, underscoring the effectiveness of active, hands-on learning approaches. Beyond genetics, this research emphasizes the broader pedagogical implications of promoting interactive, student-centered methods in science education. As educators seek to nurture profound conceptual comprehension and scientific literacy, task-based learning emerges as a promising avenue, equipping students with the knowledge and skills to tackle intricate scientific concepts and apply them effectively in real-world contexts.

Practical Implications

The research underscores the practical implications of implementing task-based learning in Mendelian genetics education. Teachers can adopt this approach to promote students' profound understanding, enhancing their problem-solving abilities and practical application of genetic principles. Task-based learning transforms genetics education, offering a dynamic, student-centered approach to improve learning outcomes and prepare students for real-world scientific challenges.

Limitation and Suggestions for Future Research

Although this research shows a promising result, several limitations need to be highlighted in this research. This includes a relatively small sample size and a short-term assessment of learning outcomes. Future research should employ larger and more diverse participant groups and extend the evaluation to long-term retention and practical application of genetic knowledge.

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Conflicts of Interest

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

Author Contributions

E. Borja: writing original draft preparation. **R. C. Mutya:** methodology, analysis, and review and editing.

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