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# The Effect of Pomodoro Technique on Student Mendelian Genetics Concept Mastery during Synchronous Remote Learning

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**Abstract**

The Pomodoro technique is a timed-based strategy used in fighting procrastination and found to increase academic performance. However, its effect on academic learning in a synchronous remote learning modality has yet to be investigated. The study used a mixed triangulation semi-experimental design using a whole sample (N=46), following all ethical equivalence procedures. The genetics concept mastery of the students was tested using a researcher-made test. ANCOVA results revealed that students taught using *Pomodoro* yielded significantly better concept mastery in genetics than the lecture method. This study contributes to the evaluation of one science teaching strategy compatible with remote learning modality.



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## 1 Introduction

Recently there have been various claims about using brain-based teaching strategies across different professional areas to increase productivity, from business-related work to the educational sector (Wang et al., 2010; Shammas, 2019). The course "Learning how to Learn" by McMaster University and the University of California defined brain-based teaching as the strategy that engages the focused, pre-frontal cortex brain area and diffused mode, the rest of the cerebrum simultaneously resulting in stronger neural connections, more meaningful learning experiences and enhanced memory storage in an educational context (Jensen, 2005; Sousa, 2016). Saleh & Mazlan (2019), found that neuro-cognitive learning stimulates the conceptual understanding and mastery of students taking a physics class. Furthermore, it was also determined to impact knowledge retention in a science course (Ozden & Gultekin, 2008). A study by Sani et al. (2019), showed that the strategy such as brain gym and mind mapping significantly increased the cognitive domain (Remembering, Understanding, and Analyzing) of the student compared to the lecture strategy; this significant difference in effect in favour of neuro-cognitive strategy has been determined by several studies (Uzezi & Jonah, 2017; Sani et al., 2019).

One notable strategy anchored with the cognitive load theory and the usage of the diffuse mode of learning is the *Pomodoro* technique (Gobbo & Vaccari, 2008). This novel technique is a time management tool that uses the concept of 25 minutes of focused, uninterrupted work on one task (Focused-mode of thinking), then 5 minutes of rest (Diffused-mode of thinking), continuing the cycle until the task is finished (Cirillo, 2007). Based on Zahariades (2015) and stipulated by Burton (2016), the efficacy of the Pomodoro Technique is due to the following principles: limits the amount of time the brain has to focus; decreases the procrastination tendencies; lessens distraction born from multitasking; forces completion of tasks (Kalyuga & Singh, 2016; Zmigro et al., 2019; Ginns & Leppink, 2019).

Pomodoro has been used by Cirillo (2007), to fight procrastination and later has been employed as a strategy, prominently by Dr. Oakley, author and associate professor in the school of engineering and computer science at the University of Oakland, and Dr. Sejnowski, Co-director and head of the computational neurobiology lab at the Salk Institute, in battling complex subjects and avoiding procrastination during independent learning of the students (Schwartz, 2017; Kuan et al., 2019; Almalki et al., 2020). However, this has yet to be fully utilized in an actual class setup, much more with a remote synchronous modality. During this pandemic, education wherein students have shifted to fully remote online learning, maximizing student learning, especially during real-time interaction, has come into the limelight (Johnson et al., 2020). That is why this research indulges in investigating this time management brain-based technique in teaching Genetics, one of the most challenging topics in Biology (Prochazk et al., 2019), and its effect on students' concept mastery against the conventional lecture method of teaching in a remote online learning modality.

This investigation provides insights into the technique that can be used in an actual classroom and a virtual remote setup. The result will provide a guide and database for policymakers on crafting policy and guidelines on utilizing neuro-strategy and promoting such activities in schools (Carey, 2000; Stockwell et al., 2015). For the teachers to be enlightened on the effects of this strategy on the students and to provide an avenue for integration in classroom teaching if found effective, this study is guided by the following research questions:

a) What is the student's mastery level in Mendelian genetics after being taught using *Pomodoro* embedded and lecture methods during remote learning?
b) Is there a significant difference in post-test scores of students between the *Pomodoro*-embedded and lecture methods in terms of student concept mastery in Mendelian genetics after controlling the effect of the pretest?
c) What are the perceived effects of the Pomodoro technique on concept mastery during the synchronous teaching of genetics in a remote-learning program for the students?

## 2 Materials and Methods

*Research design*

The study used a mixed-method triangulation design to collect quantitative and qualitative data through a quasi-experimental matching setup. Two groups were assigned to receive different treatments, the *Pomodoro*-embedded method (experimental) and the lecture method (control group) (Miller et al., 2020; Mackay & Neill, 2010). Both were pretested in their Mendelian genetics concept mastery to ensure equivalency before the experiment. After this, one week (based on DepEd Course Guide, 2016) was utilized to implement the strategies and to finish the target topic.

After that post-test was administered. Interview and focus group discussion was also done to triangulate the effect of the *Pomodoro* technique on student concept mastery (Creswell et al., 2003).

*Subjects of the study*

The study subjects were the students enrolled in the earth and life science course (N= 46). Independent sample t-test of the pretest scores assured no significant differences between lecture class (LC) in the control group (M=6.83, SD=2.39) and Pomodoro-embedded class (PEC) in the experimental group (M=7.43, SD=3.0) at 0.05 significant level, t(44)= -.762, p>.05, prior the experiment and therefore are generally equal in terms of the concept mastery in Mendelian genetics prior the start of the experimentation and are comparable (Table 1).

Table 1
Pretest Mean, SD, Independent Sample t-test

| Group | M | SD | MPS | Mastery Level | t | *p* |
|---|---|---|---|---|---|---|
| Pomodoro-embedded Class | 7.43 | 2.39 | 37.15 | Average | -.762 | .450 |
| Lecture Class | 6.83 | 3.0 | 34.15 | Low | | |

*Significant at 0.05 level of significance

*Instrumentation*

The measuring instrument on student Mendelian genetics concept mastery is a 20-item researcher-made test composed of multiple choices, a mix of recall, analysis, and problem-solving questions (Straw et al., 2021; Gyimah, 2022). The test is based upon a table of specifications, with the pre-determined length of teaching that the instructor has determined enough to teach all the chosen topics. The questions were adopted from several accredited and published books of the K-12 curriculum, including General Biology (Avissar et al., 2015), General Biology 1 (Rea et al., 2017), Conceptual Science and Beyond: General Biology 1 (Pineda & Yap, 2017) and Exploring Life Through Science Series: General Biology 1 (Morales-Ramos & Ramos, 2017).

Content validated by the learning area and learning enhancement committee was then tested on grade 11 students who were not part of the experimentation, after which the test was item analyzed, and a revision from 25 to 20 items was done after the revision and deletion of an item due to the item analysis result (Appendix). The final 20-item test was then tested for reliability using Cronbach alpha which resulted in a .900 score, translating to excellent and very high applicability for individual assessment and diagnosis (Hedden, 1997; Dela Rosa et al., 2016; Navarro et al., 2019).

The scores of the students were classified using the perspective of Department of Education (DepEd) Order No. 160, Maximizing Utilization of the National Achievement Test (NAT) (2012, pg. 1). Mastery classification bracket includes a description of absolutely no mastery, very low, low, average, moving towards mastery, closely approximating mastery, mastered (Table 2). Mean percent scores (MPS) were calculated using the actual scores of the students obtained from the twenty (20) item researcher-made test divided using the total score of the test multiplied by one hundred percent (100%) to get the MPS.

Table 2
Deped perspective of student mastery level using mean percentage score (MPS)

| Mean Percentage Score (MPS) Bracket | Description |
|---|---|
| 96 % - 100 % | Mastered |
| 86 % - 95 % | Closely Approximating Mastery |
| 66 % - 85 % | Moving towards mastery |
| 35 % - 65 % | Average |
| 16 % - 34 % | Low |
| 5 % - 15 % | Very Low |
| 0 % - 4 % | No Mastery |

*Data gathering procedures*

*Preparation*

The preparation phase included the development of the learning resources and instruments and selection samples used in the study. All resources, such as the information, grammar, and technicality of the presentation used, the type of questions, and correctness, were validated by the learning pack validation committee of the institution, composed of pedagogical, content, grammar, and formatting experts (Velásquez et al., 2022). The twenty (20) item test for the Mendelian genetics concept mastery assessment of the students was validated as well by the learning area coordinator for sciences, that are experts on the content of sciences, English grammar, and technicalities were checked by the English instructors of the assessment checking committee of the institution. Afterwards, the information technology department converted the test into Google and Microsoft forms used by the institution (Bertoncelli et al., 2016).

*Class setup procedure*

Class for the lecture method used the conventional format of classes converted into a synchronous class, in the following procedure: Routine Activities, Review, Motivation, Lecture Proper, Generalization, Application, Assessment, and Assignment. Subsequently, the Pomodoro-embedded class used the same format. The only difference was that during the lecture proper, the time was divided into three chunks: overview, punnet square, and monohybrid cross. A 5-minute brain break was implemented between these chunks, followed by a recalling activity. Several studies have claimed the advantages of in-between brain breaks in students' goal orientation, self-efficacy, and overall learning (Cirillo, 2007; Popeska et al., 2018; Kuan et al., 2019). During the brain break, students were instructed to do either of the following: Go out of their learning space, drink water, talk to someone, or listen to and watch videos or music not related to the class.

*Ethical procedure*

Permission to experiment was first secured from the parents, school administration, ethical board, and school principal. Consent forms were embedded in the electronic forms, and only students with parental approval were included in the experiment. After the experimentation, groups were re-taught with switched treatments to ensure that each class received the same teaching strategy ensuring that the experiment did not affect students' school grades. The strategy was also implemented in the sections that were not included in the experiment for the same reason.

*Methods of data analysis*

Kolmogorov-Smirnov test was done to test the type of statistical treatment to use, revealing significant normal distribution. The Control group's pretest was normally distributed, D (23) =, $p>.05$; together with the post-test, D (23) = .170, $p>.05$, are normally distributed. Subsequently, the experimental group pretest is normally distributed, D (23) =.105, $p>.05$, as well as the post-test, D (23) = .159, $p>.05$. Moreover, the test for equality of variance and equality of covariance was also tested. Levene's test showed that the pretest of groups is of equal variance, F= .154, $p>.05$, the post-test was also found to have an equal error of variance, F (1,44) =.506, $p>.05$. Additionally assumption of linearity between covariate, pretest, and the dependent variable, post-test, was also tested and found to be linear, F(1,44)= 5.669, $p<.05$.)

With all the assumptions of the parametric test fulfilled by the data acquired, the study used the following statistical treatments. Descriptive statistics such as frequency counts, mean standard deviation and mean scores were used to describe the students' mastery level. In determining the difference between the effects of the two strategies, ANCOVA was used in response to controlling pretest scores.

## 3 Results and Discussions

### *3.1 Results*

*The student's mastery level in Mendelian genetics after using Pomodoro embedded and lecture method*

After the implementation of the experiment and re-administration of the concept test, the following results were obtained. Students of the PEC were found with increased scores (Mean=16.39, SD= 1.90) and concept mastery level, 81.95% increase from the pretest score, two levels higher than the pretest score categorized as average. On the other hand, the LC students with the low concept mastery score also increased (Mean=10.21, SD=3.04), 51.05% MPS translating to average, only a one-level increase from the pretest score.

Table 3 shows the concept mastery distribution of PEC and LC after one week of implementing the varied strategy. Notably, it is only with the PEC has achieved mastered (f=2, 8%) and closely approximating mastery level (f=4,17.4%), providing that the Pomodoro technique is a better strategy in increasing student concept mastery in Genetics up to the top two most proficient mastery classification. Observable in the distribution, a high concentration of mastery (f=17, 73.9%) was categorized under moving towards mastery level, the highest mastery level of LC students (f=3, 13%) attained after instruction. This implies that the minimum and typical mastery level achievement for a Pomodoro using students is already the highest among students in a lecture class can attain. Furthermore, data suggests that students in the lecture class mainly attained an average mastery level (f=17, 73.9%), one level lower than that of the Pomodoro-embedded class. It is also observable that there are still students in the low mastery level in the lecture group, significantly not observable in the Pomodoro class. In this data analysis, evidence suggests that using the Pomodoro technique during synchronous class in a remote learning modality is better in increasing student mastery level in Mendelian Genetics than the conventional lecture approach.

Table 3
Concept mastery tabulation of post-test scores

| Student Mastery Classification | Pomodoro Class (PEC) | | Lecture Class (LC) | |
|---|---|---|---|---|
| | f | % | f | % |
| Mastered | 2 | 8.7 | 0 | 0 |
| Closely Approximating Mastery | 4 | 17.4 | 0 | 0 |
| Moving Towards Mastery | 17 | 73.9 | 3 | 13 |
| Average | 0 | 0 | 17 | 73.9 |
| Low | 0 | 0 | 3 | 13 |
| Total | 23 | 100 | 23 | 100 |

**Note that the frequency plotted is the number of students who got in the range of the mastery classification levels.*

These scores descriptively posit that Pomodoro-embedded classes can better increase concept mastery when teaching Mendelian genetics in senior high school compared to lecture classes. Moreover, the highest score obtained in the PEC was a perfect score from two students, f=2, 2% of the LC population, while in the LC, seventeen points were the highest from one student, f=1, 4.35% of the PEC population. Notably, the concentration of students' post-test scores is in the 15-point category, f=5, 21.76%, followed by 14, 16, and 17-point categories with four students, each amounting to 17.39% of the class population. On the other hand, it is observable that the lowest score in the LC group was five points, f= 2, 8.70%, while in PEC was fourteen points, f=5, 17.39%, way higher than the previous. Student score distribution is most concentrated in the nine and 12-point categories, f=4, 17.39%, five to three points, way lower than the score concentration of the PEC; this was followed by the 11-point category, with three students amounting to 13.04% of the total population.

To thoroughly investigate the difference in effects of the implemented strategies, an analysis of covariance was done for the post-test scores. While controlling for the effects of the pretest, ANCOVA revealed a statistically significant difference in the mean scores between the groups taught with a different method in favour of the PEC [$F(1,43)=72.473$, $p<.0005$, $\eta_p^2= .628$], this provides evidence that in improving student concept mastery of Mendelian genetics, the inclusion of Pomodoro technique during classes is better than lecture method. Effect size states additional evidence that the concept mastery score and subsequent level of the student are brought about by the difference in

teaching strategy while controlling for the pretest, the significant effect size exceeding 0.14 (Pituch & Steven, 2016), indicates more concrete generalizability of the varied impact of the two strategies in favour of the Pomodoro-embedded technique.

Table 4
Analysis of Covariance of Post-test scores between groups controlling for pretest

| Variables | F | p | $\eta_p^2$ |
|---|---|---|---|
| Pretest Score | 8.182 | .007 | .160 |
| Strategy | 72.473 | .000 | .628 |

*Students perceived the effects of the Pomodoro technique on concept mastery during the synchronous teaching of genetics in a remote-learning program*

The researchers interviewed selected students to determine their experience implementing the Pomodoro technique. One of the prevailing concepts among the students' responses was *"Time given to absorb information better due to the brain breaks."* According to students, the brain breaks employed every after 25 minutes of uninterrupted learning sessions helped them to remember and store information at least way better than their courses that do not use such a strategy. Moreover, it was substantiated by why students were *"not being bombarded by information"* in a single session. With the structure of a Pomodoro strategy during the online learning, students were observed to be able to rest their brains and connect with their diffused mode of learning, making each learning session not tedious but still effective, especially with the setup of class schedule that divides the total study hours into synchronous and asynchronous sessions (Johnson et al., 2020). Another noticed structure of the strategy perceived by the learners is the *"checking of learning before and after resting"* Learners have claimed that the review before each brain break helps them better remember almost all information being discussed. The review after brain breaks going into the test was claimed to provide an avenue to strengthen memorization and long-term memory storage of information through the constant usage of learned information due to constant review upon resumption of learning from the brain breaks. Moreover, students claimed to be able to train their brains to focus for a range of time and avoid distraction from multitasking; this claim is consistent with the proposition of works of literature stating the enhancement of independent uninterrupted learning (Zahariades, 2015; Burton, 2016). Moreover, the student claimed, "It is good since our minds can re-energize during the breaks allowing us more focus when we get back."

However, opposing claims by some students also emerged, such as *"I am feeling that if the breaks would be more than 5 minutes, ill lose my momentum in learning and could affect it"* since they structured the session to stop the discussion when the focus time ran out. There are some sessions in which the planned section before the focus time of the session still needs to be finished cutting the discussion in the middle. Moreover, students also negatively posit that after each brain break, they need to force themselves from getting away with what they do during breaks; this is because each brain break instructs students to do things that are not related to the learning session, such as brief talk with someone, coffee break and watching videos on social media; this, is congruent with the proposition of Dr. Oakley, and Dr. Sejnowski in the learning course that students using the Pomodoro technique exercising the usage of the focused-diffused mode of learning should be able to retract themselves from the things they do during the brain breaks to train the mind to quickly switched between focused and relaxed state without delay to make the strategy effective consistent with the positions from other studies (Cirillo, 2007; Schwartz, 2017; Almalki et al., 2020).

*3.2 Discussion*

During students' residential or distance learning caused by the pandemic, various studies claimed that students had difficulty learning due to mental stress. Though not thoroughly acquainted with academic performance, rising concern with student psychosocial and psychological well-being growing way higher during the pandemic, and the sudden shift of education, especially in the Philippines, from on-site physical learning to distance learning in its various forms has brought several factors that affect student performance in their courses (Marryat et al., 2018; Moreira de Sousa et al., 2018; Riley, 2019; Tus, 2021). Moreover, the mental stress brought by physical disengagement of students who can only communicate synchronously and decreasing motivation to attend limited online sessions were suspected to be other factors of decreased academic performance. Thus, strategies can efficiently utilize and maximize learning during limited synchronous classes while limiting cognitive overload and mental stress.

Pomodoro Technique is a strategy that conforms to the cognitive load theory. The learner's brain is only exposed to information and learning for a short time and then given a break to activate the diffused mode of thinking; this is another reason why Pomodoro adheres to the neuroscience learning of focused and diffused mode of thinking (Zahariades, 2015; Burton, 2016). Several studies have claimed that the Pomodoro technique is an efficient strategy to acquire new knowledge and fight academic procrastination and complex battle subjects, increasing retention, concept mastery, and academic performance. The usage of brain breaks between focused learning has been investigated throughout academic courses and found to be helpful in academic learning in general (Burton, 2016; Kuan et al., 2019; Sani et al., 2019). These literature are aligned claims congruent to the finding of this study, wherein students were taught using a Pomodoro-embedded strategy, by which students were taught the concept of Mendelian genetics that has been divided into learning chunks and were able to demonstrate significantly higher concept mastery than students in the lecture method as evidence by the post-test score and mean gain score comparisons.

During classes, students in Pomodoro, the class was taught for a focused time not exceeding 25 minutes, giving them concepts, information, and examples, and then were allowed to rest for 5 minutes and instructed to get away from their devices and do anything that would relax their minds, this process allows exchange between the focused-mode of thinking accessing the pre-frontal cortex of the brain responsible for direct retention and storage of information and then switching to the diffused mode of thinking that access information and incubate, connect, compare information and relating it to stored information from the rest of the brain connecting neural pathways and increasing retention (Bertoncelli et al., 2016; Popeska et al., 2018). Moreover, results also indicated that students that have been rewired to focus and switch to diffused thinking mode using the Pomodoro technique were able to fully master the concepts taught in class, as evidenced by the two students who perfected the test and three students with almost perfect score backed-up by only 13% of students who have scored 14-points out of 20 severely different in the opposite direction from the students taught using lecture method. The mastering concept in genetics is one of the most challenging subjects in biology due to its complexity and high abstractedness that student finds difficult to imagine and thus learn and retain the information; however, due to the mechanism of the Pomodoro technique based on the cognitive theory, students were able to have extra time for the brains to connect to its long-term stored memory and information allowing better storage and acquisition of information during brain breaks (Schwartz, 2017; Zmigrod et al., 2019). Cognitive load theory posits that the brain can only retain a limited capacity of seven information elements. The rest of the excess load is wasted, therefore, allowing the brain to rest after focused thinking, as in the Pomodoro method, allows the neural pathways to connect to the whole parts of the brain, cognitive processing connections that better retain and increase information storage and long-term memory that explain the difference in the test scores of the groups in this study (Kalyuga & Singh, 2016; Zmigro et al., 2019; Ginns & Leppink, 2019).

Moreover, the technique has been widely described as a practical learning practice to tackle complex subjects while decreasing focused time and reducing cognitive overloads, and this can be verified during this experiment wherein 50% of the test questions are genetic problem-solving items that are considered problematic by students and wherein students of the PEC has sufficiently demonstrated mastery of the skills in solving, recalling and analyzing, overcoming the complex topic of the course, way superior to students in the lecture class (Zahariades, 2015; Shinoda, 2020).

Reduction from distraction born from multitasking and other external distraction can also be reduced, an effective strategy, especially during remote learning where students encounter various distractions at home, such as multimedia platforms, that teachers cannot fully control; thus, practising the Pomodoro technique where students are trained to focus their mind in learning in its outmost, most efficient time range, ensuring all information will not be wasted (Zahariades, 2015; Lau, 2017; Heys, 2020). Additionally, the technique can be seen as effective in an online remote setup since, during the experimentation, students are at home and synchronously attending class; it has been observed that students can focus more as they have been instructed and are not exhausted due to the five-minute brain break every chunk scattered across the entire one-hour session, it has been described that learner that is digital natives in some debates can easily be distracted and urged to multitask but were found struggling while doing it decreasing effectiveness of learning but due to using Pomodoro technique were able to concentrate better, which student perceived as a factor for increased learning (Usman, 2020; Costales et al., 2021). Moreover, randomized individual interviews in the PEC resulted in the following supporting evidence of the technique's effectiveness. Students indicated that the five-minute brain breaks helped them process the information they encountered, increasing retention. They have also stated that brain breaks between discussions allow better information absorption than getting all concepts and ideas in one full-blown discussion.

Anchored on this is the cognitive load theory, a popularly rising instructional theory that positions itself that knowledge is primarily categorized into biologically primary knowledge that learners need to acquire and biologically

secondary knowledge for cultural reasons. Secondary knowledge is the subject of instruction and a considerable amount of effort and concentration; this is where human cognitive structure comes into play, in which an individual's limited working memory and unlimited long-term memory interact during the learning process (Sweller, 2011, 2022). While our long-term memory is unlimited and can store information is very hard to access since it requires neural pathways that are the distance between each other; working memory utilizes the neural connection of short distances and can easily be activated. However, working memory is limited, and information cannot be stored in long-term memory without being processed by the working memory. Therefore, the most practical application is that limit the instruction of secondary knowledge to students so that unnecessary cognitive load will be reduced, which the working memory can process and therefore enhances efficiency in accessing the long-term memory and storing the information; this is very much aligned with the Pomodoro technique that limits focused learning, uses working memory, and provides time for processing during brain breaks to store information in the long-term memory through varied strategies, just as the result of this study revealed (Sweller, 2022).

## 4 Conclusion

The shift in education during the pandemic and the continuous educational reforms and search for learner-centred teaching strategies, in addition to further exploration of the human grey matter related to learning, have caused teaching and learning to evolve (Rovai, 2003; Kotsiantis et al., 2010). One such novelty in education is the Pomodoro technique, which has been used to tackle complex topics, fight procrastination, and increase education productivity (Cirillo, 2007; 2013). Though found effective, its applicability and impact on academic learning have yet to be thoroughly investigated in actual class time, much more in a synchronous remote learning modality. Thus, the study investigated the technique in such a context during pandemic education. The study found in three statistical dimensions, pretest post-test within-group analysis, post-test to post-test between-group comparison and mean gain score between-group comparison that the Pomodoro technique was able to increase student concept mastery of Mendelian genetics way more than students taught using lecture, supported by literature claims of the practical positive cognitive impact of the technique to learners (Zahariades, 2015; Lau, 2017; Heys, 2020). A conclusion is that the Pomodoro technique can be used as an effective strategy in teaching abstract concepts such as genetics to senior high school students in an online, remote learning modality to increase concept mastery.

*Conflict of interest statement*
The researcher declares no competing interests during the submission of this article to this journal.

*Statement of authorship*
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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