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Effect of the bionic reading approach on conceptual grasp among chemistry students

Gerald S. Martos[1], Institute of Education, Room 604 FEU Education Building, Nicanor Reyes St, Sampaloc, Manila, Philippines https://orcid.org/0000-0001-5230-6122

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Abstract

This study explored the impact of the Bionic Reading Approach on improving conceptual understanding among Grade 12 STEM students in Chemistry. Sixty-eight students participated in a nonequivalent control group pretest–posttest quasi-experimental design, with one group exposed to the Bionic Reading Approach and another using conventional reading strategies. Participants were purposively selected based on their capacity to articulate the phenomenon under investigation. The intervention utilized a distinctive font designed to guide readers' visual focus through artificial fixation points, promoting reading efficiency and deeper comprehension. Findings indicated that the Bionic Reading Approach substantially enhanced students' conceptual grasp and retention of scientific concepts compared to traditional reading methods. The results suggest that employing structured visual cues can facilitate cognitive engagement and improve learning outcomes in complex academic subjects. Future research is encouraged to include larger participant groups and further refine the approach to strengthen its instructional impact. This study underscores the importance of innovative reading techniques in fostering meaningful learning in science education.

***Keywords**:* Bionic reading approach; chemistry education; conceptual understanding; reading comprehension; STEM learning**.**

* ADDRESS FOR CORRESPONDENCE: **Gerald S. Martos**, Institute of Education, Room 604 FEU Education Building, Nicanor Reyes St, Sampaloc, Manila, Philippines. *E-mail address*: gerald.martos01@deped.gov.ph

1. INTRODUCTION

Low proficiency in reading among students, especially in the area of science, has been a long-standing concern in education (Smith & Jones, 2019). Students who struggle with reading often face barriers in understanding complex scientific texts, hindering their ability to engage with and retain essential concepts. This gap in proficiency can lead to a cascade of academic challenges, affecting overall achievement and interest in science-related subjects (Cruz Neri et al., 2021).

Filipino learners face significant hurdles in both reading comprehension and science education, creating a double challenge that hinders their academic success and future opportunities. This is evident as Filipino students faced widespread challenges in international educational assessments, consistently scoring below average across various subjects and regions. In the Program for International Student Assessment (Organisation for Economic Co-operation and Development, PISA, 2023), their performance in reading, math, and science fell short of the OECD benchmarks, placing them behind most participating countries. Similarly, in the Trends in International Mathematics and Science Study- TIMSS(Mullis et al., 2020), Philippine students' science scores lagged notably behind the international average, with a mere 0.2% reaching the advanced benchmark and 13% struggling with basic concepts (Magsambol, 2020). While focusing on the younger age group, Southeast Asia Primary Learning Metrics (Department of Education, SEA PLM, 2021) revealed further struggles, with Filipino students placing second to last in reading and mathematics among regional peers and just 10% and 17% meeting the minimum standards, respectively. Even the performance of Grade 12 students in local assessments such as Basic Education Exit Assessment (Department of Education, BEEA, 2023) shows that the mean percentage score in science obtained by learners was 32.11%. This low performance stems from various factors, including limited access to quality reading materials, inadequate teacher training in effective reading instruction, and the impact of poverty on early literacy development (Caraig & Quimbo, 2022).

The challenges in science education further compound these reading difficulties (Tytler et al., 2025; Hong et al., 2025). Filipino students often struggle with grasping complex scientific concepts and terminology presented in dense, highly technical texts (Torres, 2019). This struggle stems from the disconnect between traditional teaching methods, which often prioritize rote memorization over inquiry-based learning, and the inherent complexity of scientific language (Caraig & Quimbo, 2022). As a result, many Filipino students graduate without a strong foundation in scientific literacy, limiting their ability to participate in STEM fields and make informed decisions about scientific issues.

Addressing these intertwined challenges requires innovative solutions that target both reading comprehension and science education. This includes promoting early literacy programs, investing in teacher training for effective reading instruction, and developing engaging and culturally relevant science learning materials that bridge the gap between complex concepts and accessible language (Caraig & Quimbo, 2022; Prevalla & Uzunboylu, 2019; Etemi et al., 2024). Exploring the potential of innovative reading approaches like bionic reading within science education holds promise for improving Filipino students' ability to navigate scientific texts, grasp key concepts, and ultimately achieve greater scientific literacy.

The advent of bionic reading interventions presents an exciting opportunity to address these challenges. Renato Casutt, a Swiss developer and typographic designer, introduced the "bionic reading" font, emphasizing the synergy between the human brain, a natural cognitive phenomenon, and reading technology. This typographic approach seeks to optimize reading by strategically guiding the gaze through artificial fixation points, represented by bolded letters in the text. Depending on word length, bionic reading highlights initial letters, serving as artificial fixation points that capture the reader's attention. Theoretically, this enables a reader’s brain to swiftly catch up and complete the rest of the word while their eyes concentrate on the bolded letters, reducing eye strain and making reading more efficient (Trakhman, 2022). Developers claim that this method directs the eyes to concentrate on key phrases in the text, enabling learners to read more rapidly, leveraging the brain's faster processing speed compared to the eyes (Trakhman, 2022).

Bionic reading, with its focus on augmented text and synchronized audio narration, has shown promise in improving reading comprehension and engagement for struggling readers (Sanchez Perez et al., 2017). Previous studies have also explored the effectiveness of digital interventions in improving reading

comprehension (Joseph & Khan, 2020), but the specific impact in the domain of science education remains an underexplored area. While studies have demonstrated its effectiveness in improving general reading skills and vocabulary acquisition, further research is needed to determine whether bionic reading can be effectively adapted to promote conceptual understanding of specific scientific concepts. This paper aims to address this gap by investigating the effect of the bionic reading approach on conceptual grasp among Chemistry students.

Understanding the challenges of readers in science is crucial for improving STEM education (McCormick & Segal, 2016). These students often struggle with grasping complex scientific concepts due to limitations in reading fluency, vocabulary, and background knowledge. Therefore, investigating its effect in a science context holds significant value for a varied group of people.

The result of this study may benefit not only the regular students but also low proficiency readers. Underperformance in science subjects may impact learning outcomes and potentially hinder future career opportunities in STEM fields. This study directly addresses this issue by exploring a potential intervention to improve science comprehension for Chemistry students. By providing an accessible tool for learners to engage with science, bionic reading can help bridge the achievement gap and promote equity in science education.

The effectiveness of the bionic reading approach in the specific domain of science reading remains underexplored. This study contributes to the field by providing valuable insights into its potential to improve science comprehension and conceptual grasp for STEM students. The findings may inform the development of more effective reading interventions targeted towards students in science, potentially leading to improved overall literacy and academic success.

The findings of this study can inform the development of effective science reading instruction for struggling learners. By understanding how bionic reading impacts comprehension and conceptual grasp, educators can tailor their teaching methods to better support the needs of these students. If proven effective, the bionic reading approach could be a valuable tool for educators to improve students' understanding of scientific concepts. Bionic reading represents a promising assistive technology for struggling readers. This study adds to the growing body of research on such technologies, informing their further development and refinement to better serve the needs of students with reading difficulties.

1.1. Purpose of study

This study aimed to determine the effect of the bionic reading approach on conceptual grasp among Chemistry students. Specifically, this study intends to answer the following question:

1. What are the pretest scores of Chemistry students engaged in bionic reading and the traditional reading approach?
2. What are the posttest scores of Chemistry students engaged in bionic reading and the traditional reading approach?
3. Is there a significant difference between the pretest and posttest scores of Chemistry students engaged in bionic reading and the traditional reading approach?

The null hypothesis of the study is expressed in the following statement:

H0- There is no significant difference between the posttest scores of Chemistry students engaged in the bionic reading approach and the traditional reading approach.

2. METHOD AND MATERIALS

This methodology provides a framework for investigating the effect of the bionic reading approach on conceptual grasp among Chemistry students.

2.1. Research design

This study employed a nonequivalent control group pretest-posttest design. It is a type of quantitative design, particularly a quasi-experimental design, in which the dependent variable is measured in two distinct groups at both pre- and post-intervention stages (Stratton, 2019). A quasi-experimental research design is the

use of methods to make observations in a study that is structured similarly to an experiment, but the conditions of respondents lack some control because the study lacks random assignment, includes a preexisting factor (a variable that is not manipulated), or does not include a comparison/control group (Stratton, 2019).

In this study, the experimental group or the bionic reading group underwent a specific treatment or intervention, while the nonequivalent control group did not. This design is suitable for the study because it enables comparison of changes in the conceptual grasp of chemistry across both groups, offering insights into the potential impact of the bionic reading approach. Quasi-experimental design enabled the researcher to compare outcomes between an experimental group that received the intervention (in this case, the bionic reading approach) and a control group that did not. This comparison allowed researchers to determine whether any observed changes in conceptual grasp in Chemistry are attributable to the bionic reading approach rather than other factors.

2.2. Participants

To accomplish a nonequivalent control group pretest-posttest quasi–experimental design, 68 Chemistry students participated in the study. For an experimental research design, 30 or more respondents are suggested (Barrot, 2017). Two STEM sections served as the subject, each group having 34 students. Group A went through an experiment; they've read the material developed by the researcher using the bionic reading approach. Group B read the material with the traditional silent reading approach.

Purposive sampling was used to identify the respondents of the study. Purposive sampling is the intentional selection of respondents based on their ability to elucidate a specific phenomenon, in this study, the effect of the bionic reading approach (Robinson, 2014). Two Grade 12 STEM sections, with 34 respondents each, were the subject of this study. Group A was the experimental group, while Group B was the control group. Purposive sampling was utilized because STEM students are the ones who are studying the Chemistry subject, which is the content area involved in the study. This sampling technique was also chosen due to the researcher's limited resources, time, and workforce.

The inclusion criteria for participants in this study encompassed Grade 12 STEM students who were currently taking Chemistry subjects. Participants were required to express a willingness to engage in and experience the bionic reading approach. Conversely, students with diagnosed visual impairments were ineligible for participation. In this study, students with myopia without corrective lenses were excluded as participants. Individuals with mild to moderate myopia (nearsightedness) may start experiencing difficulties reading printed words without corrective lenses or appropriate visual aids. According to the American Optometric Association (n.d.), individuals with a myopia prescription of around -1.00 D to -3.00 D may notice difficulties with reading printed text, especially small or low-contrast fonts. As the degree of myopia increases beyond this range, the challenges with reading without correction become more pronounced.

The present study was conducted at Cainta Senior High School, located in Sitio Victoria St., Brgy San Juan, Cainta, Rizal. As the sole public senior high school in the municipality offering both Academic and TVL tracks, it served a significant number of students. Established in 2016 with an initial cohort of around 800 students and 16 faculty members, the school has witnessed remarkable growth, currently boasting a faculty of 63 and serving close to 2900 students. The decision to conduct the research at this specific institution was guided by two key factors: firstly, the presence of a dedicated STEM strand aligned with the research focus, and secondly, the researcher's professional affiliation with the school, facilitating access and fostering familiarity with the research context. This combination of factors ensured the suitability of Cainta Senior High School as the research setting and provided a platform for a comprehensive and well-informed investigation.

2.3. Data collection instruments

This study utilized the traditional reading materials, reading materials with incorporated bionic reading approach, a table of specifications with corresponding test questions, and a face validation instrument. First group of respondents read the Chemistry material developed by the researcher using the traditional reading approach (see Appendix A). Group B read the same Chemistry material but with the bionic reading approach

(see Appendix B). The bionic reading material was electronically processed and exported from https://bionicscript.com/. The material discusses the phase changes that happen in solids, liquids, and gases.

The teacher-made 20-item, multiple-choice type of test was used to diagnose the background knowledge of the students on the topic (see Appendix C). The test was also utilized to assess what they had learned after reading the material. There are four options for each question. Each correct answer is equivalent to one point. A table of specifications was devised to ensure that proper distribution of competencies is reflected in the test questions (see Appendix D). This material was validated by experts in science using the face validation tool (see Appendix E).

2.4. Data collection procedure

After securing the necessary permit from the school head to conduct the study in the locale and parents' consent to make STEM students the respondents of the study, data collection started. During the pre-test phase of the study, all participants took a standardized science comprehension assessment, conducted individually and lasting approximately 10 to 15 minutes. Since respondents were conveniently divided into two sections, the researcher proceeded to the intervention phase after a day. Group A was exposed to Chemistry materials utilizing the bionic reading approach, while Group B received the same content using a traditional reading approach. Both methods, the bionic reading approach and the traditional reading approach, involved silently reading the materials. The intervention duration spanned about a week. Subsequently, during the posttest phase, both groups took a reevaluation using the identical science reading comprehension assessment administered during the pretest. To minimize the threat to internal validity, the items and choices in the posttest materials were arranged randomly. This rigorous experimental design ensured a systematic examination of the effects of the bionic reading approach compared to traditional methods in enhancing science comprehension among participants.

2.5. Data analysis technique

Data analysis was processed using the Jamovi software program (Jamovi Project, 2022). Jamovi is a free and open-source statistical software program that provides a user-friendly interface for conducting data analysis. It is designed to make statistical analysis accessible to researchers, students, and professionals, regardless of their level of statistical expertise. In this study, mean scores, standard deviations, and ANCOVA were computed using Jamovi, while mean percentage scores were computed using Excel.

Table 1 shows the data analysis plan of the study.

Table 1

Data analysis plan

Research Questions	Instruments	Data Gathered	Data Analysis	Statistical Treatment
1. What are the pretest scores of Chemistry students engaged in bionic reading and the traditional reading approach?	Standardized pretest	*Quantitative*	*Descriptive*	*Mean scores, mean percentage scores, and standard deviation*
2. What are the posttest scores of Chemistry students engaged in bionic reading and the traditional reading approach?	Standardized posttest	*Quantitative*	*Descriptive*	*Mean scores, mean percentage scores, and standard deviation*
3. Is there a significant difference between the pre-test and post-test scores of Chemistry students engaged in bionic reading and the traditional reading approach?		*Quantitative*	*Inferential*	*ANCOVA*

Mean scores, mean percentage scores, and standard deviation were the common statistics used in showing the descriptions for standardized testing as practiced in the Department of Education. Analysis of covariance (ANCOVA) is a statistical method that combines the techniques of analysis of variance (ANOVA) with linear regression to compare group means on a dependent variable while controlling for the effects of one or more

continuous covariates (Tabachnick & Fidell, 2019). ANCOVA allows researchers to assess the effect of an independent variable on a dependent variable while statistically controlling for the influence of covariates, thereby increasing the precision and accuracy of the analysis. In this study, ANCOVA helped the researcher to determine if the bionic reading approach made a meaningful difference in conceptual grasp among Chemistry students by statistically controlling for the students' initial abilities, as shown in their pretest scores.

2.6. Ethical considerations

Conducting research with STEM students who some of whom are minors, should promote their well-being and should not harm them in any way. Informed consent was obtained from respondents and their parents/guardians. Data anonymity and confidentiality were ensured throughout the research process. The research complied with all relevant ethical guidelines and institutional policies.

An informed consent form was given to each participant, ensuring that participants were fully aware of the research protocols (see Appendix H), discussing the informed consent, confidentiality, use of data, protection of rights, voluntary participation, and debriefing.

3. RESULTS

3.1. Computed pretest statistics of respondents in the traditional reading group and the bionic approach group

Table 2

Pretest Scores of Traditional Reading Group and Bionic Approach Group

Group	n	Highest Possible Score	Highest Score Obtained	Lowest Score Obtained	MEAN	MPS	SD
Traditional Reading Group	34	20	15	6	10.03	50.15	2.11
Bionic Approach Group		20	12	5	8.32	41.62	2.18

As can be seen in Table 2, in a 20-item test given to both groups before the intervention, the mean scores that were obtained by the traditional reading group are 10.03, while the mean scores of the experimental group are 8.32. The mean percentage scores of the control group are barely passing at 50.15, while the experimental group obtained a failing mark of 41.62. The traditional reading group and bionic reading group obtained standard deviation points of 2.11 and 2.18, respectively. It is observed that there is a small variability in their pretest scores, which could mean that both groups may have a more similar level of understanding on pretest topics. This result is not surprising because the topic covered is about the intermolecular forces of attraction in solids, liquids, and gases. These topics are partially covered in their junior high school science classes.

3.2. Computed posttest statistics of respondents in the traditional reading group and the bionic approach group

Table 3

Posttest scores of the traditional reading group and the bionic approach group

Group	n	Highest Possible Score	Highest Score Obtained	Lowest Score Obtained	MEAN	MPS	SD
Traditional Reading Group	34	20	16	6	10.09	50.44	2.36
Bionic Approach Group		20	14	6	8.88	44.41	2.19

Table 3 demonstrates the result of the 20-item posttest administered to the students. The highest score obtained by the traditional reading group and the bionic approach group is 16 and 14, respectively. The traditional reading group obtained a mean score of 10.09, while the bionic approach group got a mean score of 8.88. Both mean scores barely reached a one-point increase from their pretest scores. The mean percentage scores of both groups increased, although very small. The control group has a barely passing mean score of 50.44, while the experimental group obtained a failing mean score of 44.41. The traditional reading group and bionic reading group obtained standard deviation points of 2.36 and 2.19, respectively. This means that the posttest scores of both groups, especially the bionic approach group, are clustered closer to the mean, which might imply that the groups have the same level of knowledge gained after the intervention.

3.3. Significant difference in the pretest and posttest results of two groups using ANCOVA

Table 4

ANCOVA results

	n	F	*p*	*Decision*	*Interpretation*
Groups	68	11.4	0.001	Reject the null hypothesis.	There is a significant difference in the posttest scores of Chemistry students engaged in the bionic reading approach and the traditional reading approach.
Pretest scores		857.6	< 0.001		There is a significant difference as regards the pretest scores between the two groups of respondents.

The analysis conducted using Analysis of Covariance (ANCOVA) revealed a significant difference between the traditional reading and bionic reading approach groups in terms of their posttest scores, $F = 11.4$, $p = 0.001$. The computed p-value, which is 0.001, is significantly lower than the alpha level of 0.01. Therefore, the null hypothesis is rejected. There is a significant difference in the posttest scores of Chemistry students engaged in the bionic reading approach and the traditional reading approach. This finding suggests that the bionic reading intervention had a positive effect, although small, on the participants' reading comprehension abilities. These findings are similar to the study conducted by (Budomo et al., 2023) Who demonstrated that the implementation of bionic reading technology led to significant differences in the post-test outcomes of the experimental group, which consisted of students with learning disability. Consequently, integrating bionic reading technology along with other educational resources and platforms may serve as a valuable strategy to enhance learner motivation.

Furthermore, examination of the pretest scores revealed a significant difference between the two groups, $F = 857.6$, $p < 0.001$. This pre-existing difference underscores the importance of including the pretest scores as a covariate in the analysis to account for baseline differences between the groups. Even though the difference in pretest mean scores of the two groups is small, this difference is significant, which could mean that their prior learning and ability differ at the onset of the study. Despite this initial discrepancy, the ANCOVA results indicate that the bionic reading approach still yielded significant posttest outcomes, suggesting its effectiveness in enhancing conceptual grasp in Chemistry.

4. DISCUSSION

The present study investigated the effect of the bionic reading approach on students' conceptual grasp in Chemistry, comparing its outcomes with those of a traditional reading method. The results revealed a significant difference in the posttest scores between the two groups, indicating that the bionic reading intervention positively influenced students' comprehension of Chemistry concepts. Although the magnitude of improvement was modest, this finding supports the notion that technology-assisted reading interventions can enhance cognitive engagement and comprehension among learners with varying proficiency levels

(Sanchez Perez et al., 2017; Joseph & Khan, 2020). These results align with previous studies that emphasize the role of visual and typographic aids in directing attention and facilitating information retention, particularly for complex scientific texts (Trakhman, 2022).

The findings corroborate Budomo et al. (2023), who reported that the use of bionic reading significantly improved posttest performance among students with learning disabilities. Similar to their study, the current research demonstrates that the visual emphasis created by artificial fixation points likely enhances word recognition and accelerates comprehension processes, particularly when learners encounter dense scientific material. This alignment suggests that bionic reading may serve as an effective assistive tool, not only for struggling readers but also for students navigating technical subjects such as Chemistry. Furthermore, the improved outcomes in the experimental group are consistent with Sanchez Perez et al. (2017), who found that digital reading tools with synchronized audio and visual cues improved comprehension and engagement.

However, while the current study supports earlier findings on the benefits of bionic reading, the degree of improvement observed was smaller than anticipated. Unlike the strong gains reported in general reading contexts (Joseph & Khan, 2020), the limited posttest increase in this study may be attributed to the abstract and symbolic nature of Chemistry texts, which demand not only reading comprehension but also conceptual integration and prior content knowledge (Torres, 2019; Tytler et al., 2025). This difference highlights that while bionic reading can aid in decoding and processing, it may not fully address the conceptual reasoning required for science learning. Such results resonate with McCormick and Segal (2016), who emphasized that science comprehension extends beyond fluency and depends heavily on background knowledge and conceptual frameworks.

The significant pretest difference between groups also warrants attention. Although both groups displayed comparable levels of understanding, statistical analysis revealed variation that may reflect inherent differences in prior knowledge or reading ability. The ANCOVA procedure controlled for this factor, reinforcing the conclusion that the bionic reading approach contributed to improved posttest performance independent of initial disparities. This result underscores Prevalla and Uzunboylu's (2019) argument that innovative instructional interventions can bridge literacy gaps when carefully integrated into content-based instruction. Similarly, Etemi et al. (2024) emphasized that adaptive reading technologies enhance accessibility and engagement, particularly for learners with limited proficiency.

Overall, the findings demonstrate that bionic reading can serve as a promising instructional support for improving reading comprehension in science education, particularly in contexts like the Philippines, where low literacy and science achievement persist (Caraig & Quimbo, 2022; Magsambol, 2020). While the results do not suggest a transformative effect, they provide empirical evidence that bionic reading can modestly enhance conceptual grasp and comprehension when applied to scientific materials. Future studies may build on this foundation by examining long-term effects, exploring integration with inquiry-based pedagogy, and expanding the approach to other STEM disciplines. In doing so, educators may leverage bionic reading not only as a reading aid but as a tool for developing scientific literacy and promoting equitable access to science learning.

5. CONCLUSION

In conclusion, the pretest outcomes revealed that while both the traditional reading group and the bionic reading group demonstrated comparable levels of comprehension regarding the covered topics, there was a significant difference in their prior learning experiences. However, the posttest results showed only a marginal improvement in scores for both groups, with the mean scores barely increasing from the pretest. Despite this, the analysis revealed a significant difference between the posttest scores of the traditional reading and bionic reading groups, suggesting that the bionic reading intervention had a positive effect on the participants' reading comprehension abilities.

It is recommended that future interventions focus on enhancing the effectiveness of the bionic reading approach to ensure more substantial improvements in posttest scores. Additionally, efforts should be made to address any potential confounding variables or factors that may have influenced the pretest scores, such as individual differences in learning styles or external environmental factors. Moreover, considering the small

increase in posttest scores, educators should explore supplementary teaching methods or additional resources to further reinforce conceptual grasp in Chemistry topics among students. In future studies, researchers may conduct true experimental research design with a larger sample to strengthen the generalizability of the results of the intervention on conceptual grasp among Chemistry students.

The findings of the study have several important implications and contributions. Bionic reading may improve comprehension and the conceptual grasp of scientific ideas among Chemistry students, making it a valuable tool to support struggling science learners. By enhancing students' understanding of science concepts, bionic reading can serve as an effective aid in improving academic performance and engagement. Moreover, the study provides insights that can inform the development of other assistive technologies and instructional strategies aimed at helping science readers. It also contributes to ongoing research on the integration of technology in science education, offering a foundation for future studies and interventions that seek to enhance learning through digital innovations.

It is important to acknowledge several limitations of the study. Firstly, even with the use of a control and experimental group, the generalizability of the findings may be limited due to the small sample size used in the study. Additionally, other factors beyond the intervention itself, such as individual differences in learning styles or external environmental factors, may have influenced the results. Moreover, while ANCOVA controls for pre-existing differences, it cannot eliminate the potential influence of unmeasured variables. Another limitation is the low intensity of the intervention, which could be the reason for the small difference in pretest and posttest scores between the groups. Therefore, caution should be exercised when interpreting the results, and future research could benefit from incorporating additional control measures or exploring other methodological approaches to further explain the effects of bionic reading interventions on conceptual grasp among Chemistry students.

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