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A Causal-Comparative Analysis on the Integration of Bionic Fonts in Science Reading Materials

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Abstract: A Causal-Comparative Analysis on the Integration of Bionic Fonts in Science Reading Materials. Objectives: The study aimed to evaluate the effect of Bionic fonts on reading speed and comprehension levels among Filipino 10th grade students. **Methods**: The study involved 490 Filipino 10th graders, utilizing Mann-Whitney U-tests for quantitative analysis and thematic analysis for student attitudes towards Bionic fonts. **Findings:** The study found comparable reading speed and comprehension levels in Bionic and Traditional font groups, with most participants categorized as "Slow Readers" with "Instructional" or "Frustration" levels. The Mann-Whitney U-tests also showed no significant differences in reading speed or comprehension. **Conclusion:** The findings called into question previous claims about the consistent benefits of Bionic Fonts, highlighting the necessity of tailored font designs for optimal reading experiences, especially in scientific contexts.

Keywords: bionic fonts, bionic reading, reading speed, reading comprehension, science educational materials.

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INTRODUCTION

In the current years, Bionic Fonts have emerged as a modern-day topic of study in typography and reading comprehension. Renato Casutt, a Swiss typeface designer, inadvertently discovered a novel reading method that concerned highlighting the first sections of phrases to create artificial fixation points, giving birth to Bionic Fonts. The principle behind this new reading method was that by directing the attention's focus to particular regions of a text, the mind should correctly fill in the remaining information, potentially improving the reading experience. Ultimately, this discovery piqued the interest of both researchers and educators as it seemed to offer a novel technique to enhancing reading speed and reading comprehension.

While this new mode of reading generated international interest, it should be noted that there has been little research on Bionic fonts in the Philippines. As a result, the available literature on its empirical effectiveness in the Philippines was significantly lacking. This gap suggests a lack of research specifically examining how Bionic fonts affect reading outcomes in the unique Philippine educational context. In terms of reading

comprehension, this gap was made even more pronounced in the Philippines, where the country's reading proficiency, as evidenced by the results of the Programme for International Student Assessment (PISA) 2018 assessment conducted by the Organisation for Economic Co-operation and Development (OECD), ranked the lowest for both boys and girls among 79 participating countries and economies (OECD, 2019). These numbers highlighted the severity of the challenge the Philippines had in reading skills, critical for academic success and lifelong learning. This pressing need highlighted the importance of conducting research to determine whether Bionic Fonts, as a novel reading approach, could help overcome the nation's reading challenges and, ultimately, lead to improved reading skills for its students.

More so, the PISA 2022 results highlighted the ongoing struggles of Filipino students in Mathematics, Reading and Science, with less than a quarter achieving minimum proficiency in all three subjects. Despite the efforts of the Philippines to change its education system after PISA 2018, the latest results show no significant improvement, placing the country below the global average in all categories (OECD, 2023). These findings highlighted the critical need for interventions to improve educational outcomes, particularly in areas where the Philippines face significant challenges, such as reading.

In relation to reading-based innovative approaches, Kuster et al. (2017) investigated the effectiveness of Dyslexie font, an alternative reading approach known for using thicker lines on the bottom of the letters, to enhance reading in children with and without dyslexia. The study discovered that the Dyslexie font did not significantly benefit reading in children with or without dyslexia, and that children preferred traditional fonts over Dyslexie. This underscored the importance of subjecting such font-based approaches to empirical scrutiny, indicating that not all font modifications necessarily lead to enhanced reading outcomes.

Although studies elsewhere, such as one by Daniel Doyon in June 2022 and another in July 2022, have provided more insight into alternative reading-based approaches, these have yet to provide conclusive evidence. In the June pilot study, Doyon assessed the effectiveness of Bionic Fonts and determined a marginal development in reading speed with Bionic Fonts but fell short of demonstrating statistical significance (Doyon, 2022a). However, Doyon found no evidence to suggest that Bionic Fonts had any positive effect on reading speed and comprehension levels in the July study, which analyzed data from over 2,000 participants, with participants reading 2.6 words per minute slower with Bionic Fonts than without such reading methods (Doyon, 2022b). These differences in findings highlighted the difficulty of examining the effect of Bionic fonts on reading, where it indicated that the effectiveness of this reading approach can vary depending on different factors, and the results were not as straightforward as expected. Such differences emphasized the need for further studies to provide evidence on the effect of Bionic fonts on both reading speed and reading comprehension.

Given the conflicting findings of the previous researches revealed, this study aimed to fill a gap in the literature and assess the potential of Bionic fonts in improving reading speed, reading comprehension, and student attitudes in the Philippine educational landscape. Specifically, this study aimed to answer the following questions:

RQ1: What is the level of reading speed and reading comprehension among students exposed to Science reading materials presented in Bionic font compared to those in Traditional font?

RQ2: Is there a significant difference in the reading speed and reading comprehension

among students exposed to Science reading materials presented in Bionic compared to Traditional font?

RQ3: What are the students' experiences when exposed to Science reading materials presented in Bionic Font?

RQ4: Based on the findings, what recommendations can be made regarding the integration of Bionic font in Science reading materials?

Overall, the study sought to determine whether the findings were consistent with previous studies and whether Bionic Fonts provided viable solutions for improving the reading skills of Filipino students. Embedded in a causal-comparative approach, this study had the potential to provide valuable suggestions for students and teachers in the Philippines by shedding light on whether these innovative font approaches can offer practical solutions for enhancing the reading skills of Filipino students. In the end, the researchers' commitment to contributing to the understanding of innovative reading approaches and offering insights that may benefit the educational landscape in the Philippines was reflected in this research.

METHODS

Participants

This study was carried out in Toledo City, Philippines, specifically at a public high school under the Department of Education - Toledo City Division, which is known for having the division's second-highest enrollment population. To streamline participant selection, the researchers employed a stratified random sampling method, where a population of approximately 800 Grade 10 Filipino students was divided into a single stratum comprising students aged 15-16 years old. From this stratum, a total of 490 participants were randomly distributed into two distinct groups, Group A (experimental group) and Group B (control group), each consisting of 245 students. Group A had access to science reading materials thoughtfully integrated with Bionic Fonts, while Group B engaged with identical science reading materials in the traditional font format. This random assignment within the stratum ensures an unbiased distribution, enabling a rigorous examination of the effectiveness of Bionic Fonts on reading speed and comprehension within the specific age range of 15-16.

Research Design and Procedures

To investigate the effect of Bionic Fonts on students' reading performance and perceptions, this study used a causal-comparative research design that combined quantitative and qualitative research methodologies. The study aimed for a comprehensive understanding through the combined use of both methods, quantitative and qualitative, drawing inspiration from the approach outlined by Yu and Khazanchi (2017).

The quantitative dimension entailed a meticulous evaluation of reading speed and comprehension in two distinct groups, Group A (experimental group) and Group B (control group). This evaluation included a reading comprehension test aligned with the science curriculum relevant to the participants' grade levels. Specifically, Group A received science reading materials integrated with Bionic Font, while Group B used the same reading material in Traditional Font, ensuring identical content for fair comparison. To eliminate reading biases, participants were given a timer to measure reading speed, followed by a 10-item multiple-choice comprehension test.

For efficient quantitative data collection, the research team used ZipGrade, printing answer sheets for participants to shade responses and allowed the participants to indicate the time it took them to finish reading. With the data gathered, quantitative analysis was used to identify significant performance differences, following the framework of Johnson et al. (2017).

Simultaneously, the qualitative component explored the attitudes and experiences within the experimental group via open-ended survey questionnaires. After qualitative data was gathered, thematic analysis was then used, following Braun and Clarke's (2006) framework.

This dual-method approach, combining quantitative and qualitative research methodologies, enabled a thorough examination of both measurable outcomes and nuanced participant perspectives, contributing to a thorough examination of the research questions.
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Instrument

The research instrument, a test instrument, comprised a modified science reading material sourced from the OECD's PISA Assessments, focusing on scientific concepts. Bionic Fonts, emphasizing initial letters for artificial fixation points, were integrated into the material for the experimental group, while the control group received the same material without Bionic Fonts. Comprehension assessments utilized questions aligned with the reading material, combining OECD items with researcher-made questions, totaling 10 items. To gauge students' comprehension skills, the researchers employed the Revised Bloom's Taxonomy, utilizing words as indicators for both Lower Order Thinking Skills (LOTS) and Higher Order Thinking Skills (HOTS).

Questions which encourage LOTS are those with interrogatives such as *when, where, which, how many* and *who*, while interrogatives which develop HOTS include *why, how* and *fill-in-the-blank questions*. In essence, questions 1, 2, 7, 8, 9, and 10 primarily focus on Lower Order Thinking Skills (LOTS), while questions 3, 4, 5, and 6 engage Higher Order Thinking Skills (HOTS).

The modified science reading material and comprehension assessment were subjected to pilot testing with 20 students from a different school, followed by reliability testing, resulting in a Cronbach's alpha of 0.71. These instruments also underwent further validation by three experts, all of whom were esteemed professors in the field of science education.

Alongside the comprehension assessment, open-ended survey questions were also utilized to gauge participant experiences and attitudes toward Bionic Fonts. The first question seeks opinions on the readability and impact of bolding certain parts of words. The second question delves into whether the use of Bionic Fonts influenced reading habits and comprehension positively or negatively. The third question addresses specific challenges encountered while reading with these fonts. The fourth question probes beliefs regarding the potential for Bionic Fonts to enhance reading outcomes like speed and comprehension. Lastly, the fifth question solicits suggestions for improving Bionic Fonts specifically for scientific reading based on personal experiences and insights.Top of Form Each questions included 10 indicators, resulting in a total of 50 indicators.

Finally, to enhance the validity and reliability of the open-ended survey questions, content validation was conducted by expert validators. These validators, who each possess a Master's Degree and a minimum of ten years of teaching experience, demonstrated expertise in qualitative research, ensuring their capability to offer pertinent insights into conducting qualitative research effectively. That being said, the three professors who validated the modified science reading material and comprehension assessment were also qualified and participated in validating the questionnaire.

Data Analysis

Quantitative Analysis

In the quantitative analysis process, the researchers applied The Philippine Informal Reading Inventory (Phil-IRI) 2018 guidelines to comprehensively evaluate reading speed and comprehension levels among Grade 10 students.

Reading speed was calculated by dividing the number of words read by the reading time in seconds, then multiplying by 60 to determine words per minute. Similarly, reading comprehension was assessed by calculating the percentage of correct answers to the total questions. To establish reading speed criteria, the study adopted the Silent Reading Test Criteria for Grade 6 students, categorizing readers as "Fast Readers" (190 words per minute and above), "Average Readers" (161-189 words per minute), and "Slow Readers" (160 words per minute and below). Additionally, predefined criteria for reading comprehension levels were applied, classifying scores as "Independent" (80-100%), "Instructional" (59-79%), and "Frustration" (58% and below) based on Phil-IRI criteria.

Tests of Normality

Prior to analyzing the reading speed and reading comprehension of students exposed in both Bionic Font and Traditional Font, normality tests were conducted to assess the distribution characteristics of the data. Results indicated a departure from normal distribution characteristics in both groups. For reading speed in Group A, the Kolmogorov-Smirnov test yielded $p=0.072$, and the Shapiro-Wilk test showed a significant $p=0.002$, signifying non-normality, while Group B exhibited a more pronounced departure with $p<0.001$ for both tests. Skewness and kurtosis values further supported non-normality in both groups for the reading speed data. Similarly, reading comprehension data in both groups showed significant departures from normality, with $p<0.001$ for both tests, indicating that the skewness and kurtosis values suggested a non-normal distribution pattern

Qualitative Analysis

Thematic analysis was used in the qualitative data analysis process, following Braun and Clarke's (2006) framework, to systematically extract qualitative insights from open-ended survey questionnaires administered to participants. The content was familiarized through repeated readings to allow for a more nuanced understanding of students' experiences and attitudes toward the incorporation of Bionic Fonts in Science reading materials. To capture key features, initial codes were generated, and these codes were then organized into overarching themes during subsequent stages of analysis. The end result was a detailed narrative that depicted patterns and variations in students' perceptions and was supported by relevant quotes. Ultimately, the purpose of this thematic analysis was to provide a rich and nuanced exploration of participants' subjective experiences, revealing the complexities of their responses to Bionic Fonts in Science reading materials.

■ RESULTS AND DISCUSSION

The Reading Speed and Comprehension Levels of Grade 10 Students

The reading speed levels of Grade 10 students were examined in two font groups: Group A (Bionic Font) and Group B (Traditional Font). In both groups, the distribution revealed a majority of "Slow Readers," with 84% in Bionic Font and 85% in Traditional Font. Traditional Fonts showed a slightly higher percentage of "Fast Readers" (5% vs. 4%), while both groups had an equal percentage of "Average Readers" (10%). Despite a more complete dataset for Traditional Fonts, the overall distribution of reading speed levels was comparable, emphasizing the prevalent need for improvement in reading speed among Grade 10 students. Regarding reading comprehension, marginal differences were observed between font types. In the Bionic Font group, 14% were "Independent" readers, 33% "Instructional," and 53% faced "Frustration." The Traditional Font group showed 13%, 29%, and 58% in the respective categories, with slightly

higher frustration levels. The choice of font type had limited effects on comprehension levels, highlighting the predominant need for instructional support. The data for these analyses can be found in Table 2

Based on the findings, the analyzed data portrayed similar distributions in reading speed levels between Grade 10 students exposed to Bionic Font and Traditional Font. Both groups primarily consisted of "Slow Readers," with 84%

Table 2. The reading speed and comprehension levels of grade 10 students

		Level	Frequency	Percentage
Reading Speed	**Group A** (Bionic)	Fast Readers	9	4%
		Average Readers	26	10%
		Slow Readers	206	84%
		Unspecified	4	2%
	Group B (Traditional)	Fast Readers	9	5%
		Average Readers	26	10%
		Slow Readers	206	85%
		Unspecified	0	0%
Reading Comprehension	**Group A** (Bionic)	Independent	34	14%
		Instructional	82	33%
		Frustration	129	53%
	Group B (Traditional)	Independent	32	13%
		Instructional	72	29%
		Frustration	141	58%

for Bionic Font and 85% for Traditional Font. While Traditional Fonts showed a slightly higher percentage of fast readers (5% compared to 4% for Bionic Font), both groups had an equal percentage of average readers (10%). Overall, the majority of Grade 10 students in both groups exhibited slow reading speed, highlighting a predominant need for improvement in reading speed.

As for reading comprehension, the analyzed data indicated comparable patterns between the two font groups. In the Bionic Font group, 14% of students were identified as independent readers, 33% as instructional, and 53% as experiencing frustration. In the Traditional Font group, 13% were independent readers, 29% instructional, and 58% experienced frustration, with slightly higher frustration levels than the Bionic Font group. Drawing out from these, the choice of font type had a limited effect on the distribution of reading comprehension levels, as both groups demonstrated a predominant need for instructional support, with the majority of the students being identified as either "Instructional" or "Frustration."

These findings, derived from the analysis of Grade 10 students' reading speed and comprehension levels in the Philippines, showcased parallels with the challenges highlighted in the Programme for International Student Assessment (PISA) 2018 and 2022 results, which continued to underscore the struggle of Filipino students in essential subjects like Reading and Science. Despite slight variations in the percentages of fast and average readers between font types, the overarching need for improved reading speed among Grade 10 students remained consistent. Additionally, the prevalence of instructional and frustration levels in the current study aligned with the broader challenges faced by the Philippines in improving reading proficiency.

Hence, the urgency of addressing these challenges, especially in reading and science, was paramount considering its foundational role in academic success and lifelong learning. The alignment between the current study's findings and the PISA assessments emphasized the critical need for effective interventions to bolster reading skills among Filipino students, potentially exploring innovative approaches like Bionic Fonts to contribute to overcoming the country's persistent reading challenges.

Table 3. Comparison of reading speed and comprehension between bionic and traditional font

		N	Mean Rank*	U	Z	Significance
Reading Speed*	**Group A** (Bionic)	241	244.23	29346.50	-0.114	0.909
	Group B (Traditional)	245	242.78			
Reading Comprehension	**Group A** (Bionic)	245	249.31	29079.00	-0.602	0.547
	Group B (Traditional)	245	241.69			

Note: *Mean Rank difference is significant at the 0.05 level

The findings from the Mann-Whitney U tests revealed no significant differences in reading speed or comprehension between students exposed to Bionic Fonts compared to Traditional Fonts. The statistical analysis demonstrated that individuals exhibited similar reading speeds (U= 29346.500, z= -0.114, p= 0.909) and comparable comprehension levels (U= 29346.500, z= -0.114, p= 0.909) regardless of font type.

These outcomes suggested that the choice between Bionic and Traditional Fonts did not yield discernible effects on reading speed or comprehension levels among the participants in this study.

However, these conclusions were set against contrasting findings. Doyon's comprehensive study (Doyon, 2022b) challenged the perceived advantages of Bionic Fonts, showing no significant differences in reading speed or comprehension. This study, involving over 2,000 participants, contradicted his earlier assertions of Bionic Fonts enhancing reading speed and comprehension (Doyon, 2022a). These contrary outcomes cast doubt on the generalizability of previous findings regarding the efficacy of Bionic Fonts and emphasized the necessity of exploring diverse reader populations and circumstances to ascertain the applicability of these fonts.

With the current study's findings, coupled with the contrasting results of Doyon (2022a & 2022b), it challenged Renato Casutt's claim of consistent benefits from Bionic Fonts, stating that Bionic Fonts assist readers, especially with attention issues, by emphasizing fixation points in bold aimed to guide the eye and aid in quicker word recall. These divergent outcomes underscored the need for further research and investigations to delineate the circumstances under which Bionic Fonts may or may not significantly affect reading outcomes, particularly across diverse reader demographics.

Therefore, while this study found no significant differences, it was crucial to exercise caution when extending these conclusions to broader contexts. The potential limitations within the study design, such as sample size, specific

reading material, or duration of exposure to fonts, could influence the observed outcomes. Additionally, variations in participant characteristics, including diverse reading abilities, cognitive differences, or familiarity with specific font styles, might impact how individuals interacted with and responded to different font types. Thus, although these findings provided valuable insights, further research with more diverse participants and settings will be necessary to validate and articulate these results together beyond the scope of this research.

Students' Reading Experiences on Bionic Fonts

In this comprehensive exploration of students' experiences with reading material and Bionic Fonts, a thematic analysis was conducted to discern the diverse perspectives on the effect of this innovative font. Findings reveal a spectrum of opinions, with a majority acknowledging Bionic Fonts for their positive contributions to readability and learning engagement. Table 4 below presented the overview of students' experiences reading material and Bionic Fonts:

Table 4. Themes and formulated meanings of students' experiences on the reading material and bionic fonts

Themes	Formulated Meanings	Frequency	Sources
Readability Enhancement	Bionic Fonts enhance readability for easier and smoother reading.	52	P2. P4. P7. P8. P9. P10. P11. P13. P18. P19. P22. P24. P26. P28. P29. P30. P31. P32. P33. P34. P35. P38. P39. P42. P43. P44. P46. P49. P53. P57. P58. P60. P62. P64. P65. P69. P76. P78. P81. P82. P90. P92. P93. P94. P95. P98. P99. P101. P102. P104. P106. P107
	Bionic Fonts boost reading speed, enabling rapid identification and understanding of vital information.	27	P6. P26. P29. P30. P31. P32. P33. P34. P36. P41. P47. P48. P62. P65. P70. P74. P75. P76. P77. P78. P79. P92. P98. P100. P103. P104. P105
	Bionic Fonts help in maintaining focus while reading, directing attention to crucial aspects of the material being read.	27	P1. P6. P8. P11. P17. P18. P20. P26. P31. P36. P42. P43. P46. P47. P56. P64. P69. P70. P71. P73. P74. P78. P82. P97. P100. P103. P107
Aid Comprehension	Bionic Fonts add interest, making the text more enjoyable and potentially boosting reader engagement.	15	P6. P24. P25. P26. P27. P28. P35. P36. P63. P67. P81. P99. P101. P102. P107
	Bionic Fonts contribute to an improved learning experience, boosting confidence in reading.	7	P15. P75. P76. P91. P94. P95. P105

Learning Experience Improvement	Bionic Fonts serve as cues for importance, helping readers easily identify and comprehend important content.	19	P2. P7. P8. P9. P12. P14. P27. P32. P42. P44. P46. P49. P50. P51. P54. P75. P86. P90. P107
	Bionic fonts contribute to better retention and recall of information.	15	P7. P8. P14. P34. P35. P37. P48. P54. P55. P67. P82. P91. P96. P99. P104
Cognitive Challenge	Bionic Fonts contribute to confusion during reading.	19	P5. P11. P16. P18. P21. P45. P58. P59. P69. P70. P72. P80. P83. P84. P88. P89. P104. P105. P107
	Bionic Fonts disrupt the reading experience, introducing distractions that may hinder overall engagement.	10	P23. P37. P56. P58. P66. P81. P85. P102. P104. P105
Visual and Physical Strain	Bionic Fonts may cause visual discomfort, such us dizziness, affecting overall reading comfort.	5	P16. P21. P52. P86. P87
	Bionic Fonts may pose difficulties for individuals with poor eyesight.	2	P80. P85
Ambiguity of Experience	Bionic Fonts have no clear positive or negative effect on reading; their effect on the reading experience is not distinctly observable.	3	P26. P87. P108

Readability Enhancement

Based on student responses, there is a unanimous agreement regarding the enhanced readability facilitated by Bionic Fonts. Participants consistently expressed that these fonts contribute to smoother and more accessible reading experiences, resulting in improved comprehension. This sentiment is encapsulated in participants' remarks:

"The Bionic Fonts enhance the readability and comprehension of the reader. This helps the readers remember those important information." (P8).

"I think it (Bionic Fonts) is good and useful because it is readable, and we can comprehend what we are reading." (P29)

"Using bold for certain word parts (Bionic Fonts) is nice because it makes reading easier and enhances understanding." (P92)

Moreover, students emphasized that Bionic Fonts positively impact reading speed, facilitating rapid identification and understanding of crucial information. This view is supported by participants' statements:

"I believe yes, it changes your reading speed and comprehension." (P26)"Yes,

because it is easier to read and it helps your reading speed." (P29). "Yes, it enhances or helps your reading speed and comprehension." (P30).

The positive effect on maintaining focus while reading was also highlighted, directing attention to critical aspects of the material, as evident in remarks such as:

"*I think it's a great idea to use Bionic Fonts as it helps the reader to focus on the texts that they are reading." (P17). "In my opinion, I can focus on reading because the fonts (Bionic Fonts) are enhancing readability." (P43) "I believe that using Bionic Fonts improved my understanding and focus." (P97)*

This widespread agreement highlights Bionic Fonts' potential to improve overall readability and comprehension of reading materials. These positive perceptions are consistent with the findings of Beier and Oderkerk (2019), who discovered that fonts with certain characteristics, such as thicker strokes and heavier weights, improve readability. As a result, the visual characteristics of Bionic Fonts were perceived as helpful in facilitating a simple and accessible reading experience, emphasizing the importance of visual characteristics in effective communication and learning.

Aid Comprehension

Various alternative conceptions about the use of Bionic Fonts to aid comprehension were identified based on student responses. A recurring theme is that fonts add interest to the text, making it more enjoyable and possibly increasing reader engagement. Students expressed their opinions in the following ways:

"For me, it's alright and it is much more interesting." (P25). "Yes, it's interesting to read and it gives off a different vibe when reading." (P27). "In my experience, reading a phrase or sentence in a Bionic Font is much easier and enjoyable." (P102)

These findings highlight the potential benefits of Bionic Fonts in aiding comprehension and suggest that they may play a role in improving students' overall learning experience. These narratives corresponded to Doyon's (2022a) research, which suggested that with Bionic Fonts, readers could process scientific material more quickly while maintaining a deep understanding of the subject matter. These preliminary findings, together with the aligned responses from Group A, laid the groundwork for future research into the role Bionic Fonts may play in improving the efficiency and efficacy of reading practices.

Learning Experience Improvement

Based on responses from student participants, there are notable perceptions regarding the impact of bionic fonts on the learning experience. Commonly reported is the idea that bionic fonts serve as cues for importance, aiding readers in easily identifying and comprehending crucial content. Participants mentioned:

"The Bionic Fonts helped me understand what I read and it make me remember some parts because of the bolded parts." (P48). "Yes, it helps to remember certain words and ideas by using the bolding certain words (Bionic Fonts)." (P55). "I personally think that reading with the use of (...) Bionic Fonts is quite helpful because it highlights the word that helps us optimize our reading experience." (P75)

These positive receptions aligned with the findings of Kuster et al. (2017), suggesting a potential avenue for incorporating Bionic Fonts, or font customization, to improve accessibility and engagement in educational materials, particularly in the context of science-related content. The alignment of the current study's findings with the font customization study of Kuster et al. (2017) emphasized the importance of tailoring reading materials to individual preferences, contributing to an improved reading experience.

Cognitive Challenge

Based on the analysis of student responses, there is a notable cognitive challenge associated with the use of Bionic Fonts. Participants expressed instances of confusion during reading, with some reporting disruptions to the overall reading experience. This nuanced perspective on the fonts' usability had resonated with the concept of extraneous cognitive load in Cognitive Load Theory, suggesting that these distracting elements could have imposed additional cognitive load, potentially hindering the reading experience. Participant responses included:

"Yes, it (Bionic Fonts) kinda hinders my understanding because it distracts me, though." (P37). "The Bionic Fonts did affect how I read. (...) It was more of an annoying experience for me. (...) Bionic Fonts is not for everyone." (P84). "Yes, it truly does help me read better, although certain words are quite difficult to read since they are so near to one another." (P102)

Moreover, several respondents also pointed out an initial period of confusion or difficulty in adapting to Bionic Fonts for reading, implying a potential learning curve associated with these fonts. This recognition aligned with John Sweller's notion of intrinsic cognitive load when dealing with new information. The subsequent responses documented that initial confusion:

"(...) I was confused why some of the letters are bold, but as time passed, I got used to it and it helped me focus on the important parts." (P18). "Yes, it hinders my understanding because when I read, I got confused." (P21). "There were only a few that I understood even though it is confusing." (P83)

These responses and nuanced perspectives on Bionic Fonts' usability aligned with the principles of Cognitive Load Theory, underscoring the importance of carefully considering design features to manage cognitive load effectively and optimize the learning experience.

Visual and Physical Strain

A minority of participants in the conducted study reported negative effects associated with Bionic Fonts, aligning with findings from Bernard et al. (2013). These negative effects included instances of visual discomfort, as illustrated through the following:

"It affected how I read and it did not quite help for me." (P23). "Yes, for me, (...) the Bionic Fonts are a bit painful on the eyes." (P52). "(..) For me, it poses an inconvenience since I find half of the words blurry. I think it is much better if all words are bolded for it to not look unpleasant." (P86)

These responses underscored the need to consider potential drawbacks, particularly regarding user comfort and perceived utility, when implementing Bionic Fonts in educational materials. This aligned with Bernard et al.'s (2013) emphasis on carefully evaluating font characteristics, including boldness, to ensure a positive reading experience. The alignment between the negative effects observed in both studies emphasized the need for careful customization of fonts to optimize readability and user experience in various contexts (Bernard et al., 2013).

Ambiguity of Experience

Lastly, a sub-theme emerged as participants expressed ambiguity of experience, emphasizing the minimal effect of Bionic Fonts on the reading experience or overall perception of the material. The following comments highlighted a lack of strong positive or negative sentiments:

"I don't mind the font used in any reading material I read." (P26) "It (Bionic Fonts) was okay." (P87) "No it did not affect how I read; it's just basically a word." (P108)

These sentiments indicated that, for some individuals, Bionic Fonts did not significantly alter their reading experience or overall perception of educational materials. This aligned with the concept of user variability and personal

preferences, reinforcing the idea that the effectiveness of Bionic Fonts could vary among individuals. As Gencoglu et al. (2021) revealed in their findings, variance in student perceptions existed within a class and between countries, emphasizing the influence of individual factors on these perceptions. Just as factors influenced student perceptions, the ambiguity of experiences on Bionic Fonts underscored the need for flexibility in educational material design to accommodate user preferences.

Students' Recommendations on Bionic Fonts

Table 5 below presented the themes and formulated meanings of student recommendations for enhancing Bionic Fonts in Science Reading Materials. It offered valuable insights into the multifaceted nature of participants' experiences and preferences with Bionic Fonts in science reading materials. The findings in this table offered a nuanced understanding of students' perspectives, contributing valuable information for enhancing the effectiveness and user experience of Bionic Fonts in the realm of science education.

Format and Emphasis Enhancement

In the analysis of responses to the question concerning difficulties or confusion with Bionic Fonts, a notable theme emerged, indicating technical suggestions for improvement. Various

Table 5. Themes and formulated meanings of students' recommendation on the reading material and bionic fonts

Themes	Formulated Meanings	Frequency	Sources
Format and Emphasis Enhancement	Bionic Fonts enhance visibility and readability through bold letters, aligning visual elements for an improved reading experience.	18	P21. P24. P25. P28. P35. P38. P39. P52. P54. P55. P56. P58. P67. P74. P75. P76. P95. P98
	Bionic Fonts, with strategic formatting like bolding and color, enhance reading by emphasizing key words, aiding comprehension and focus.	14	P3. P4. P5. P6. P7. P8. P9. P10. P32. P33. P34. P42. P45. P49
	Bionic Fonts use selective highlighting for effective information conveyance, emphasizing essential details and ensuring a targeted reading experience without overemphasis on all information.	3	P79. P100. P107
	Bionic Fonts enhance readability with adjustments in letter size, font size, and clarity, creating a more accessible and user-friendly reading experience for better content understanding.	2	P41. P91
	Bionic Fonts enhance comprehension and engagement by encouraging a strategic reading approach, emphasizing bolded parts for readers to prioritize key information.	2	P70. P78
Educational Integration and Application	Bionic Fonts, versatile across subjects beyond science, expand accessibility and promote effective learning in diverse disciplines.	10	P29. P30. P36. P53. P72. P73. P81. P82. P90. P99

participants provided insights into enhancing Bionic Fonts by suggesting technical adjustments, specifically advocating for the use of bolder letters. Noteworthy recommendations from participants included:

"Maybe change the color of certain parts and not just bolding them." (P35). "I think the color should be black and the important parts should be in bold" (P52). "Yes, I suggest not only bold one to two words but rather the whole sentence." (P75)

Consistent with the findings of Palmén et al. (2023), who investigated the effect of font quality and readability, the participants in the present study reflected a similar concern for font aesthetics. The suggestions made by the participants echoed the considerations outlined in Palmén et al.'s (2023) research, emphasizing the significance of color contrast between text and background in relation to reading speed. The recommendations also included changes in color, highlighting the importance of font aesthetics and the potential influence of color choices on user preferences (Palmén et al., 2023).

As such, this recommendation also aligns with the suggestions on the study of Picardal (2019), where teachers should value the voice of students by recognizing alternative conceptions and elicitation of prior knowledge. Teachers, in response to students' flawed and inadequate conceptions, should utilize various strategies, including visual representations and adjustments to accommodate students' learning styles (Picardal, 2019).

Educational Integration and Application

In the present study, a notable theme was identified, aligning with the suggestions made by Picardal and Paño (2018), and Picardal and Sanchez (2022). This theme centered on the educational integration and application of Bionic Fonts across various subjects. Multiple participants acknowledged the potential advantages of applying Bionic Fonts beyond the realm of science. They proposed that these fonts could prove beneficial in diverse academic contexts, as indicated by these responses:

"I think Bionic Fonts is better to use in informational texts, surveys, etc." (P36) "My suggestion (...) is to apply it to other subjects, not only in science." (P73) "Based on my experiences, science teachers should incorporate Bionic Fonts into their science reading materials to make the content easier for students to read." (P99)

This aligns with the findings from a meta-analysis conducted by Picardal and Paño (2018), where the use of contextualization approach; such as the integration of Bionic Fonts, in science instruction was instrumental for students' conceptual understanding. The positive impact on learning and performance was underscored in their study, suggesting that such pedagogical approaches are crucial for creating meaningful educational experiences (Picardal & Paño, 2018).

Moreover, additional support for this perspective comes from a more recent meta-analysis by Picardal and Sanchez (2022), which demonstrated that contextualized instruction; such as the integration of Bionic Fonts, has contributed to improving science learning. As such, educators and instructional designers had to exercise caution when considering the adoption of Bionic Fonts in educational settings, especially in subjects like science, where precision and comprehension were paramount.

■ CONCLUSIONS

Therefore, the study addressed primary research questions by revealing no significant differences in reading speed and comprehension levels among Grade 10 students exposed to Bionic Fonts compared to Traditional Fonts. Despite slow reading speeds in both font groups, the findings underscored the urgent need for interventions to enhance overall reading skills in

key subjects such as Reading and Science among Filipino students. Contrary to previous assertions, research has challenged claims of consistent benefits from bionic fonts, advocating for a nuanced understanding of the conditions that influence their impact on reading outcomes across a variety of reader demographics.

As for the thematic analysis of student responses, the findings highlighted the potential of Bionic Fonts to enhance readability and aid comprehension. However, the findings emphasized the importance of addressing potential cognitive challenges and considering individual preferences and comfort. Educators were advised to approach the integration of Bionic Fonts with a nuanced understanding of potential benefits and challenges, ensuring that these fonts contribute positively to the learning experience for a diverse range of learners.

In light of this findings, the study formulated recommendations for the integration of Bionic Fonts in Science reading materials, emphasizing the need for specification of participants, multiple pilot trials, individualized testing methods, alternative mechanisms for measuring reading speed, and in-depth discussions or interviews for nuanced insights. The study also advocated for extending the assessment of Bionic Fonts to other academic subjects, using recommended methodologies to fortify the rigor of future investigations.

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