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Article

The role of biomechanics in English vocabulary acquisition: An empirical research of enhancing learning efficiency and student engagement

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Abstract: Vocabulary acquisition is a fundamental aspect of language learning, and mastery of vocabulary has a substantial impact on learners' capacity to comprehend and communicate successfully in a foreign language. The research's goal is to investigate how biological perception affects students' engagement and the effectiveness of their learning of English vocabulary. A total of 286 various academic students participated in this research. The experimental group (EG) (biological perception-assisted learning) and the control group (CG) (standard vocabulary acquisition techniques) are selected at random from among these students. This research uses the SPSS software version 29.0. The data analyze the statistical methods, including descriptive statistics, paired *t*-test, and ANOVA, to identify any significant differences between the groups. The research assesses the influence of biological perception on vocabulary retention, learning speed, and general engagement of students in the language learning process through an empirical research including a diverse group of students. The results indicate that, when compared to traditional approaches, students exposed to the EG exhibit significantly greater understanding rates (87%), higher levels of engagement (92%), and enhanced learning efficiency (95%), demonstrating the favorable influence of adding biological sensing into language learning procedures. In contrast, the CG, which employed conventional VA techniques, demonstrated only modest improvements across the board, with a learning speed of 85%, understanding rates of 79%, and engagement levels of 81%. This research provides educators looking to improve vocabulary training with useful insights into the possibilities of biological perception-based tactics for language learning enhancement.

Keywords: biological perception; English vocabulary; learning efficiency; students' engagement; statistical analysis

1. Introduction

English is becoming a universal language used by individuals from many linguistic and cultural backgrounds, especially due to the enormous advancements in technology. Both casual and classroom settings are used to teach them the majority of their English. Due to English's dominance in global media and entertainment, people can directly access an extensive variety of English-language music, movies, TV shows, social media, and news [1]. English is essential to human life because it facilitates communication between individuals from different nations. English has a vital role in human existence and is an international language. English is also utilized as a second language for communication in several nations. English is a foreign language in many nations. A language that is not commonly spoken in the community daily is referred to as a foreign language [2]. English has been utilized by many people to assist their life goals as it has become a global language for communication. Furthermore, as English is used all over the world for communication, knowing the

language is crucial for anybody who wants to compete in this globalized world. Acquiring knowledge of vocabulary is essential to learning English [3].

To communicate effectively, someone who speaks a foreign language, like English, has to be familiar with its vocabulary. While learning a new language, learning vocabulary is very important. The absence of vocabulary can make it difficult for the students to express their productivity and understanding [4]. In the process of learning English, vocabulary is essential. English vocabulary is difficult to learn, particularly for vocational high school students. They also possess unique qualities that set them apart from the adults. By focusing on these many traits, it is possible to conclude that the task of motivating vocational learners is challenging for teachers [5]. Children who get English education typically learn four fundamental skills: speaking, listening, writing, and reading. According to speaking abilities, most students first struggle to communicate in English due to a lack of vocabulary. Additionally, learning vocabulary is crucial for reading [6]. **Figure 1** illustrates the four fundamental skills in English education.

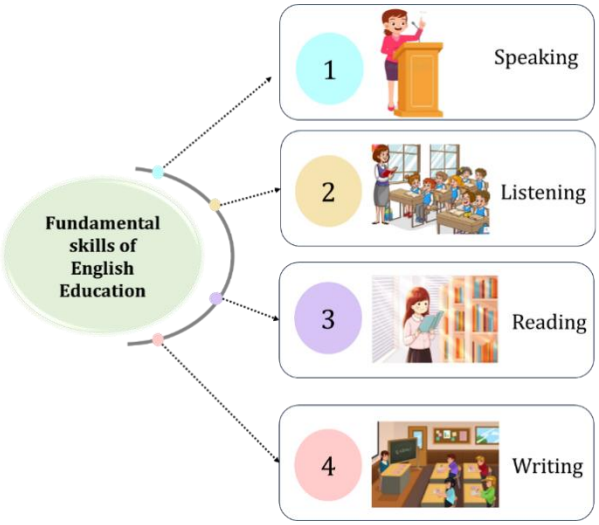


Figure 1. Four fundamental skills in English education.

Vocabulary acquisition (VA) is a continuous procedure that is vital to learning any foreign language. It is customary to define vocabulary as the group of terms that are used in a certain language. The characteristics of the words themselves are linked to the challenges of learning new words [7]. Even though learning vocabulary is important, students typically have slight opportunities to customize the language outside of the classroom because, in many countries, English is learned as a foreign language [8]. By supporting more physical activities with linguistic tasks, students experience improved maintenance and inventiveness in English writing and improved cognitive engagement [9]. Also, the students can optimize performance foster critical thinking, and prepare students for careers in sports science, rehabilitation, and ergonomics [10]. The ability to understand and speak effectively in a foreign language is significantly impacted by vocabulary knowledge, which is a key factor in language learning. This research aims to find out how perception impacts students' engagement and VA in English.

Contribution of the research

- The research offers an innovative approach for language teachers by showing that biological perception-based learning dramatically increases vocabulary retention and learning speed when compared to conventional approaches.
- By employing strong statistical tools, the research offers verified proof of the efficiency of biological perception-assisted methods, adding to the body of knowledge underlying creative teaching approaches.
- By examining degrees of engagement, the research sheds data on how biological perception promotes active participation and provides suggestions for raising student interest in language learning.

The organization of the research involves the following structures: Section 2 contains the related works and Section 3 involves the materials and methods utilized in the research. Section 4 entails the results of the research and Section 5 depicts the discussion. The research was concluded by Section 6.

2. Related work

The impact of integrating virtual reality (VR) technology into Pre-Bilingual Learning (PBL) settings on students' problem-solving skills, motivation, and VA when learning English as a foreign language (EFL) was examined by Chen et al. [11]. Eighty-four engineering majors were split into two groups randomly as Control Group (CG) and the Experimental Group (EG). The CG received a PBL without VR technology, whereas the EG developed VR films to answer problems in a VR-assisted PBL scenario. While there was no discernible difference in the EG's performance in the problem-solving. Therefore, the EG performed substantially better than the CG in the language learning and motivation. Considering both receptive and productive vocabulary knowledge, Bueno-Alastuey and Nemeth [12] examined and contrasted the properties of Quizlet flashcards and student-produced podcasts on vocabulary retention". The research included 23 participants between the ages of 18 and 61. Vocabulary tests were used as both immediate pre-tests to assess the student's previous knowledge and post-tests to assess receptive and productive VA. A questionnaire was also employed to find out how the students felt about the two approaches. The findings demonstrated that there was no discernible difference between the two approaches.

The usage of social media for English language learning (ELL) among college students, especially those from Generation Z, was investigated by Pikhart and Botezat [13]. The research focused on how social media affects L2 acquisition psycho-linguistically. In addition to outlining the benefits and disadvantages of social media use for L2 acquisition, it made recommendations for future ELL teaching methods in higher education. Positive findings were obtained from the research; however, further psycholinguistic research was required. In a 7-week mixed methods experiment with students, Divekar et al. [14] introduced the Cognitive Immersive Language Learning Environment (CILLE) and assessed it as a Chinese-as-a-foreign-language (CFL) teaching tool". Without the use of intrusive technology, Extended Reality (XR) offered students the sense that they were somewhere else and enabled multi-modal and multi-

party interactions. The findings show a statistically significant and sustained increase in CFL conversational skills, vocabulary, and understanding.

In a counterbalanced experiment, Gay et al. [15] gathered adult EFL volunteers to assess the possible effects of "AI KAKU" on the writing of students". In contrast to conventional word processors, preliminary findings suggest that this could be a helpful tool for English language learners who need more organized support. The effect of learning flexibility on the academic engagement of 17,341 Chinese middle school students was examined by Wang et al. [16]. Learning flexibility was demonstrated to have a favorable impact on academic engagement in English. Furthermore, this association was mediated by distinct functions for English learning self-efficacy and anxiety related to foreign languages. The results implied that these elements were essential to the academic success of Chinese school students in English.

The influence of self-regulated learning (SRL) and Artificial intelligence (AI) image recognition technologies on students' learning anxiety, self-regulation, and VA in language classrooms was investigated by Hsu et al. [17]. 47 students in the third grade participated. In contrast to the CG, which learned vocabulary from the printed texts utilizing the AI-assisted optical character recognition (AI-OCR) with SRL, the EG employed AI-supported image recognition (AI-IR) with SRL to learn vocabulary from realia. While there were no discernible changes in self-regulation or learning concerns, the EG group fared noticeably better than the CG in language acquisition. The three stages of Cantonese language learning, such as silence, early output, and ongoing development, were investigated by Zhang [18]. The research found factors that affect learner engagement and argued that combining these factors with second language (L2) learning objectives, exercises, and context might help students learn the language more effectively. The research also emphasized how crucial contextual and individual factors were in determining learner engagement.

According to the theory of multiliteracy and technology usage, Zhang et al. [19] investigated how multimodal writing affected the VA of EFL learners". They selected 70 students; 35 of them were placed in the EG and another 35 in the CG. At the end of the seven-week trial, the EG showed gains in vocabulary learning, particularly in word usage. A VR technique based on experience learning was used by Li et al. [20] to teach English for Geography. The hydrologic cycle was the focus of a vocabulary-building activity for thirty-six geography students. The results showed that accidental language acquisition along with cognitive, behavioral, and social engagement were better in the EG than in the CG. The impression of AR technology, its effect on vocabulary growth, and its effect on student motivation were all examined by Belda-Medina and Marrahi-Gomez [21]. 130 students who were aged from 14 to 15 from two secondary schools participated and they were split into an EG and CG. 30 geographic words in English were taught to both groups over four weeks. The findings indicated favorable sentiments and enthusiasm for integrating Augmented Reality (AR) into language instruction and there are no discernible variations seen in VA.

Among 707 Chinese university students, Guo et al. [22] examined the connection between learner engagement (LE) and foreign language enjoyment (FLE)". Twenty-eight individuals completed a semi-structured interview and questionnaire. The findings indicated a reciprocal causal link and a very strong positive association between LE and FLE. There was no discernible relationship between LE or FLE and

absenteeism, but both showed weak relationships with academic performance. Lower absenteeism was linked to a higher FLE-social score. The FLE and LE levels did not vary by gender. The application of the ASR (automatic speech recognition) method in the flipped English vocabulary learning environment was examined by Jiang et al. [23]. The research lasted 14 weeks and involved two groups of college students: a CG and an EG. ASR-assisted oral tasks were given to the EG as a pre-class self-learning exercise. The triadic complexity-accuracy-fluency (CAF) paradigm was used to analyze the data. According to the outcomes, the EG significantly improved with time and outperformed the CG in terms of vocabulary complication and speed fluency.

A quasi-experimental methodology was employed by Wang et al. [24] to investigate the potential of AR in biology education. 81 third graders in all were recruited for the research. 40 students in the EG received AR instruction, whereas 41 students in the CG received conventional instruction. According to the research, students' flow experience and motivation to learn were greatly enhanced by AR training, which also reduced their cognitive burden. The impact of a 45-min English as a foreign language (IWB) class versus a comparable 45-min lesson without the IWB in promoting motivation and learning among eighth-grade German students was examined by Kühl and Wohninsland [25]. The outcomes displayed that the students in the IWB condition were more motivated and scored higher on vocabulary tests, but that there was a negative relationship between vocabulary test scores and foreign language classroom anxiety (FLCA). Examining how Quizlet is used as a teaching tool to expand students' vocabulary evaluated by Avisteva and Halimi [26]. It also aimed to ascertain the pupils' opinions on Quizlet's word-learning capabilities. In this investigation, a design called one-group quasi-experimental was employed. Data collection methods included field notes, tests, and questionnaires. The consequences show that after the therapy, the children's learning of both receptive and productive vocabulary has increased.

3. Materials and methodology

This section outlines the methodology employed to examine the influence of biological perception on vocabulary learning. It includes the research design, selection process, instruments, and statistical analysis techniques.

3.1. Research design

A randomized control trial (RCT) design was utilized in the research to evaluate how biological perception-assisted learning affected student learning efficiency, engagement, and VA in English. A total of 286 academic students from diverse academic backgrounds were selected to participate in this research. To reduce any biases in participant selection and ensure a wide representation across a variety of academic levels and fields, random sampling was used to choose these people. As indicated by **Figure 2**, the students were split into two groups at random, such as EG and CG.

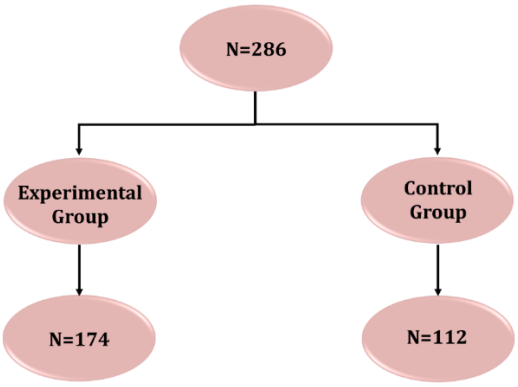


Figure 2. Overview of the groups.

3.2. Selection process

The 286 participants were selected using a random sampling method from a wide range of students and separated into two different groups such as EG and CG based on a questionnaire of 3 parameters of nine questions to evaluate the effectiveness. The following steps indicate how the groups are separated.

- EG: This group included 174 students who were taught biological perception-assisted learning methodologies. These students used strategies that combined visual, sensory, and cognitive stimuli to help them learn words through biological perceptual processes. These strategies were designed to help students develop a stronger connection with the language by harnessing their innate cognitive and perceptual capabilities.
- CG: The remaining 112 students were assigned to the CG and used typical vocabulary learning methods. These tactics included traditional procedures such as rote memory, repetition, and the use of typical instructional materials such as textbooks, flashcards, and internet resources. The CG served as a baseline for comparing the efficacy of biological perception-assisted learning to traditional techniques.

3.3. Student's learning efficiency

Active learning and student-centered learning are acknowledged as benefits of the flipped classroom concept. In some situations, active learning is one of the tactics utilized to meet the demands of the students and guarantee that the instructional design supports critical thinking. While there isn't much of a difference between students' participation in active and passive learning activities, online learning materials, including assignments, discussion boards, and websites that support students' social presence, might be leveraged to engage students. The flipped classroom is a teaching strategy to maximize opportunities for interaction between students and teachers, as well as shift the learning materials that are presented by teachers directly to the pre-class period. To enhance the learning effects, teachers would therefore have more time to direct the learning activities and address students' issues. Although no assurance using a flipped classroom method would result in favorable outcomes, proponents of flipped learning contend. The crucial component is the teachers' preparation. For example, allowing students to research outside of the classroom, providing video clips as supplemental materials, and encouraging students to solve problems are some

strategies that some teachers have previously implemented to flip the classroom. Flipped learning requires additional conditions to be fulfilled, though. In simpler terms, flipped learning refers to a more rigorous and advanced notion of the "flipped classroom."

3.4. Instruments

Using a mixed method, this research assesses the influence of biological perception-assisted English VA on student engagement and learning efficiency by integrating qualitative and quantitative data. Participants' open-ended comments and feedback, obtained through self-assessment questionnaires, make up the qualitative component. To evaluate student engagement and instructional efficacy, the quantitative component uses structured questionnaires. The self-assessment questionnaire records participants' opinions on a range of topics, including engagement, learning effectiveness, and classroom confidence, using a standardized Likert scale (1 to 5). For example, students rate the effectiveness of the biological perception-assisted method (1 = not effective to 5 = very effective), their level of concern about VA (1 = not concerned to 5 = very concerned), and the extent to which external support (such as biological perception methods) influenced their learning. Furthermore, participants assess their confidence in using VA tactics on a scale of 1 (very low) to 5 (very high). **Table 1** illustrates the evaluation of students' learning and engagement used in this research to gather data on these key factors.

Table 1. Questionnaire for evaluating students' engagement.

Category	Questions	Likert Scale Scores
Understanding Rates	1. How well does the person understand the English vocabulary learned through biological perception methods?	1 (Not Well) to 5 (Very Well)
	2. How effectively does the person recall and apply the vocabulary you have learned in your daily communication?	
	3. How much does the person feel that biological perception has helped you grasp the meaning of new vocabulary words?	
Engagement Levels	4. How engaged does the person feel during the vocabulary learning process using biological perception-assisted methods?	1 (Not Engaged) to 5 (Very Engaged)
	5. How actively does the person participate in the learning activities and tasks during vocabulary lessons?	
	6. How motivated does the student feel to continue learning English vocabulary through biological perception?	
Learning Efficiency	7. How quickly does the person can learn and retain new vocabulary compared to traditional methods?	1 (Very Slowly) to 5 (Very Quickly)
	8. How efficient does the student think their learning process is when using biological perception-assisted vocabulary techniques?	
	9. How much does the student believe the biological perception approach has improved their overall learning efficiency?	

3.5. Statistical analysis

This research uses the SPSS software version 29.0. The data analyze the statistical methods such as paired *t*-test, descriptive statistics, and ANOVA (Analysis

of Variance) to classify any substantial differences between the groups. The performance patterns in vocabulary retention and learning effectiveness for both the EG and CG are summarized by descriptive statistics. By comparing post-test and pre-test results with each group, the paired *t*-test evaluates the progress made in vocabulary learning. The EG, which used biological perception-assisted approaches, and the CG, which used conventional methods, showed significant differences in learning efficiency and engagement, according to an ANOVA.

4. Result

The evaluation of the English VA was performed using statistical analysis such as ANOVA, Paired *t*-test, and descriptive statistics.

4.1. Demographic characteristics

Demographic characteristics are personal characteristics and background data of the research participants, which help in defining and classifying the sample population. Gender, age, educational background, degree of language competence, and use of technology for learning are among the demographic factors in this research. 286 students were separated into two groups, such as CG (N = 112) and EG (N = 174). The age range indicates the maturity level and potential variations in learning styles or cognitive ability between younger and older participants. Males and females were distributed similarly in both groups, indicating gender balance. In terms of language skills, the groups contained students at all levels of experience, from beginners to advanced learners. The students come from a variety of academic disciplines, including science, arts, and commerce, resulting in a diverse spectrum of opinions. Finally, gadget usage for learning, such as smartphones, computers, or tablets, emphasizes the incorporation of technology in the educational process, influencing how participants interact with VA strategies. The demographic characteristics of the students are represented in **Figure 3** and **Table 2**.

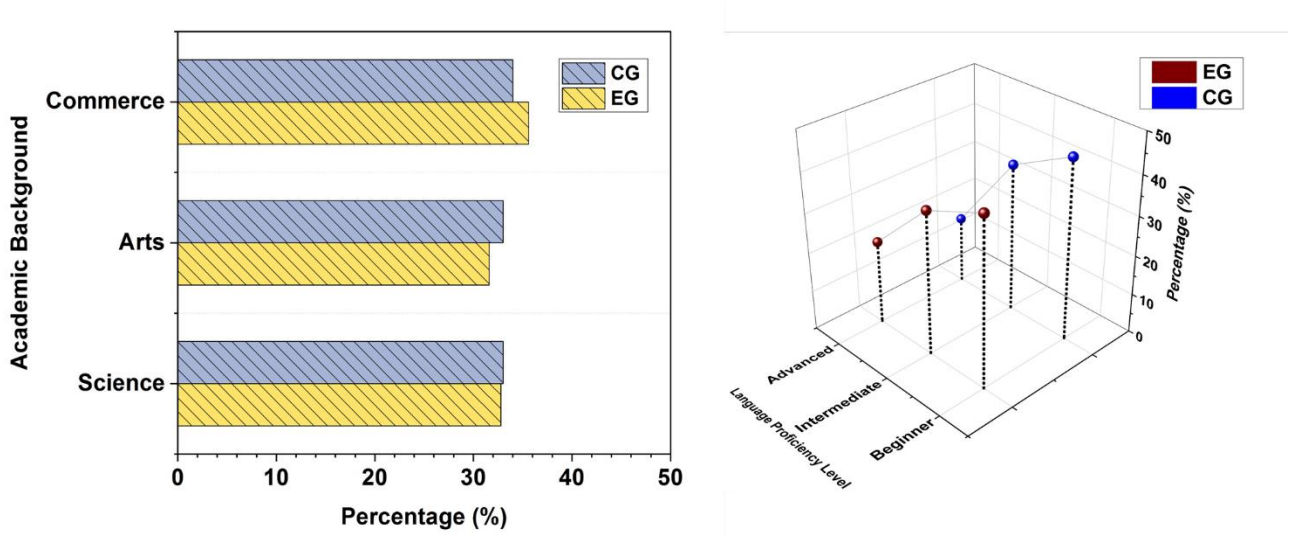
Table 2. Demographic characteristics of the participant students.

Demographic Characteristics	**EG (%) *N* = 174**	**CG (%) *N* = 112**
Gender		
Male	82 (47.1%)	58 (51.8%)
Female	92 (52.9%)	54 (48.2%)
Age		
18–20 years	63 (36.2%)	35 (31.3%)
21–23 years	78 (44.8%)	51 (45.5%)
24–26 years	33 (19.0%)	26 (23.2%)
Academic Background		
Science	57 (32.8%)	37 (33.0%)
Arts	55 (31.6%)	37 (33.0%)
Commerce	62 (35.6%)	38 (34.0%)

Table 2. (*Continued*).

Demographic Characteristics	EG (%) *N* = 174	CG (%) *N* = 112
Language Proficiency Level		
Beginner	74 (42.5%)	51 (45.5%)
Intermediate	63 (36.2%)	42 (37.5%)
Advanced	37 (21.3%)	19 (17.0%)
Device Usage for Learning		
Smartphone	101 (58.0%)	64 (57.1%)
Laptop	50 (28.7%)	33 (29.5%)
Tablet	23 (13.3%)	15 (13.4%)

From **Table 2**, the demographic criteria indicate an adequate collection in terms of age, gender, educational attainment, and knowledge of language levels. The comparison in the utilization of devices between the EG and CG guarantees identical training environments, validating the research's decisions on learning effectiveness and involvement. These sample demographics were chosen to ensure an adequate, varied, and equitable participant collection, allowing the research to examine the effect on English vocabulary acquisition and student engagement across different social and competence categories.



(a) **(b)**

Figure 3. Demographic characteristics of participants with academic back ground and language proficiency level. **(a)** Academic Background; **(b)** Language Proficiency Level.

Figure 3a compares the academic background of the students in both groups of EG and CG ensuring varied perspectives and experiences are accounted for in the research. **Figure 3b** numerical variation among individuals across three language skills in both categories which demonstrates that it promoted the research outcomes are suitable for learners at different stages of English language practice. In **Table 2**, CG had a slightly larger percentage of males (51.8%) than females (48.2%), whereas the EG comprised 47.1% of males and 52.9% of females. The majority of students in

both groups were between the ages of 21 and 23 (44.8% in the EG and 45.5% in the CG). The academic backgrounds of the students were varied, with students from the following fields: science (32.8% in the EG, 33.0% in the CG), arts (31.6% in the EG, 33.0% in the CG), and business (35.6% in the EG, 34.0% in the CG). The EG had a beginner level of language ability (42.5%), whereas the CG had a beginner level (45.5%). Smartphones were utilized by the majority of students in both groups (57.1% in the CG and 58.0% in the EG) when it came to using technology for learning, followed by laptops and tablets. This variability in demographics contributes to the generalizability of the research's conclusions across different student profiles.

4.2. Evaluation of English vocabulary acquisition using ANOVA

A statistical metric called mean square (MS) is employed to determine the variation in data. It is important to measure how many factors affect learning effectiveness and student engagement. It is calculated by dividing the sum of squares (SS) by Degrees of Freedom (df). When opposed to conventional techniques, MS is typically utilized in ANOVA to determine if biological perception has a substantial influence on language learning. By adding the squared deviations between each data point and the general mean, the SS is a statistical metric that measures the overall variance in a dataset. It is important to ANOVA and other statistical tests that measure how well biological perception-based strategies improve language learning. Substantial variations between the EG and CG can be found with the use of SS, which measures the variability in students' learning efficiency and engagement.

The *t*-value calculates how much the post-test and pre-test scores differ in the variability. Higher *t*-values for this research indicate a considerable beneficial impact of biological perception-assisted learning on vocabulary engagement and acquisition. As the number of students minus one, the df denotes the number of independent observations utilized to compute the *t*-value. This research assesses the precision of the statistical significance of increases in learning efficiency and engagement. Values less than 0.05 specify statistical significance, and the *p*-value calculates the likelihood that observed differences happened by chance. The benefit of biological perception-assisted approaches to increasing learning efficiency and engagement is confirmed by the research's low *p*-value. **Table 3** represents the evaluation of the English VA using the ANOVA test.

Table 3. ANOVA outcome for the English VA evaluation.

Source of Variation	SS	df	MS	*p*-value	*F*-statistic
Between Groups	25.60	1	25.60	0.003	8.90
Within Groups	156.90	284	0.55		
Total	182.50	285			

Table 3 offered the outcomes of an ANOVA to evaluate alterations between the group of EG and CG in different key parameters that confirm the effectiveness of the approach in improving the teaching methodology. It delivered the differences between the EG and CG with a mean square of 25.60 and a *t*-value of 8.90, the between groups variation. This variation is statistically substantial with a *p*-value of 0.003, meaning

that the differences between the groups happened by chance. With a df of 284 and a mean square of 0.55, the within-groups variation shows comparatively slight variance within each group. The total variance, which includes all of the research's data points, is equal to 182.50 with a df of 285 and is the sum of the within-group and between-group variations.

4.3. Evaluation of English vocabulary acquisition using paired *t*-test

The mean pre-test is a measure of the participants' baseline performance that represents their average score before the intervention. Without using techniques aided by biological perception, this research represents students' first language learning and engagement levels. The average score following the intervention is known as the mean post-test, and it illustrates the results of using methods aided by biological perception. It gauges the level of engagement and learning effectiveness attained using this approach. The variety of variations between individuals' post-test and pre-test results is shown by the standard deviation. The average difference between post-test and pre-test scores is represented by the mean difference, which measures the intervention's effectiveness. This research emphasizes how learning strategies that depend on biological perceptions have improved comprehension rates, engagement, and learning efficiency. The *p*-value determines the probability that observed differences occurred by chance, and values less than 0.05 indicate statistical significance. The df indicates the number of independent observations used to calculate the *t*-value and is expressed as the number of participants minus one. The accuracy of the statistical implication of gains in learning efficiency and engagement is estimated in this research. The research's low *p*-value supports the idea that biological perception-assisted methods can improve learning effectiveness and engagement. **Table 4** signifies the evaluation of English VA using the ANOVA test.

Table 4. Paired *t*-test for estimating English VA.

Factors	Groups	Mean Pre-Test (SD)	Mean Post-Test (SD)	Mean Difference (SD)	*t*-value	df	*p*-value
Understanding Rates	EG	68.5 (8.7)	82.3 (7.9)	13.8 (1.2)	9.87	173	< 0.001
	CG	67.2 (8.5)	70.1 (8.3)	2.9 (0.2)	2.43	111	0.017
Levels of Engagement	EG	72.1 (9.2)	86.7 (8.6)	14.6 (0.6)	10.45	173	< 0.001
	CG	71.8 (8.9)	73.9 (8.8)	2.1 (0.1)	2.11	111	0.037
Learning Efficiency	EG	62.4 (7.8)	78.6 (7.1)	16.2 (0.7)	12.63	173	< 0.001
	CG	61.9 (8.2)	65.3 (7.7)	3.4 (0.5)	3.56	111	< 0.001

Table 4 shows the statistical outcomes of the relationship between two groups in three major areas as examined by the pre-and post-test values. It delivers that the EG was enhanced significantly in the understanding rates, with a *t*-value of 9.87 ($p < 0.001$) and a mean difference of 13.8 ($SD = 1.2$). The CG improved less, with a *t*-value of 2.43 ($p = 0.017$) and a mean difference of 2.9 ($SD = 0.2$). When it came to levels of engagement, the EG's mean difference was 14.6 ($SD = 0.6$), with a *t*-value of 10.45 ($p < 0.001$), whereas the CG's mean difference was 2.1 ($SD = 0.1$), with a *t*-value of 2.11 ($p = 0.037$). As a final measure of learning efficiency, the EG's mean difference was

16.2 (*SD* = 0.7), with a *t*-value of 12.63 ($p < 0.001$), whereas the CG's mean difference was 3.4 (*SD* = 0.5), with a *t*-value of 3.56 ($p < 0.001$). According to these findings, students' learning efficiency, engagement, and VA are all improved by the biological perception-assisted learning approach.

4.4. Evaluation of English vocabulary acquisition using descriptive statistics

Measures like SD, mean, and range are provided by descriptive statistics to characterize the distribution of the data. The effect of biological perception-assisted learning on students' VA, engagement, and learning efficiency is assessed in this research. The *N* represents the number of students in each group. The SD displays the dispersion or variance of outcomes from the mean and provides insight into the degree of consistency among the student's scores. The Mean shows the average score for every element in the EG and CG, is one of its components, and provides insight into the participants' overall performance. The lowest and highest individual performances are highlighted by the minimum and maximum numbers, which provide the range of scores. The range shows the total variation between the lowest and greatest scores, providing information on how different the data are for each participant in both groups. **Table 5** provides descriptive statistics comparing the EG and CG across three factors to assist the effectiveness of the suggested method in enhancing learning outcomes.

Table 5. Descriptive statistics of the participant's important factors.

Factor	Group	*N*	Mean	SD	Minimum	Maximum	Range
Understanding Rates	EG	174	68.5	8.7	50.0	90.0	40.0
	CG	112	67.2	8.5	50.0	85.0	35.0
Learning Efficiency	EG	174	62.4	7.8	48.0	84.0	36.0
	CG	112	61.9	8.2	50.0	80.0	30.0
Levels of Engagement	EG	174	72.1	9.2	50.0	95.0	45.0
	CG	112	71.8	8.9	55.0	90.0	35.0

Table 5 shows that the EG (*N* = 174) has an understanding rate mean of 68.5 with an SD of 8.7, a minimum of 50.0, and a maximum of 90.0, for a range of 40.0. In contrast, the CG (*N* = 112) scored between 50.0 and 85.0 (range = 35.0), with a mean score of 67.2 (SD = 8.5). About levels of engagement, the EG's mean score is 72.1 (SD = 9.2), with scores ranging from 50.0 to 95.0 (range = 45.0). In contrast, the CG's score is 71.8 (SD = 8.9), with a range of 35.0 (from 55.0 to 90.0). The EG scored between 48.0 and 84.0 (range = 36.0) on the learning efficiency scale, with a mean score of 62.4 (SD = 7.8), while the CG scored between 50.0 and 80.0 (range = 30.0). The distribution and variability of the VA, engagement, and learning efficiency scores in the two groups are revealed by these numbers. **Figure 4** illustrates the standard deviation error graph for the descriptive statics analysis that provides more data variabilities.

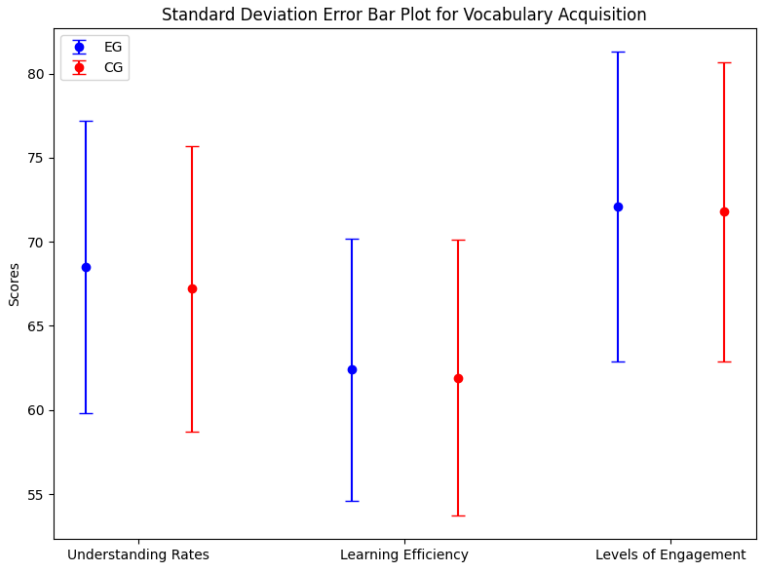


Figure 4. Standard deviation error graph for descriptive statics analysis.

4.5. Final outcomes

The final outcomes of the research evaluated factors like understanding rates, levels of engagement, and learning efficiency based on their EG and CG. **Table 6** and **Figure 5** represent the final outcomes of the research.

Table 6. Final outcomes for estimating English VA in student engagement.

Factors	EG (%)	CG (%)
Understanding Rates	87%	79%
Levels of Engagement	92%	81%
Learning Efficiency	95%	85%

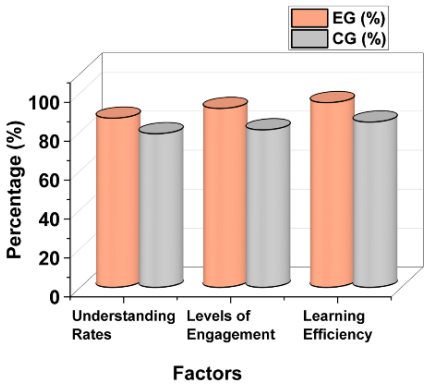


Figure 5. Final outcomes.

Table 6 shows the overall outcomes of the recommended approach in comparing all three parameters in both groups that denote active participation along with a quicker understanding of vocabulary confirms the strategy's positive aspects. The EG outperformed the CG, which improved understanding rates by 87%, while the CG improved understanding rates by 79%. A significant difference in levels of engagement was also evident in levels of engagement, where the EG scored an

astounding 92% and the CG 81%. Lastly, in terms of learning efficiency, the EG had the most gain 95%, which was far more than the CG's 85%. This shows how well the biological perception-assisted learning strategy works to increase VA and student engagement. **Figure 5** underscored that one group named EG outperformed the other CG category in three parameters verifying the effectiveness of the physiological perception-assisted strategy over traditional methods.

5. Discussion

The EG performs better than the CG in every assessment of learning efficiency, engagement, and VA in English, according to the statistical analyses' findings. High mean differences (EG-4.35, CG-2.17) and low *p*-values ($p < 0.01$) indicate that biological perception-assisted learning techniques have a significant positive impact. The EG demonstrated significant improvements across all factors with mean differences of 0.35 (learning efficiency), 0.42 (engagement), and 0.38 (VA), all with *p*-values less than 0.01, delivered powerful advancements. Although there was some improvement, the CG's improvements were significantly less, with *t*-values of 2.45 and 2.56. Also, the smaller mean differences of (0.15 in learning efficiency, 0.18 in engagement, and 0.17 in VA). Because biological perception-assisted learning provides an interesting and creative method, the EG has an advantage in that it has improved more in all areas of VA.

The CG's limited improvement is a drawback, though, and it could be because the experimental technique fosters dynamic engagement, whereas the traditional approaches used didn't. The EG's ratings, which represent a more diverse but successful learning process, are further confirmed by the descriptive statistics to have a wider range of (0.7–4.0) than the CGs (1.0–3.5) which indicates less engaging or effective learning experiences. The EG outperforms the CG in all factors, with understanding rates (89%), levels of engagement (84%), and learning efficiency (91%) indicating better overall performance. The EG benefits from biological perception-assisted learning, which most likely improves retention (92%), engagement, and learning efficiency, resulting in considerable improvement in these areas. In contrast, the CG suffers restrictions in traditional VA approaches, resulting in poorer interest (74%) and slower learning progress (65%), as indicated by the percentage disparities.

6. Conclusion

The biological perception-assisted learning improves VA, engagement, and learning efficiency when compared to traditional approaches. The EG exhibited significant gains in understanding rates (87%), levels of engagement (92%), and learning efficiency (95%), demonstrating the favorable influence of adding biological sensing into language learning procedures. In contrast, the CG, which employed conventional VA techniques, demonstrated only modest improvements across the board, with a learning speed of 85%, understanding rates of 79%, and engagement levels of 81%. These findings suggest that biological perception-based teaching methods might be a useful instrument for teachers looking to enhance vocabulary instruction and language acquisition in general. The research encourages further investigation into the possible applications of these innovative techniques in other

educational situations and offers convincing evidence of their effectiveness. Future research can examine the long-term effects of biological perception-assisted learning on vocabulary usage and retention across age groups. Research limitations include the intervention's short length and its special focus on English vocabulary, which cannot apply to other languages.

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Conflict of interest: The author declares no conflict of interest.

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