Abdolmaleki and Saeedi
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Brain-based CALL in flipped higher education GE courses held through LMS: Boosting vocabulary learning and reading comprehension

Nasrin Abdolmaleki[1*] and Zari Saeedi[1]

*Correspondence:
Abdolmaleki.nasrin@gmail.com

[1] Faculty of Foreign Languages, Department of English Language and Literature, Allameh Tabatabai University, Allame St., Tehran, Iran

Abstract

The thriving technology penetration in all aspects of today's life and deficiency of traditional pedagogies necessitate wise adoption of modern approaches in the educational context. As a few studies concerned the simultaneous application of classical educational theories with modern technological pedagogy, the present researchers launched General English (GE) courses enjoying the consolidation of Brain-Based Computer-Assisted-Language-Learning (BBCALL) and Flipped-Model (FM) with the aid of the Learning Management System (LMS) for fourteen 150-min sessions to explore their impact on vocabulary learning and reading comprehension (RC). In this pre/post-test experimental study, conducted in coeducational GE courses of a state university, 61 homogenous non-English major bachelors, selected via the convenience-sampling technique and screened by standard RC and GE-VOC tests, participated. Articulate Storyline software was used to develop intentional instructional content according to 12 BBL principles. BBCALL was the common aspect and in-class content attainment of non-flipped versus in-class content engagement and formative quizzes of flipped courses were the distinguishing features of the applied treatments. The statistical analyses of this action research demonstrated significantly meaningful outperformance of flipped BBCALL participants in vocabulary learning ($sig = 0.001$) and RC ($sig = 0.033$). To enhance results interpretation precision, gender was considered in groups' differences. Although females in flipped course meaningfully outperformed on RC, male partakers of flipped course experienced the most meaningful improvement in VOC learning. Additionally, low-proficient learners benefited the most from such a self-paced and learner-centered education. The findings suggest that flexible instructional materials and effective tech integration could facilitate the improvement of higher-order thinking, creative problem-solving, and scaffolding.

Keywords: Flipped-Model, Brain-Based Computer-Assisted-Language-Learning (BBCALL), Learning Management System

Introduction

During recent decades, technology has experienced drastic change all around the globalized village. Consequently, the need to learn a foreign language as a lingua franca in the scientific and social world had a dramatic increase. In addition to the burgeoning development of technology, pandemic years' constraints have led to educational settings revolution across the world.

Computer Assisted Language Learning (CALL) emergence and evolvement were techera souvenirs. This umbrella term is simply delineated by Levy (1997) as "the search for and study of applications of the computer in language learning and teaching" (p. 1). Such overarching definition illuminates that CALL is not restricted to the utilization of commonly used personal computers or laptops and involves "the networks connecting them, peripheral devices associated with them" (Hubbard, 2009, p. 1) and any other technological innovations in which a kind of computer is included. Despite the significance of the ubiquitous technology in the process of learning and the cognitive dimensions of integrating tech-tools in second language acquisition, the gap is still strongly felt in the pertaining studies since not much experimental research, to the best of the researchers' knowledge, has been carried out concerning brain-based/cognitive CALL. One major contribution of future research with such an orientation, which has a high level of potential to fill the existing gap, can be a move towards more interdisciplinary areas and apply the findings of cognitive psychology to technology-oriented language learning with a focus on language skills and components.

Following the above-line research and the migration of courses to online platforms, flipped method was embraced increasingly. However, as Berrett (2012) finely mentioned FM cannot be deemed as an innovation in the teaching field since it had been implemented and investigated under diverse corresponding terms such as just-in-time teaching (Novak et al., 1999), inverted classroom (Lage et al., 2000), inverted learning (Davies et al., 2013) and flipped classroom (Bergmann & Sams, 2012). Contrary to the diversity of terminologies, there is a general agreement on the type of instruction and pedagogical activities. However, FM came under criticism for its anecdotal theoretical foundations rather than systematic underpinnings (Lundin et al., 2018), rare attention to an appropriate theoretical framework to guide pedagogical design (Karabulut-Ilgu et al., 2018), excessive focus on the delivery of blocks of content knowledge, examination-oriented learning (Jiang et al., 2022), considerable challenges related to out-of-class activities, particularly inadequate learners' preparedness (Akc¸ayır & Akc¸ayır, 2018), and adversities in the development of students' higher-order thinking skills (Lin & Hwang, 2019).

Cognitive psychology and the research motives

Exciting discoveries in cognitive psychology and neuroscience illuminated the tip-up between classroom teaching and human brain learning. As the recipient of the Noble Prize in physiology, Gerald Edelman, argued there is lifetime inspiration of classroom teaching by administrators' cognizance of the brain. However, the wealth of current worthy sources on Brain-Based Learning (BBL) owes principally to the studies of neuroscience and psychology, and physiology (Willis, 2008). BBL is defined by Caine and Caine as "acknowledging the brain's rules for meaningful learning and organizing teaching

with those rules in mind" (1991, p.13). Under BBL conventions, the brain is a parallel processor that processes parts and whole simultaneously. Besides, learning engages focused attention, peripheral perception, conscious as well as unconscious processes, and the entire physiology. Based on BBL, the quest for meaning is innate happening through meaningful organization and classification of information. The human brain is emotionally sensitive, thereby learning action is impeded by threats but enhanced by challenges. It asserts that almost all human beings enjoy a spatial memory and a set of systems for rote learning but when facts or skills are embedded in spatial memory, they can be recalled better. Last but not least, each brain is unique.

Acknowledging the importance of tech integration into learning courses, in general, and language ones, in particular, its consolidation by BBL theories consideration, and concerning apparent issues like lack of enough motivation and time for class participation, reluctance to rely on specific learning methods (Cavus, 2015), learners' geographical or personal inaccessibility, dissatisfaction from boring traditional approaches to language instruction within a limited time, assumption of technology as an indispensable rather than a supplementary aspect of everyone's life (Brown & Lee, 2015), net access as pen and paper availability (Ur, 2012), the new generation of learners that are digitally wise (Prensky, 2010) and immersed in technologies (Prensky, 2001), and healthcare concerns over pandemic crises, as covid-19, which recently made many institutes defer their face-to-face courses for lack of suitable infrastructure and pedagogies or transfer their traditional courses to online platforms (Crawford et al., 2020), the urgent demand of satisfying the needs and expectations of contemporary students and resorting to modern methods most likely to be welcomed substantially is tangible.

Scope of the study

The present probe concerned boosting EFL reading as almost the fundamental skill for enlarging knowledge of a language (Jain & Patel, 2008) and vocabulary acquisition as the building blocks of linguistic context for its determinative role in input comprehension and knowledge perception. The latter is asserted by numerous scholars, namely McCarthy (1990) discussing neither it matters how professional the EFL learners sound nor how well they perceive the grammar of target FL since meaningful communication in L2 hangs on the large lexicon. Likewise, Hunt and Beglar (2005) described vocabulary as the heart of language. Wilkins (1972) states, "While without grammar little can be conveyed, without vocabulary nothing can be conveyed" (p. 111). Moreover, as asserted by O'Keeffe (2012), one's lexicon plays a vital role in his performance, attainments in language tests, and different language skills. Laufer (1996) also spelled out the detrimental effect of a poor lexicon on RC and argued: "No text comprehension is possible, either in one's native language or in a foreign language, without understanding the text's vocabulary" (p. 20, as cited in Coady & Huckin, 2012).

To this aim, the researchers considered the prevalent problems of face-to-face, common CALL courses, and aroused criticisms of FM, namely learners' exposure to plenty of preordained materials without enough recognition of the target audience, their levels, and learning styles, time pressure, and little adaptability of the course plans. Correspondingly, this study with its mixed-methods sequential explanatory design specifically addressed the impacts of BBCALL treatment on vocabulary learning and RC of the EFL

learners in non-flipped versus fully-structured flipped classes. Furthermore, the learning achievement of male and female participants in both course types had been analyzed to determine who and in which kind of classes had most benefited. Therefore, in line with the objectives of this study, the following research questions were proposed:

1- How statistically different is vocabulary learning of EFL learners in flipped versus non-flipped classrooms through the application of BBCALL?
2- How statistically different is reading comprehension ability of EFL learners in flipped versus non-flipped classrooms through the application of BBCALL?
3- How statistically different is vocabulary learning of male and female EFL learners within as well as across flipped and non-flipped classrooms through the application of BBCALL?
4- How statistically different is reading comprehension ability of male and female EFL learners within as well as across flipped and non-flipped classrooms through the application of BBCALL?

Literature review

Previously made attempts like developing "Brain-Science and Education" programs in Japan or the program "Mind, Brain, and Education" by Harvard Graduate School of Education and the establishment of the International Mind, Brain and Education Society in the USA feasibly resonates the integrity of neuroscience and education. Following Howard-Jones' line of approach (2006) arguing that interdisciplinary research with scientific and educational approaches can shed light on the practical use of scientific premises and be beneficial to each community, we employed BBL, CALL, and FM in the hope that theory, course design, and practice alignment would lead to a variety of learning experiences that are connected to the participants' background information without boring repetition and eventually their learning optimization. To establish the context of the study, a brief theoretical and empirical literature on the intended variables is included hereafter.

BBL principles underscore engaging learners with metacognitive activities that can enhance, enrich, and extend the learning and retrieval of the material by long-term memory. On the other hand, the foremost features of real Brain-Based teaching are relaxed alertness, orchestrated immersion in complex experiences, and active processing of learning experiences (Caine et al., 2015; Gülpinar, 2005). Thus, an expert BBL teacher is expected to teach attention, memory, and processing skills, notice students' prior knowledge on a topic, and present content in a contextual framework through a flexible process in terms of input, reflection opportunity, and output (Perez, 2008).

However, as Lago and Seepho (2012) argued the design and development of brain compatible-activities are among the outcomes of occupied neuroscientists, psychologists, and physiologists' work on human learning. So, they adopted BBL approach to ESP instruction in a pre-experimental study on 31 third-year ESP students and investigated the impact of such activities on vocabulary learning and retention. The quantitative data was collected by pre-test, immediate post-test, and two delayed post-tests. The qualitative data was also gathered through semi-structured interviews. The results revealed

that not only vocabulary learning but also vocabulary retention on the delayed post-tests, given six weeks after the instructional period, was significant.

Reasonably, the wholistic nature of Brain Based Language Teaching (BBLT) that encourages comprehension rather than memorization has led to its reportedly promising results and noticeable embracement by language educators with diverse objectives in different contexts over recent years. For instance, Salem (2017) reported the positive effect of running an ESP course with BBL underpinning on vocabulary retention, listening skill, and motivation. Similarly, Salama (2015) observed the enhancement of vocabulary learning of 61 male participants through BBLT.

Nafa (2013) particularly focused on Arab ESL learners' vocabulary learning through BBLT and its satisfactory results were congruent with those of Kandasamy et al. (2021) examining BBL on primary ESL learners' vocabulary acquisition and retention.

Other researchers, namely, Nur et al. (2020) put BBL theory into practice for teaching RC to 22 first-year MA students and observed its application effectiveness. Similarly, Haghighi (2013) investigated BBL strategies over a 16-week-ESP course in which 63 EFL sophomores participated and reached significant improvement in their retention and achievement. Likewise, Kohar (2022) examined BBL model impact on RC level in Indonesian junior high schools based on exposition reading structures and its results indicated the participants' improved reading ability on a variety of structures including list structure, topic structure, matrix, hierarchy, sequence of events, and tree structure.

Although the studies grounded on BBL principles have improved teaching effectiveness, no track of modern technology had been found. While it seems that tech-oriented courses running based on BBL theories can augment its interests to the related stakeholders. Consequently, to make FL instruction interesting enough to engage learners' attention, alleviate foreign language learning difficulties, and meet learners' needs, technology in support of pedagogy is appealed to.

Like BBL advocates, the proponents of cognitive CALL paradigm believe that learning mainly relies on one's cognitive capacities and society is the second priority since language as a means of communication and participation in social activities "is both the product and the process of learning" (Zeungler & Miller, 2006, p. 38). Brain-Based Language Learning (BBLL) (as referred to by Saeedi, 2021) as a core concept which deals with the field of Educational Neurolinguistics has a lot of potential in applied linguistics and can open new doors to a new interdisciplinary world that can merge brain-related findings, language learning, and technology.

Historically, diverse theoretical and practical issues imposed three divisions on the CALL spectrum, namely structural CALL, cognitive CALL, and socio-cognitive CALL (Warschauer, 2000) that are simultaneously distinct from and dependent on the others to result in proper function. Cognitive CALL, hanging on cognitive theories, suggests that instruction is not purely the transmission of information from a teacher's head to the eager students'. Fitting it into their previous knowledge or revising their background knowledge based on what they are provided, learners wisely interpret and systematize the information (Dole et al., 1991; Van Dijk & Kintsch, 1983; Warschauer & Healey, 1998).

Discontented with the major focus of online course development literature on broad principles rather than applicable theoretical model design, Tompkins (2007) launched a

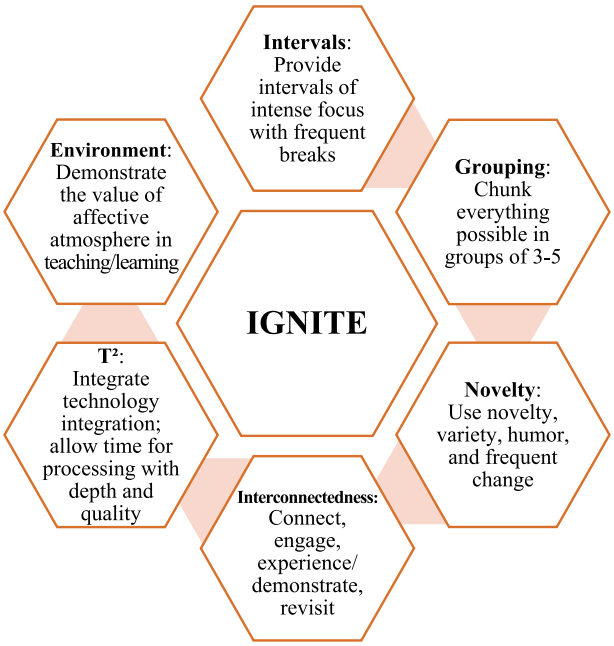

Fig. 1 Brain-based online course design model (Tompkins, 2007, p. 72)

qualitative study and developed a theoretical brain-based online course design model for higher education with transferability potential across LMS platform. The following diagram presents the resulting model; *IGNITE* (see Fig. 1).

Certainly, utilization of online platforms and adopting approaches that involve "active learning" by which students have to "reflect upon ideas and how they are using those ideas" (Michael, 2006, p. 160) could make the passive students more active, yet the implementation of FM has more specifically dealt with obstacles to higher-order skills development in an interactive and collaborative context. More precisely, the complementary divisions of active learning, namely cognitive one whose essence is reflection, suggest active thinking and construction of new concepts, ideas, and meaning based on the current or previous learners' knowledge, as BBL, and social active learning, as FM, stands for learning through active engagement in meaningful communication with collaborators and resources (Watkins et al., 2007). Accordingly, for cognitive psychology findings on human learning and higher education missions, Brewer and Movahedazarhouligh (2018) thoroughly reviewed FM implementation, efficacy, and quality in higher education settings. Importantly, Divjak et al. (2022) systematically reviewed online flipped classroom studies specifically in higher education over the pandemic. Among 205 publications as the corpus of this study, 18 ones were analyzed exhaustively to realize their revelations, implications, and recommendations. Interestingly, the success of educators who had previously experienced FM in blended and/or face-to-face courses was remarkably noticed in online contexts.

Principally, the four pillars of the flipped classroom are flexible environment, learning culture, intentional content, and professional educator (Hamdan et al., 2013). It demands out-of-class instruction of the core content via videos, PowerPoints, demonstrations along with annotations, etc., that students receive and are supposed to study by

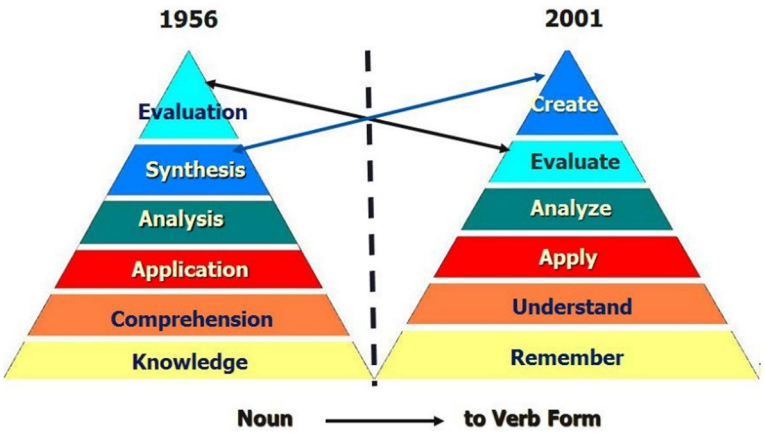

Fig. 2 Primary and revised Bloom's taxonomy

class attendance (Bergmann & Sams, 2012). Thereby, get ready for the concept engagement taking place in the classroom with the instructor's assistance. Scientifically speaking, the obligatory tech-oriented pre-class activities in FM can facilitate self-learning at two basic levels of Bloom's learning taxonomy (Anderson & Krathwohl, 2001) and assist in evaluating learners' mastery of the core content as preparation for class (Jiang et al., 2022). Moreover, flipped courses, by contrast with the previous lecture-formatted context, make view, rewind, and review of the content possible, resulting in a cognitive load decrease (see Fig. 2).

Reviewing 654 published documents on flipped methodology, González-Zamar and Abad-Segura (2022) determined the stages, progress, development, and current situation of this model. It manifested that Social Sciences, Computer Science, Engineering, Mathematics, Medicine, Arts, Humanities, and Psychology are the major fields in which FM was implemented and investigated. However, a dearth of systematic research to recognize the contribution of STEM areas to the knowledge of flipping education in higher education was noticeable. Therefore, Lundin, et.al. (2018) studied 530 academic articles published over 2000–2016 and argued the outcomes of those research, mostly conducted locally, underline the need for more coherent studies "anchoring in, for example, learning theory or instructional design known from educational technology traditions and which would have helped much of the flipped classroom research to examine aspects of the flipped classroom approach more fully." (p. 1).

Expanding the primary model, Chen et al. (2014) proposed a revised FM by including seamless learning platforms, progressive networking activities, and engaging learning experiences. Likewise, Bishop and Verleger (2013) distinguished the traditional and de-facto flipped courses by "an expansion of the curriculum rather than a mere rearrangement of activities" (p. 5). They comprehensibly summed up the restricted and broader definitions of flipped classrooms (see Table 1).

Based on flipped literature this model was increasingly taken up since 2015 by language educators, nevertheless, the adopted approaches towards the role of technology differ, particularly in terms of in-class activities as occasionally face-to-face practices are prioritized. O'Flaherty and Phillips (2015) is one of the comprehensive overviews of FM studies in higher education systems and its links to pedagogy and educational outcomes.

Table 1 Definitions of flipped classrooms (Bishop & Verleger, 2013)

Style	Inside class	Outside class
Traditional flipped classroom	Lectures Practice exercises Problem solving	Practice exercises Problem solving Video lectures
De-facto flipped classroom	Questions and answers Group-based/open-ended problem solving	Video lectures Closed-ended quizzes Practice exercises

However, some experimental studies explored the impact of the Flipped Teaching Model (FTM) on English language learners (Abdelshaheed, 2017; Hung, 2015). Hung (2015) revealed the outperformance of undergraduates in the structured flipped classes compared to the non-flipped and semi-structured participants'.

Likewise, Abdelshaheed (2017) investigated the impact of utilizing FM on EFL learning of sixty-two English-major female students of Majmaah College. It demonstrated a higher significant positive change in flipped students' scores after the intervention. The greater satisfaction from flipped classes rather than lectured-based ones had been recorded in other studies (e.g., Frydenberg, 2013; McGivney-Burelle et al., 2013). Moreover, Zarrinfard et al. (2021) studied the impact of traditional FM on GE of 50 undergraduates randomly divided into control and experimental groups and received conventional and traditional flipped instruction, respectively. It is noteworthy that the due literature on FM reports its promising effects provided that advanced technologies are excluded.

Although E-learning/Technology has been widely acknowledged and studied particularly for universities and higher education institutions over the past decade (e.g., Coates et al., 2005; Dahlstrom et al., 2014; Mtebe, 2015; Saeedi, 2013; Saeedi & Biri, 2016; Saeedi & Meihami, 2015; Saeedi et al., 2014; Saeedi & Sajjadi, 2013; Saeedi & Sharafinezhad, 2013), in this research context, few studies had been conducted on comparison of BBCALL and BBCALL in flipped classrooms in a public academic context. Furthermore, flipped studies considerably adopted preparedness-checking mechanisms, mostly through clickers, LMS, and online forums, however recourse to educational technologies not only enhances learners' understanding and remembering of core instructional content but also assesses their learning after content engagement. Thus, the current study aimed to bridge this gap and shed light on the effect of such classes on the focused variables.

Method

This section describes the adopted method, research sample, and instruments of the study. The following figure simply demonstrates the experimental research design (see Fig. 3).

Participants

The participants were 61 non-English major undergraduates of ATU,[1] an outstanding state university, aged 18–43, with no or the least experience of private EFL class

[1] Allameh Tabatabai University.

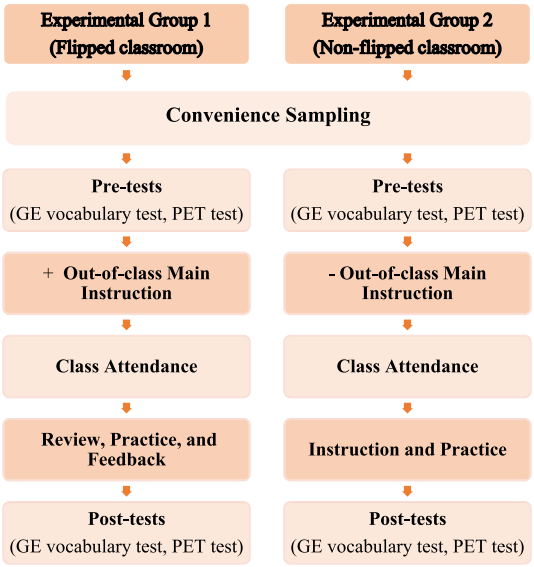

Fig. 3 Research design

Table 2 Sample of the study in each course

Groups	Course		Frequency	Percent
Experimental 1	Flipped	Female	15	48.4
		Male	16	51.6
		Total	**31**	**100.0**
Experimental 2	Non-flipped	Female	18	60.0
		Male	12	40.0
		Total	**30**	**100.0**

participation. Inevitably, the research sample was intact groups and a convenience sampling technique was adopted. To prevent the study from sharp diversities, the pretest was administered. Screening the pretest takers, outliers were excluded and the homogeneous participants were randomly divided into two experimental groups.

As technocentrism, typically assumed to vary across men and women in the researchers' context, can affect e-course partakers' learning, not only the researchers studied it comparatively in contrast to the results of surveys conducted with the same scale in other countries' similar contexts (Abdolmaleki & Saeedi, 2018), but also considered gender variable in groups' differences to enhance the results interpretation precision. Moreover, gender is culturally important in the present research context. Table 2 briefly presents the experimental groups.

Instrumentation and materials

LMS platform

LMS was applied as the major administrative platform since it enjoys a collection of standards and specifications required for web-based e-learning in terms of packaging (i.e., how content may be packaged into a transferrable zipped file), tracking (i.e., how the content communicates with the host server to keep track of students'

Fig. 4 Assignment modular

performance), and metadata (i.e., offers information about the learning object). Moreover, it provides synchronous and asynchronous educational communications that the former enjoy webcam, microphone, whiteboard, as well as screen sharing attributes. Simply put, through LMS the lesson plans, course content, and learning sessions were managed. Additionally, the period of users' access to the SCORM-based content and recorded sessions was specified by the researchers. Through this platform, learners' e-portfolios, performance, and studying process were monitored over and after the class (see Fig. 4).

Articulate storyline 2 software

To develop engaging and interactive electronic training materials, Articulate Storyline 2 was applied. Supporting interactive elements like quizzes, simulations, and games, it enables the development of multimedia content, interesting activities, and effective assessments with a range of question types, regular scoring, and feedback options. Its utilization made the final content easily shareable across multiple platforms and devices and facilitated tracking participants' progress. The following figures show some of its features (see Fig. 5, 6).

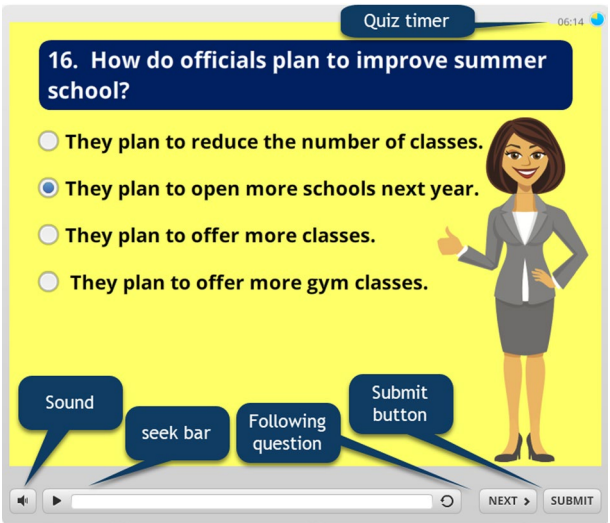

Fig. 5 An instance of the quiz scene

Fig. 6 Corrective feedback on the matching questions

Assessment tools

To select homogenous participants and evaluate their progress, individuals' entry language level and their ability to accomplish the activities were assessed by the administration of PET Reading test and Cambridge GE Vocabulary Test before and after the intervention. To single out the appropriate level of reliable and valid measures participants' demographic information and prior English knowledge, expected to be gained in school education as the prerequisite of BA entrance exam acceptance, were considered. It is noteworthy that the sample had never taken part in English courses at institutes.

Materials

The bases of BBCALL and FM treatments are flexible brain-compatible instruction and intentional content. Although Perry (2000) asserted that teachers do not need to be neuroscientists and some knowledge on how the brain perceives senses, processes, stores, and retrieves information would suffice, for this action research core and supplementary content including graded reading passages, followed by vocabulary and comprehension activities were selected after gauging the participants' pre-knowledge on the intended variables by a technophile neurolinguist in accordance with the intended bedrocks and the course objectives. In so doing, the type of materials was determined by a personal connection between one's life concepts and class content, reflection opportunities, and different ways of acquiring and expressing knowledge. California Distance Learning Project (CDLP) (suggested by Chapelle and Jamieson, 2008) which is a popular platform for reading instruction to adult EFL distance learners was the main utilized online source. It provided the reading passages on diverse topics developed based on the real news stories

Fig. 7 Adult learning activities of CDLP

of KXTV Sacramento, graded from beginning to intermediate level, and thematically categorized (see Fig. 7).

The sole printed source was the Oxford Picture Dictionary (Adelson-Goldstein and shapiro, 2017), compiled by Jayme Adelson-Goldstein along with Norma Shapiro, and published by Oxford University Press.

Procedure

Data collection procedure over this experimental research with three major phases is simply presented in Fig. 8.

As it is shown in Fig. 8, first of all, two face-to-face sessions were devoted to (1) pretest administration; and (2) a brief orientation on LMS. Then, the content attainment and engagement followed by formative assessments took place over eleven sessions of the second phase. As this study sought to investigate the efficiency of both BBCALL and FM, two distinct courses were held and participants of the flipped class were required

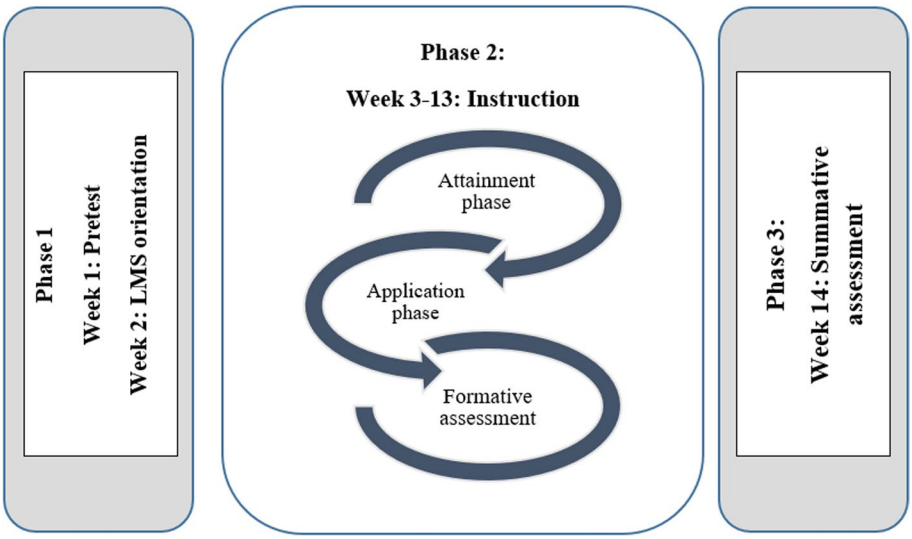

Fig. 8 Major phases of the procedure

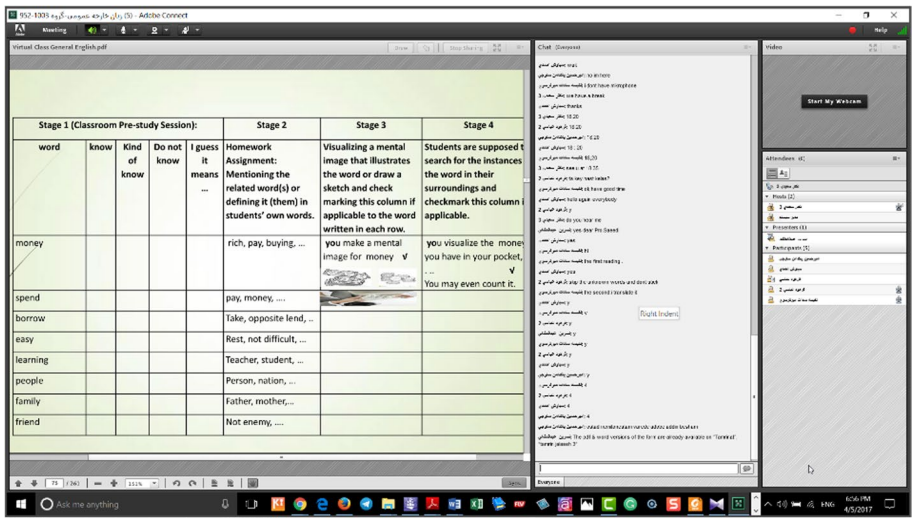

Fig. 9 Class environment in one of the due sessions for practicing designed vocabulary form

to study the core instructional content before class attendance and more practice on the supplementary content and students' assignments were done during the class hours.

Assuming that successful RC involves decoding skills, linguistic knowledge, and interaction with text, GE VOCs were taught through a form with four major columns to be filled out for the less familiar words of the intended reading passages. This form was developed in line with BBL principles, Nation's (2001) definition of vocabulary knowledge engaging knowledge of form, meaning, and use, Schmitt's taxonomy (1997) of strategies for learning and consolidating vocabularies, and Waring's (1999) description of vocabulary knowledge as a continuum on which there is no lower or higher level and corroborates the existence of several stages in one's vocabulary knowledge and their inter-connectedness (see Fig. 9).

The participants had to determine their knowledge status for the keywords of assigned passages. The first major column dealt with the extent of learners' familiarity with the highlighted lexicon. In the second column, for each vocabulary, they put down the most related word(s) that came to their minds or a word they could associate its meaning with the intended keyword. For instance, if the intended keyword was "teacher" the related word coming to their mind might have been "classroom", which is the case of meaning association and is indeed one of the principles of meaning learning. As sensible and meaningful learning can facilitate retention and retrieval of information (Sousa, 2001; Sprenger, 1999), the instructors had recourse to tangible and concrete concepts in the learners' real life to involve their textual, visual, and kinesthetic learning styles (Caine & Caine, 1991, 1995; Jensen, 1995, 2005; Paivio & Csapo, 1973). Consequently, to engage spatial and tactile learning styles with the aim of a greater content digest, by the third and fourth columns of the vocabulary form, learners had to include visualization and other related vocabularies of their surroundings. Then, the class time was devoted to working on a detailed understanding of the passages.

In these classes, grammar was taught inductively. Hence, reciting the words, the participants drew a meaningful association among the keywords and attempted to make the simplest meaningful sentences with minimum words. In so doing, they

added a related word to the intended word in the list of keywords, and then for the third round they were asked to add a verb or another word to turn the two previous ones into a simple sentence. It was to decrease their dependence on translation and make them think in L2. In the subsequent stages, the sentences were modified in terms of grammar and punctuation and the required function words were added. Then, they were extended as much as possible with learners' collaboration within their competence. Thereby, they could distinguish content words from the function ones and recognize the leading content words progressively. Therefore, the lesson plan was not structure-oriented but in cases of coming across new grammatical rules, they were taught inductively.

In the non-flipped course, the core instructional material of each session was taught within class hours and the videos of all class sessions were available on the LMS platform for later reference. In the flipped course, the core content presented via instructional videos was not always accessible but the researchers provided the participants with the designed materials of each session two days before the upcoming session to study before attendance and concept engagement had taken place during the virtual sessions. To fulfill the requirements of the concept engagement phase, the supplementary materials selected according to the learners' level and defined objectives of each session were practiced in class.

According to Sylwester (1995), "Our brain is most efficient at recalling and using episodic memories that have important personal meanings". Accordingly, in each slide of the published scene, the meaning of sentences was conveyed with appropriate pictures appearing one by one. Simultaneously, they heard the native reading the text. In the end, they had access to the whole passage. By providing examples, pictures, and sounds attempt was made to involve spatial and auditory learning styles and let the learners have mental scripts (see Fig. 10).

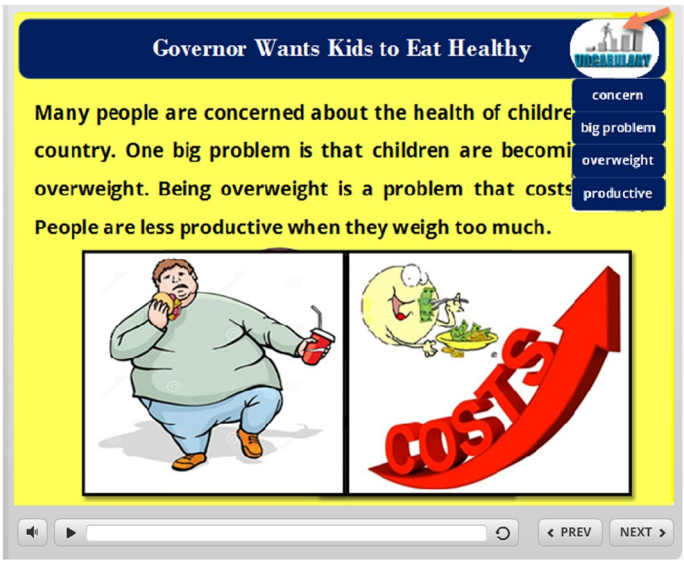

Fig. 10 VOC visualization within linguistic context

The researchers uploaded the quiz of the previous session designed and developed by Articulate Storyline software every weekend and kept the participants informed via Telegram as soon as they could access the core materials of the upcoming session and the quiz of the preceding session. Importantly, the published quizzes were interactive and by pressing the REVIEW button on the final slide of the quiz scene, the test takers were provided with feedback on all of the submitted answers.

By the last phase of this procedure, the effect of applied treatments was assessed. To this end, participants' progress after the intervention was evaluated by PET Reading test and Oxford GE VOC test administered at the last session of the academic semester.

Results

This section embodies five sub-headings which deal with the descriptive statistics/tables (homogeneity and normality) and the findings pertaining the four formulated research questions.

Normality and homogeneity

This study was to align pedagogical and technological considerations to promote learning outcomes and this section considers the statistical results on their effectiveness. To this end, first of all the homogeneity/normality of experimental groups was investigated.

Table 3 presents descriptive statistics on the normality and homogeneity of the participants. The values of Skewness and Kurtosis (0.031 & 1. 07) for the mean of 37.56 and standard deviation of 15.97 are placed within the acceptable range of ± 1.96 (Field, 2000) which imply the normality of the target groups. Furthermore, the homogeneity of variances and statistically insignificant difference between the two experimental groups were assured by the median version of Levene's test due to its greater robustness and statistical power (Lowie & Seton, 2013) (see Table 4).

Table 3 Descriptive statistics of the experimental groups' general English proficiency

	N	Minimum	Maximum	Mean	Std. deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Valid N (list-wise)	61 61	7	65	37.56	15.977	− 0.031	0.306	− 1.072	0.604

Table 4 Test of homogeneity of variance

		Levene Statistic	df1	df2	Sig
Pretest.sum	Based on mean	0.421	1	59	0.519
	Based on median	0.432	1	59	0.514
	Based on median and with adjusted df	0.432	1	58.873	0.514
	Based on trimmed mean	0.415	1	59	0.522

The results indicate that the difference between the experimental groups is insignificant (sig = 0.519, p > 0.05) and they were homogeneous in terms of intended variables before the treatment

Table 5 Descriptive statistics of the two experimental groups' progress in vocabulary learning

	Course	N	Mean	Std. deviation	Std. error mean	Skewness		Kurtosis	
		Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Valid	Non—flipped	30	1.17	4.169	0.761	− 0.095	0.427	− 1.075	0.833
	Flipped	31	5.39	5.571	1.00	0.466	0.421	− 0.359	0.821

Flipped/non-flipped vocabulary learning and BBCALL

The first question compared the effect of BBCALL on EFL learners' vocabulary learning in flipped versus non-flipped classes. To recognize it the average of each group's pretest and posttest scores were computed by SPSS 23. Then, an Independent-Samples T-Test with a significant level of 0.05 was conducted to determine the extent of change in their vocabulary learning caused by the interventions. Table 5 includes descriptive statistics of the experimental groups' progress.

As is shown, while participation in the flipped course resulted in 5.39 average improvement, non-flipped course brought about 1.17 points improvement in the students' vocabulary learning. Table 6 summarizes the results of the Independent-Samples T-Test through which the significance of improvement was investigated statistically.

As Table 6 demonstrates, the mean difference between the flipped and non-flipped English classes at 0.05 level of significance is 4.22 and $t_{obs}\ (59) = 3.34 > t_{crit} = 2$. Besides, the $Sig_{(2\text{-tailed})}$ value is smaller (0.001) than the assumed level of significance 0.05. Therefore, the difference between the two experimental groups was statistically significant and FTM had a tangible effect on learning GE vocabularies. To avoid merely systemic judgments, a field-specific scale (Plonsky & Oswald, 2014) is used for effect size interpretation. Accordingly, medium effect size ($d = 0.80$) also asserted the flipped course had enhanced the vocabulary learning of its participants.

Flipped/non-flipped reading comprehension classrooms and BBCALL

In the same vein, to find any conceivable contrast between the performances of the experimental groups in terms of RC, the results of descriptive statistics (Table 7) and Independent-Samples T-Test with a significant level of 0.05 (Table 8) were used.

According to the results included in Table 8, the mean difference between the non-flipped and flipped English classes at 0.05 level of significance is 2.88 and $t_{obs}\ (59) = 2.18 > t_{crit} = 2$. Besides, the smaller $Sig_{(2\text{-tailed})}$ value than the assumed level of significance ($0.03 < 0.05$) can support the statistically significant difference. Considering the small effect size ($d = 0.55$), it can be concluded that compared with participants of the non-flipped course, those of the flipped class had statistically outstanding progress in RC.

Gender differences and brain-based flipped/non-flipped vocabulary learning

By the third research question, the efficacy of BBCALL on vocabulary learning of male and female EFL learners within as well as across flipped and non-flipped classes

Table 6 Independent-samples t-test for the experimental groups' progress in vocabulary learning

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference	
									Lower	Upper
Dif.VOC	Equal variances assumed	1.878	0.176	− 3.341	59	0.001	− 4.220	1.263	− 6.748	− 1.692
	Equal variances not assumed			− 3.357	55.53	0.001	− 4.220	1.257	− 6.739	− 1.701

Table 7 Descriptive statistics of RC progress of the two experimental groups

	Course	N	Mean	Std. deviation	Std. error mean	Skewness		Kurtosis	
		Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Valid	Non-flipped	30	3.60	4.789	0.874	0.293	0.427	0.516	0.833
	Flipped	31	6.48	5.464	0.981	− 0.250	0.421	0.045	0.821

As Table 7 shows flipping the course led to 6.48 points improvement in RC scores of the participants, while participation in non-flipped classes has brought only 3.60 points improvement in the learners' outcomes. The following Table demonstrates its statistical significance

was subjected to analysis. Accordingly, general information on the differences of mean improvement in vocabulary learning for each group is provided in Table 9.

As Table 9 shows males in non-flipped and in flipped courses, respectively got the lowest and the highest increase in their vocabulary scores. Moreover, in the flipped course the progress of males exceeds that of females. The results of the one-way ANOVA test elucidate the statistical significance of the above differences.

Table 10 demonstrates that the statistical significance of the observed mean difference between and within the targeted groups is supported (p = 0.02). Moreover, the extent of change varied according to the class-gender variable and at 0.05 level of significance, $F_{crit} = 2.77 < F_{(3,\ 57)} = 3.65$. While the *F* ratio is greater than the appropriate critical *F* at 0.05 level of significance, certainly at least one case of statistically significant difference exists among the groups' means (Brown, 2005). So, the Scheffe test was conducted for multiple comparisons to find the details of the existing difference.

According to Table 11, the flipped and non-flipped teaching models resulted in statistically different benefits for female (p = 0.034) and male (p = 0.017) learners from the GE classes. Interestingly, the comparisons manifested that the male partakers of the flipped course experienced the most meaningful improvement in VOC learning, however, gender does not heavily matter since within groups observed differences were not statistically significant ($P(non - flipped) = 0.767, P(flipped) = 0.841$.

Gender differences and brain-based flipped/non-flipped reading classrooms

Finally, the effect of BBCALL on RC of male and female participants of two experimental groups was explored. The following table provides an overview of the groups' progress.

Considering gender.course type, Table 12 indicates females of the flipped course outperformed all, while females of the non-flipped course had experienced the lowest improvement. The results of One-way ANOVA show the meaningfulness of the observed differences.

Table 13 demonstrates that male and female participants within and across the experimental groups benefited statistically differently from the applied treatments (Sig = 0.011). Additionally, at p = 0.05, $F_{(3,\ 57)} = 2.77$ (< 4.042).

Table 14 information implies that the teaching model was more efficient in females' RC improvement (sig = 0.002) than in males' (sig = 0.956). Furthermore, the statistically meaningful outperformance of female participants in the flipped GE course not only suggests their greater benefit from FM than that of male partakers (sig = 0.014) but also underlines their greatest RC improvement.

Table 8 Independent-samples t-test for the experimental groups' progress in reading skill

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference	
									Lower	Upper
Dif.RC	Equal variances assumed	0.714	0.402	− 2.189	59	0.033	− 2.883	1.317	− 5.519	− 0.247
	Equal variances not assumed			− 2.194	58.44	0.032	− 2.883	1.314	− 5.514	− 0.253

Table 9 Descriptive statistics of the four groups' improvement in VOC learning

	N	Mean	Std. deviation	Std. Error	95% Confidence interval for mean	
					lower bound	Upper bound
Female. Non-flipped	18	1.389	4.202	0.990	− 0.701	3.478
Male. Non-flipped	12	**0.833**	4.281	1.236	− 1.887	3.553
Female. Flipped	15	5.**200**	5.401	1.394	2.209	8.191
Male. Flipped	16	**5.563**	5.898	1.474	2.419	8.705
Total	61	3.312	5.333	.682	1.945	4.677

Table 10 One-way ANOVA test for comparison of VOC learning based on course.gender

		Sum of squares	df	Mean square	F	Sig
Dif.VOC	Between groups	274.800	3	91.600	3.65	0.02
	Within groups	1432.282	57	25.128		
	Total	1707.082	60			

Table 11 Scheffe results on multiple comparisons of VOC learning

	(I) Course. gender	(J) Course. Gender	Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval	
						Lower Bound	Upper Bound
Scheffe	Female, Non-flipped	Male.Non-flipped	0.555	1.86	0.**767**	− 3.18	4.29
		Female. Flipped	− 3.811*	1.75	0.**034***	− 7.32	− .30
		Male.Flipped	− 4.173*	1.72	0.**019***	− 7.62	− .72
	Male, Non-flipped	Female.Non-flipped	− 0.555	1.86	0.767	− 4.29	3.18
		Female. Flipped	− 4.366*	1.94	0.**028***	− 8.25	− 0.47
		Male.Flipped	− 4.729*	1.91	0.**017***	− 8.56	− 0.89
	Female, Flipped	Female.Non-flipped	3.811*	1.75	0.**034***	0.30	7.32
		Male.Non-flipped	4.366*	1.94	0.**028***	0.47	8.25
		Male.Flipped	− 0.362	1.80	.841	− 3.97	3.24
	Male, Flipped	Female.Non-flipped	4.173*	1.72	.**019***	0.72	7.62
		Male.Non-flipped	4.729*	1.91	.**017***	0.89	8.56
		Female. Flipped	0.362	1.80	.**841**	− 3.24	3.97

*The mean difference is significant at the 0.05 level

Discussion

Considering the global trend of collaborative research, the application of neuroscience and education, and the existing difficulties of foreign language learning in addition to the necessity of tech integration into instruction to the natives of modern technology, these language courses were held. More succinctly, in this study, the

Table 12 Descriptive statistics of the groups' improvement in RC

	N	Mean	Std. deviation	Std. Error	95% Confidence Interval for mean	
					lower bound	upper bound
Female, non-flipped	18	**3.056**	4.276	1.008	0.928	5.182
Male, non-flipped	12	4.417	5.567	1.607	0.879	7.953
Female, flipped	15	**8.800**	4.329	1.117	6.402	11.197
Male, flipped	16	4.313	5.641	1.410	1.306	7.318
Total	61	5.066	5.303	.679	3.707	6.423

Table 13 One-way ANOVA test for comparison of RC based on course.gender

		Sum of squares	df	Mean square	F	Sig
Dif.RC	Between groups	296.1	3	98.680	4.042	0.011
	Within groups	1391.699	57	24.416		
	Total	1687.738	60			

Table 14 Scheffe results on multiple comparisons of RC mean differences

	(I) Course. Gender	(J) Course. Gender	Mean Difference (I–J)	Std. error	Sig	95% Confidence interval	
						Lower bound	Upper bound
Scheffe	Female.Non-flipped	Male.Non-flipped	− 1.361	1.84	0.463	− 5.04	2.32
		Female.Flipped	− 5.744*	1.72	0.**002***	− 9.20	− 2.28
		Male.Flipped	− 1.256	1.69	0.462	− 4.65	2.14
	Male.Non-flipped	Female.Non-flipped	1.361	1.84	0.463	− 2.32	5.04
		Female.Flipped	− 4.383*	1.91	0.**026***	− 8.21	− 0.55
		Male.Flipped	.104	1.88	0.956	− 3.67	3.88
	Female.Flipped	Female.Non-flipped	5.744*	1.72	0.**002***	2.28	9.20
		Male.Non-flipped	4.383*	1.91	0.**026***	0.55	8.21
		Male.Flipped	4.487*	1.77	**0.014***	0.93	8.04
	Male.Flipped	Female.Non-flipped	1.256	1.69	0.462	− 2.14	4.65
		Male.Non-flipped	− 0.104	1.88	0.956	− 3.88	3.67
		Female.Flipped	− 4.487*	1.77	0.**014***	− 8.04	− 0.93

* The mean difference is significant at the 0.05 level

flexible environment referred to asynchronous and/or synchronous instruction followed by online learning opportunities, learning culture to learners' authority in self-paced learning, intentional content to BB core and supplementary materials, and professional educator to an expert neurolinguistic with years of EFL teaching to whom needing guidance on what to use and how to use from the online sources. Its outstanding research-driven finding is that the low proficient learners benefited most and advanced learners could be ahead of time.

In terms of the effectiveness of vocabulary learning strategies involving association, imagination, and analysis in learners' lexicon expansion, which were the brain-based stages focused on in vocabulary learning, it was in line with the results of similar studies on EFL learners of Japan (Schmitt, 1997) and China (Gu & Johnson, 1996), CAL learners (Segler et al., 2002), Indian preschool female learners (Nemati, 2009), and ESP students (Lago & Seepho, 2012). The reason is that similar to these studies, the teaching model used in the current research had a positive effect on the learners' vocabulary learning due to the significance index reported earlier (sig. = 0.001).

In line with the findings of the present study, which supported the efficiency of flipped instruction, some other research projects have been carried out worldwide showing the positive aspects of this teaching technique. Flipped learning literature is mostly empirical with a focus on non-natives and their promising findings encourage its practice. FM's practicality for higher education systems, in particular, due to students' higher self-regulation and student/instructor satisfaction was remarkably noticed as had been by Davies et al. (2013), Lundin et al., (2018), and Huang and Hew (2018). It is additionally approved by Bredow et al. (2021) who evaluated 317 research on FM with respect to academic, intra-/interpersonal, and satisfaction-related outcomes in higher education contexts. The present findings are also backed by that of Abdelshaheed (2017) and Hung (2015) revealing better achievements of participants of the flipped classes and the greatest effort of those taking part in the structured-flipped courses. Although Hung (2015) argued learners' positive attitude and satisfaction approve usefulness of this method, here their relation was reciprocal. Similarly, the results of Zarinfard et al. (2021) comparing GE vocabulary and grammar learning outcomes of 50 engineering students, being taught with the conventional or flipped method, were in favor of the experimental group with a large effect size for vocabulary and middle effect size for the grammar. They assigned the outcomes to the underlying theories of FTM underscoring higher-level cognitive skills and the necessity of providing low-level learners with appropriate teaching aids and learning strategies.

BBL reasonably suggests that the exclusion of learning challenges and breaks makes learners 'tune out" (Dwyer, 2002, p. 267), though their inclusion results in neural connection, information association, and learning rehearsal. Therefore, BBL with implicit instruction and purposeful intervals suited the purpose of FM and the present treatments' impact is explicable by intentional learning breaks, frequent interactive feedback, and active learning theory (Bonnell & Eison, 1991) leading to better engagement and materials retention. This was indeed the intention of the researchers in the current study to accentuate the vital role of brain-based techniques in improving the learning process of the core language component of vocabulary and RC as one of the most significant skills in a second language learning context. There are of course more concise meta-analyses that reconfirm the statistical efficiency of FTM on cognitive learning as Cheng et al. (2019) analyzing students' cognitive learning achievements across the findings of 55 FTM studies and Shi et al. (2020) reviewing 33 research for cognitive learning of college students.

Conclusions

The current study's aim was to scrutinize the role of brain-based technique in a CALL-oriented classroom context with regard to learning vocabulary and reading comprehension through the application of flipped versus non-flipped methodology. To this end, four research questions were formulated where two questions focused on gender of the learners as the moderator variable. It was indeed hypothesized that the flipped classroom setting could have a positive effect on the students' learning of vocabulary and reading comprehension in comparison with the non-flipped course. The general purpose of the study was to delve into the cognitive aspects of CALL and integrate the principles of educational neurolinguistics into the practical stages of teaching and learning. As Hardiman (2001) believes "education initiatives that link current practice with promising new research in neurological and cognitive sciences…offer real possibilities for improving teaching and learning" (p. 2). Accordingly, this review presented the need for greater attention to theoretically brain-based online courses consolidated with more modern tech-oriented pedagogical approaches.

Concurring with Verleur et al., view (2011), modern learners "are in image-rich environments, have a need for interactivity, are emotionally open, and show a preference for activities that promote and reinforce social interaction" (p. 573). Thus, BBL-considered application of cutting-edge technologies, while observing critics including privatization of education, excessive technologies use, and teachers' elimination (Marshall and Taylor, 2003) can make educational settings highly leveraged. It is due to the fact that the bedrock of BBL is not merely augmenting learners' achievement but their perception and boosting long-term memory for information storage and retrieval. In so doing, Jensen (2005) puts forward the multitasking power of the brain including pattern assembling, meaning comprising, and categorizing personal experiences accordingly.

Due to the paucity of Brain-Based Flipped Model in the higher education system, this study will be helpful in understanding the use of a BBL and FM in both higher education and communication-themed classrooms. Its findings regarding language teaching modernization can encourage educational officials and stakeholders, namely, course administrators and learners, to design and plan for more dynamic and innovative curricula particularly in higher education contexts as they coincide with those of flipped learning studies in twenty-two universities, namely Washington, British Columbia, and Michigan universities (Aronson et al., 2013).

In contrast to the present findings and the foregoing analyses, Van Alten et al. (2019) found a slight positive effect of FTM on school learners' gains based on the results of 114 publications comparing traditional and flipped courses. However, college students are typically self-disciplined and clear expectations of the instructor can contribute to the success of such courses by changing the mind of some being accustomed to the traditional courses and may find such experience hard. Hence, to organize k-12 education and superficial learning in CALL courses, it seems school officials may need to endeavor to systematize the instructional pedagogies and the plethora of existing online content.

In conclusion, acknowledging the prerequisites of FM implementation as promoting the digital competence of teachers and students, redesigning the courses, and providing the educational platforms and infrastructures costly and demanding, its notable and long-lasting benefits namely critical thinking, efficient participation, effective

communication, and greater comprehension alongside once but multi-purpose investment make it noteworthy.

Therefore, it is hoped that in education curricula, BBL-oriented syllabus design and content development be more concerned to launch creatively interactive online courses. Reasonably, some drawbacks of this study as the impossibility of random sample selection, critical role of gender in the culture of research context leading to be considered as a moderator rather than an independent variable, and the lack of previous studies with the same focus were inevitable. Certainly, future investigations with larger samples and other foci in diverse contexts would not only strengthen the body of pertinent literature but also increase the generalizability of the achieved results. Further studies on the cognitive and emotional aspects of students' learning and engagement can also bring about interesting revelations.

Abbreviations

BBCALL	Brain Based Computer Assisted Language Learning
BBL	Brain Based Learning
BBLL	Brain Based Language Learning
BBLT	Brain Based Language Teaching
CALL	Computer Assisted Language Learning
EFL	English as a Foreign Language
FM	Flipped Model
FTM	Flipped Teaching Model
GE VOC	General English Vocabulary
LMS	Learning Management System
PET	Preliminary English Test
RC	Reading Comprehension
SCORM	Sharable Content Object Reference Model

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