Embodied English Grammar Learning: Language Learning Anxiety Predicts Learning Progress Mediated by State Anxiety and Flow

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***Abstract*—Can shaking electronic devices (e.g., Pads or smartphones) affect participants' embodied learning? To address this question, in this study we designed an application (app) named "Shaking-On" for students to answer quizzes, and applied the achievement emotion theory to design the research model. To understand whether activated/ deactivated emotions have positive/negative impacts on the learning process, the present study involved a 3-week teaching experiment with participants using Shaking-On during class for 15 minutes per week, totaling 45 minutes. The 288 seventh graders from three junior high schools were randomly selected to join this experiment, and 231 data were usefully returned. Questionnaires underwent reliability and validity testing for research model verification, and the results showed that the learners' English learning anxiety was positively associated with their anxiety about using Shaking-On to take quizzes, but was negatively related to flow state while taking quizzes using Shaking-On. Their test anxiety was negatively associated with their learning progress, whereas their flow state was positively related to their learning progress. The results of this study imply that English as a second/foreign language teachers can use Shaking-On to reduce students' state anxiety and promote their flow state and learning progress. Results indicate that adopting game-based learning enables students to be immersed in the learning process and enhances learning outcomes.**

***Keywords*—digital game-based learning, embodied learning, test anxiety, English learning anxiety, flow state, learning progress**

I. Introduction

Digital technology and the use of computers have become part of our daily life. Game apps are especially more popular in various fields, including education. For example, there are a number of free applications (apps) available for use in learning formative assessment, including Edmodo (LMS, examinations, surveys, and indicators); Kahoot! (quizzes, gamification, surveys, and indicators); and Quizizz (quizzes, and word and cultural games). Some of these apps provide a leaderboard which allow players to see how well they are doing [1]. Previous studies have indicated that, compared to the other apps [2], Kahoot! is more frequently used in gamification activities and is popular for involving students in taking quizzes in the classroom [3]. Therefore, Kahoot is considered to be a good teaching aid [4]. However, different designs of e-learning platforms provide different ways for students to interact that promote various psychological outcomes. A previous study indicated that Kahoot! provides a more static approach to answering quiz questions compared to shaking a device, resulting in lower learning achievement [5]. When learning via body movement, students become aware of how their bodies, psyches, and actions are associated, and are stimulated to engage with the concept of the collective mind [6]. It has been suggested that devices with motion sensors are suitable for embodied learning [7], and Schmidt *et al*. found that embodied learning was effective in terms of teaching children new foreign language vocabulary [8]. A study by Alipova *et al*. also found the potential of interactive and participatory methods to enhance learning experiences and outcomes [9]. Nevertheless, few studies have particularly explored the effect of shaking electronic devices on embodied learning of English grammar. Therefore, in the present study, we developed a way for L2 students to practice English grammar through Shaking-On, and examined the learning effect.

The theory of embodied cognition proposes that motor simulation has an immediate effect on individuals' emotional and mental states while learning [10]. Thus, our bodily experiences broadly shape our cognitive abilities [11], which shape the concepts that we have extracted from our primary experiences. For example, Schmidt *et al*.'s study, which designed physical activities to help primary school children learn foreign language vocabulary, showed that embodied activity could improve their learning performance [8]. Particularly, gamification in learning has been found to emotionally engage learners, supporting the brain function that links emotions and cognition in a task [12]. Considering that the task version of Shaking-On may drive students' activated emotion such as flow state, and their deactivated emotion such as anxiety when taking quizzes (hereafter, test anxiety), the present study aimed to understand how participants' English learning anxiety (ELA) related to their text anxiety and flow state, and how their flow and text anxiety were reflected in their learning progress while playing Shaking-On.

II. Theoretical Background

In language learning, the information process emphasizes encoding, storage, and retrieval, which are suitable for processing semantic and episodic information in which the

individual's emotion affects their ability to recall fluently [13]. The present study explored anxiety, which is relevant to trait and state psychological factors, in the context of using Shaking-On to practice English grammar. Trait anxiety and its impact on flow state and anxiety when using the new app to take quizzes are described in the following paragraphs.

A. English Learning Anxiety and Test Anxiety

According to Spielberger and Gorsuch, anxiety is made up of two main components, specifically Trait and State anxiety [14]. Trait anxiety has been defined as one's tendency to feel threatened by stressful situations. This then increases one's basal level of anxiety, leading to susceptibility to chronic anxiety [15]. On the other hand, Bradley explained that State anxiety is a transitory state rather than a tendency, in which one experiences feelings of apprehension and tension when one finds oneself in a stressful situation [15]. This is not a stable state, but rather varies in intensity and over time. Comparing the two types of anxiety, State anxiety denotes an acute response to a situation, whereas Trait anxiety is a more stable trait [16]. In line with this, the present study considered English Learning Anxiety (ELA) as a form of Trait anxiety, while text anxiety was considered as a form of State anxiety.

In the educational process, many adolescents are faced with a variety of assessment tests and competitions from elementary school onwards, which may trigger test anxiety [17]. Based on a concept analysis of students' test anxiety, Gibson defined it as a psychological state that involves worry and emotionality [18]. Test anxiety often involves intense fear, and feelings of hopelessness, inferiority, and desperation [19]. Test anxiety is common among adolescents, and may have long-term negative effects on their physical and mental health [17]. However, student anxiety about performing tests with psychomotor manipulation can be reduced by the use of quick response codes with information processing provided by mobile technology [20]. Considering the time limitation for students to answer English grammar quiz questions by shaking their mobile devices, we were interested in exploring how participants' test anxiety was impacted in the process.

B. Flow State

A relevant mental state that facilitates technology adoption is the state of mind-flow [21]. Flow theory states that individuals experience flow when the challenges of the activity fully engage their skills, but do not overwhelm them. In the study of educational methods that are both challenging and engaging, gamification has emerged as an innovative strategy [22]. Flow is related to a state of profound concentration which is experienced while individuals are performing game activities [23]. Sport psychology scholars working on the flow experience since 1992 have predominantly focused on individual experiences "on the move," where the flow experience occurs in diverse sets of physical practices [24]. However, the time of being "on the move" in most sports is short, and the flow state occurs during peak performance [25]. Accordingly, considering Shaking-On as an example of being "on the move" while answering quiz questions for three periods of 45 minutes, the level of flow may be aroused when students' experience is associated with their peak performance. Thus, participants' flow state as they used Shaking-On to answer English grammar questions was explored in this study.

C. Learning Progress

Learning progress is the progress and achievement of the learner in the learning process. Cognitive Theory of Multimedia Learning suggests that in the context of multimedia learning, learning outcomes are influenced by various cognitive factors [26]. In addition, the theory of processing efficiency states that anxiety leads to task-irrelevant processing, for example worry, which then negatively impacts the working memory's capacity to store and process information that is relevant to the task [27]. As the quality of learners' performance with embodied learning may well increase if the information related to a simulation meets their working memory capacity [28], the present study explored whether, and to what extent, participants' English grammar performance improved while using Shaking-On.

D. Research Questions

Considering the advantage of using arm movements for embodied function, we designed an app named Shaking-On as a way to stimulate embodied learning. The app requires players to shake their smartphones or Pads to initiate the G sensor to connect with the teacher's device after selecting their answers to multiple-choice questions. The app was designed based on new neurological evidence which indicates the activation of affective circuits prior to the activation of cognitive circuits during learning tasks [29]. That is, the features and functions of the learning device design can affect learners' cognition and affection. Accordingly, this study drew on the Achievement Emotion Model (AEM) [30], with the particular aim of understanding the correlates between players' English learning anxiety, test anxiety, flow state, and learning progress while playing Shaking-On to evaluate English grammar learned by answering quiz questions; thus, the following research questions were proposed:

RQ1: Is there a relationship among students' ELA, test anxiety, flow state, and learning progress when using the Shaking-On app?

RQ2: Is there any significant improvement in learning with the Shaking-On app?

III. Research Hypotheses and Model

A. English Learning Anxiety and Test Anxiety

Trait-anxiety refers to a pre-existing form and is considered as a stable dispositional difference [31]. Individuals exhibit high anxiety because they process a great deal of attentional bias and interpretive bias [31]. Notably, the level of trait anxiety reflects to a certain degree the emotional changes brought about by the learner's awareness of feelings in their body [32]. Research on the awareness of internal body states has found that trait anxiety plays an important role in sensing information concerning the state of the body, and then in integrating that information so as to create a subjective emotional experience [33]. For psychological correlations, general anxiety measures are correlated with test anxiety moderation [34]. Language anxiety has a direct influence on test anxiety [35].

Watthanapas *et al.*'s study also found that Thai language anxiety was positively related to test anxiety [36]. In China, the teaching of English as a foreign language at various levels has been characterized as being input-based, text-centered, and test-oriented [37]. Accordingly, to explore how English learning anxiety related to test anxiety while participants played Shaking-On, the following hypothesis was proposed:

H1: English learning anxiety is positively related to test anxiety.

B. English Learning Anxiety and Flow State

Flow has been defined as a state of total immersion in an activity, during which one is faced with a challenge at the upper limits of one's ability. While in a flow state, one follows a series of goals and receives feedback, according to which one adjusts one's behavior [38]. However, flow can be negatively influenced by worry, as it has been found that worrying, a characteristic of highly anxious individuals, has a detrimental impact on cognitive processing, which makes it more difficult to focus on the task at hand [27]. Consistent with this, anxiety and stress have emerged as unique negative outcomes of absent-minded smartphone use and as a unique negative predictor of flow [39]. Moreover, language anxiety as a type of cognitive anxiety has been found to impact flow experience [40]. For example, one study found that reducing student anxiety related to asking questions while frequently playing Kahoot! over a period of 5 months had an effect on students' flow experience [41]. Another study found that Thai language anxiety has been shown to be negatively related to playfulness [36]. In conclusion, these two emotions have been shown to co-exist and negatively correlate with each other [42]. In addition, recent sport literature has specified that activity shifting requires extensive attention, and that anxiety co-varies in a negative manner with flow [43, 44]. When students engage in using Shaking-On to answer quiz questions, the activity includes "on the move" processing (shaking the device) and non-move processing (looking at the questions and thinking of the answer); thus, how the learners' ELA related to their flow state when using Shaking-On to answer English grammar quiz questions was hypothesized as follows:

H2: English learning anxiety is negatively related to flow state.

C. Test Anxiety and Learning Progress

Early models of test anxiety attempted to explain the effects of test anxiety on performance [34]. According to Eysenck *et al.*'s attentional control theory, anxiety disrupts the activity of some, but not all, functions in one's working memory [45]. Additionally, according to this theory, anxiety can hinder the ability to inhibit irrelevant stimuli, and thus exacerbates the influence that distractions have on the individual's working memory [45], which may function less efficiently as a result of feeling anxious[46]. Recent research has found that poor academic performance is closely related to the worry or cognitive component [47]. Exam anxiety plays a role in lowering grades through a number of theorized mechanisms that divert attention from the exam[34]. That is, students who suffer from test anxiety can be easily distracted during tests, and this distraction decreases their attention to the test and prevents them from effectively processing the test information [48]. It is therefore generally accepted that anxiety has a negative influence on task performance. Thus, to understand how test anxiety affects learning progress when playing Shaking-On, the following hypothesis was proposed:

H3: Test anxiety is negatively related to learning progress.

D. Flow State and Learning Progress

When the focus of emotion is on relevant stimuli, flow experience is generated. This indicates that the individual is totally absorbed in a challenging task, and has no energy left for distractions [49]. It is not only during physical activity that flow occurs; it can also be experienced with symbolic reaction and attitudes toward information processes [50]. According to Flow theory, it is more likely that one will experience optimized learning and performance when in a state of mind flow [51]. Enjoyment of activities will cause one to feel strong hedonic processes that will make one unaware of oneself while performing actions. That is, flow has the strongest effects on fostering learning performance. A previous study found that flow experience influenced learning outcomes, as well as both memorization and comprehension [52]. Moreover, flow has an impact on individuals' attention to cognitive processes, and therefore ultimately influences their learning progress [53]. Accordingly, to understand how flow state affects individuals' learning progress in English grammar learning by using Shaking-On, the following hypothesis was proposed:

H4: Flow state is positively related to learning progress.

E. Research Model

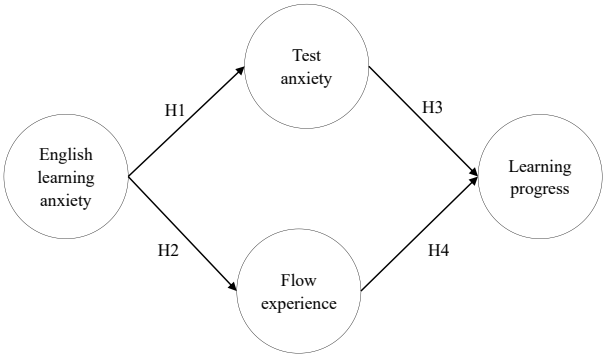

Fig. 1. Research model.

The Achievement Emotion Model (AEM) posits that there are two main types of emotion: activated and deactivated emotion, where activated emotions such as interest, enjoyment, and flow can sustain one's cognitive ability to achieve learning goals [30]. In contrast, deactivated emotions such as anxiety and boredom can lead to negative learning motivation and can reduce one's information processing ability [30]. With reference to cognition and affection in multimedia learning (CAML) [54], the present study sought to identify how trait anxiety would activate students' psychological states, such as flow state and test anxiety, as reflected in their learning progress while playing Shaking-On. Taken together, the relationship between ELA and test anxiety is proposed in hypothesis 1, the relationship between ELA and flow state is proposed in hypothesis 2, the

relationship between test anxiety and learning progress is proposed in hypothesis 3, and the relationship between flow state and learning progress is proposed in hypothesis 4, as shown in Fig. 1. Thus, the following research model was proposed:

IV. The Context of Shaking-on

A. The Features of Shaking-on

The adoption of technology in learning pedagogies enables students to interact with their technological devices. An innovative learning environment was created in light of embodied learning based on cognitive science theories. Moreover, Mavilidi *et al*. highlighted that physical activity advocating body movements can inextricably trigger cognitive processes in a task [55]. For example, when combined with speech, physical activity can reduce working memory load, enhance embodied cognition, and improve learning. In particular, Abrahamson mentioned that an action-based design can specify the facilitation of learning activities [56]. According to the action-based design for promoting embodied learning, in the present study, we designed an app which uses the G sensor in students' mobile devices. Students needed to shake their devices to connect with the Internet to send their answers to the teacher's mobile device.

The teachers in this study used the last 15 minutes of class to give quizzes to students after English grammar teaching. Multiple-choice quiz items were installed in the Shaking-On system. That is, we designed the Shaking-On app to have students shake their mobile devices after selecting answers to multiple-choice questions.

B. Examples of the Learning Content

Taiwan's official language is Chinese, so English learning at the elementary school level is about learning the alphabet and pronunciation and the understanding of short sentence patterns, specifically present simple tense and interrogative sentences. The learning of more formal grammatical concepts starts from the junior high school stage. In Taiwan, the first 6 weeks of the fall semester in the English program for seventh grade students focus on present simple tense, interrogative sentences, and pronouns.

C. How to Play

In this game, the game mode is divided into single player (tournament) mode and group (tournament) mode, which also comprises two types of group mode, elimination and round robin. Learners are invited to join game rooms created by their teachers based on the learning theme. Players have to choose the correct answer to each question in a limited amount of time, and then submit their answers by shaking their mobile phones (see Fig. 2). Moreover, during the game, users and instructors can see the current status of the questions through the "status screen," and after the answers have been given, they can also clearly see the results of each participant's answers on the score screen. In addition, the game has a ranking page function, on which learners can see the total scores of users in different subjects, so as to motivate them to perform better in the game. This game mechanism can help learners learn implicitly. In addition, the game has social features that allow players to become friends and to have conversations in chat rooms. There is also a leaderboard where they can see how well they are doing.

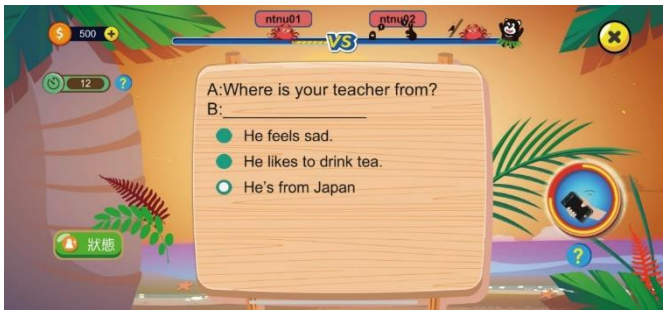

Fig. 2. Screenshot of the shaking-on game.

V. Research Design

A. Methodology

The Hawthorne Effect refers to behavioral changes due to knowing that one is being observed [57]. The existence of the Hawthorne effect could lead to bias, which could profoundly impact the research results [58]. Moreover, it has been found that when technology is used in an experiment, the results tend to be more significant than when no technology is used or when it is only partly used [59]. Taking these issues into consideration, it was decided to use a single group quasi-experiment in this study to examine the research hypotheses, rather than adopting a control group for comparison with an experimental group. The focus was on the relationship between cognition and affection when using Shaking-On to take quizzes.

When performing confirmatory (or relationship-testing) research, the researcher has preconceived ideas about how the variables being examined are related, and aims to determine whether the data support the hypotheses[60]. In confirmatory research, Structural Equation Modelling (SEM) can be conducted using a Confirmatory Factor Analysis model (CFA) represented a multitude regression as a technique, which could be well explained the correlates comprehensibly by its core perspectives of the target group [61]. Accordingly, the data analysis included testing the credibility of the questionnaire by examining item suitability with first-order CFA and the construct reliability and validity for the research participants. Subsequently, second-order CFA and SEM were conducted to verify the hypotheses in the research model from the target samples' perspectives.

B. Procedure and Participants

This study adopted the convenience sampling method, inviting a total of 288 students from the seventh grade of three junior high schools in northern Taiwan to take part in the 3-week game-based learning experiment with the consent of the school, learners, and their parents. In this study, Shaking-On was used as a quizzing tool to review and practice each week's English grammar content. Each week's 15 minutes of practice time allowed students to answer quiz questions on the grammar covered in class that week using Shaking-On. The number of quiz questions answered correctly reflected the learners' retrieval and generation success [62]. Moreover, time pressure when responding to a number of questions can occur as the game playing

progresses [63]. In Taiwan, it is very common for junior high school students to take quizzes comprising over 30 questions in 15 minutes during their so-called early self-study time [64]. Accordingly, for the present study, we designed 35-40 quiz items for each 15-minute quiz. Before the experiment started, participants first filled out the English learning anxiety questionnaire and practiced the English course content via playing Shaking-On for 45 minutes during the 3 weeks, then filled out the flow state and test anxiety questionnaires after completing the learning activity in the 3rd week.

There were 288 participants in this study. Of the 288 data, 57 incomplete responses (including incomplete questionnaires and incomplete participation in the three teaching experiments) were deleted; finally, 231 data were counted as useful for further statistical analysis. The effective recovery rate was 82%, and the data consisted of 123 boys (53.2%) and 108 girls (46.8%). The average age of the participants was 12.68 years old (±.468).

VI. Instruments

A. Development of the Questionnaire

The questionnaire items were developed with reference to previous theories and research. The forward-backward translation method was used, and the questionnaire was examined by experts to ensure face validity. A 5-point Likert scale was adopted as the scoring model. To achieve credibility of the measurements, this was a confirmatory study which re-tested the reliability and validity of the questionnaire constructs by using SPSS 24.0 after data collection.

Table 1. Questionnaire

Item	*M*	*SD*
English learning anxiety		
1. I worry about making mistakes when I speak English.	3.36	0.93
2. I get upset when I don't understand why my teachers are correcting my English.	3.43	0.95
3. I can feel my heart pounding when I'm called on and I have to answer in English.	3.27	0.76
4. Even when I'm prepared to speak English, I get nervous.	3.12	0.92
5. I get so nervous I forget how to say things I know in English.	3.38	0.99
6. I tremble when I know I'm going to have to speak in English.	3.31	1.01
Test anxiety		
1. When teachers use Shaking-On as a quiz, I worry that I cannot answer well.	2.94	0.96
2. When the teacher says that she is going to use Shaking-On as a quiz, I find that my heart begins to beat faster.	2.94	0.94
3. I worry about making mistakes when the teacher uses Shaking-On to find how much I know.	3.20	0.95
4. When playing Shaking-On, I am worried that my score is lower than that of other students.	2.96	0.99
6. When playing Shaking-On, I am so worried that I forget the answers I had previously mastered.	2.90	0.95
Flow state		
1. I have experienced enjoyment when playing Shaking-On.	2.61	0.93
2. I was fully immersed when playing Shaking-On.	2.29	0.94
3. I am completely lost in thought when I play Shaking-On.	2.30	0.85
4. I am absorbed when I play Shaking-On.	2.45	0.96
5. When I play Shaking-On, my mind is too concentrated to feel time passing.	2.09	0.97
6. While playing Shaking-On, my mind un-wandered.	2.54	0.93
7. I feel that any challenge is under control when I play Shaking-On.	2.16	0.97

ELA measurement: This study adapted the English learning anxiety scale developed by Hong et al. which was revised from Horwitz's foreign language learning anxiety scale to measure participants' perceptions of English learning anxiety [65, 66]. Test anxiety measurement: Test anxiety is defined as a state of anxiety regarding tests in which learners feel worried and nervous. Based on this definition, we compiled eight items in the test anxiety scale to measure participants' perceptions of their test anxiety. Flow state measurement: Csikszentmihalyi conceptualized nine dimensions which he considered to be key characteristics of the state of flow, namely challenge and skills balance; merging of action and awareness; clear goals; unambiguous feedback; concentration on the task at hand; sense of control; loss of self-consciousness, transformation of time; and autotelic experience [38]. For this study, we revised Csikszentmihalyi's flow experience scale to measure participants' perceptions of flow state [38]. Nine items were designed for this construct, as shown in Table 1.

B. Item Analysis

In this study, item analysis was performed using first-order confirmatory factor analysis. It has been recommended that χ^2/df values should be below 5; RMSEA values should be below 0.1; GFI and AGFI values should exceed 0.8; and questions with factor loading (FL) values that do not exceed 0.5 should be deleted [67, 68]. Meeting these thresholds indicates a good fit. As can be seen in Table 2, the FL values were all between 0.61 and .00=93. To meet the criteria, several items were deleted, reducing the number of items for English learning anxiety from seven to six, for test anxiety from nine to six, and for flow state, from nine to seven.

Table 2. Item analysis

Constructs	**Internal validity**				
	χ^2/df	GFI	AGFI	RMSEA	Fl
Threshold	< 5	> 0.8	> 0.8	< 0.08	> 0.05
English learning anxiety	3.22	0.96	0.98	0.08	0.71~0.88
Test anxiety	1.48	0.99	0.96	0.04	0.65~0.93
Flow experience	1.21	0.980	0.96	0.30	0.61~0.85

C. Reliability and Validity Analysis

In a validation study, the reliability and construct validity of each construct need to be examined before conducting structural model validation to confirm the stability, consistency, and validity of the instrument. Measuring the reliability and validity of English learning anxiety, Table 3 shows that *Cronbach's α* = 0.92 and *CR* = 0.92. The internal consistency and composite reliability of this construct were therefore acceptable. The average variance extracted (AVE) = 0.65 and FL = 0.80, indicating that the convergent validity of this construct was acceptable [69].

Measuring the reliability and validity of test anxiety, Table 2 shows that the *Cronbach's α* = 0.86 and *CR* = 0.86. The internal consistency and composite reliability of this construct were therefore acceptable. The AVE = 0.66 and FL = 0.67, indicating that the convergent validity of this construct was acceptable [69].

Measuring the reliability and validity of Flow state, Table

3 shows that *Cronbach's α* = 0.85 and *CR* = 0.88. The internal consistency and composite reliability of this construct were therefore acceptable. The AVE = 0.62 and FL = 0.72, indicating that the convergent validity of this construct was acceptable [69].

Table 3. Construct reliability and validity analysis

Constructs	*M*	*SD*	*α*	CR	FL	AVE
English learning anxiety	3.31	1.05	0.92	0.92	0.80	0.65
Test anxiety	2.99	0.98	0.86	0.86	0.67	0.66
Flow experience	2.35	0.85	0.86	0.88	0.72	0.62

VII. Results

A. Learning Progress Analysis

Learning with multimedia is an emotional and cognitive experience [54, 70], and emotions negatively or positively lead students to concentrate on cognitive resources, which affects their achievement [71]. Considering the use of mobile devices to answer quiz questions as a type of multimedia, the students' learning progress was assessed by comparing their first and last quiz scores. In Taiwan, the first 6 weeks of the fall semester of the seventh grade English curriculum focus on present simple tense and interrogative sentences, so this was the scope of this study. In order to assess the students' learning progress, the seventh grade English mock test questions published by the National Academy for Educational Research of Taiwan (NAERT) and which have expert validity were used to evaluate those quiz items before the playing of Shaking-On. From the NAERT mock test, 10 questions of similar difficulty were selected for each time Shaking-On was played, and six experts, including three junior high school teachers and three English professors, helped to examine the content validity of the Shaking-On questions (see Table 4). The result of the learning progress analysis showed that the average score of the first trial was 4.52 points (standard deviation = 1.85 points), and the average score of the last trial was 7.34 points (standard deviation = 1.46 points). Table 5 shows that learners' learning performance improved by an average of 2.82 points, and the paired sample *t*-test results also reached a significant level.

Table 4. Some samples of English grammar content in shaking-on

Question	Options	
Sample quizzes of the first trial		
A: ____ the new cook?	1. How's	3. Where's
B: Great! He is a nice man. Look over there. He is cooking fish now.	2. What's	4. Who's
A: ____is the basketball game?	1. How old	3. What day
B: It's on Saturday.	2. What time	4. Where
Sample quizzes of the last-trial		
A: ____ can your brother do?	1. How	3. What
B: He can play tennis.	2. Why	4. When
A: Is this Rose and Carl's orange farm.	1. No, it isn't.	3. Yes, it is.
B: ____ Their farm is not here. Go to Lucky Town, and you can see it.	2. No, they aren't.	4. Yes, they are.

Table 5. Learning progress analysis

Test	*M*	*SD*	*t*-value	*d*	Result
First trial	4.52	1.85	−31.68***	1.69	2>1
Last-trial	7.34	1.46			

***$p < 0.001$

B. Model Fit Analysis

Model fit analysis is used to evaluate the stability and fit of a structural model and as a basis for judging the merits of a structural model. Scholars suggest that the recommended value of each fitting index is that the chi-square degree of freedom ratio (χ^2/df) must be less than 5 [67], and the root mean square error of approximation (RMSEA) should be less than 0.1. The goodness-of-fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), non-normed fit index (NNFI), comparative fit index (CFI), incremental fit index (IFI), and relative fit index (RFI) should be greater than 0.8 [72], and the parsimonious normed fit index (PNFI) and parsimonious goodness of fit index (PGFI) should also be greater than 0.5 [67]. The statistical verification values of this study were $\chi^2 = 195$, $df = 149$, $\chi^2/df = 1.31$, RMSEA = 0.04, GFI = 0.92, AGFI = 0.90, NFI = 0.92, NNFI = 0.98, CFI = 0.98, IFI = 0.98, RFI = 0.91, PNFI = 0.80, and PGFI = 0.72. All values reached the suggested index values and fit the model well.

C. Path Analysis

This study adopted AMOS20 to verify the paths of the research model, and to confirm the relational nature between hypothetical paths. The results indicated that: English learning anxiety was positively related to test anxiety (β = 0.38***, t = 5.34); English learning anxiety was negatively related to Flow state (β = −0.33***, t = −4.33); test anxiety was negatively related to learning progress (β = −0.19**, t = −3.03), but Flow state was positively related to learning progress (β = 0.35***, t = 4.93). As shown in Fig. 3, test anxiety $f^2 = 0.13$, Flow state $f^2 = 0.16$, and learning progress $f^2 = 0.22$, all indicating that the effects were moderate [67].

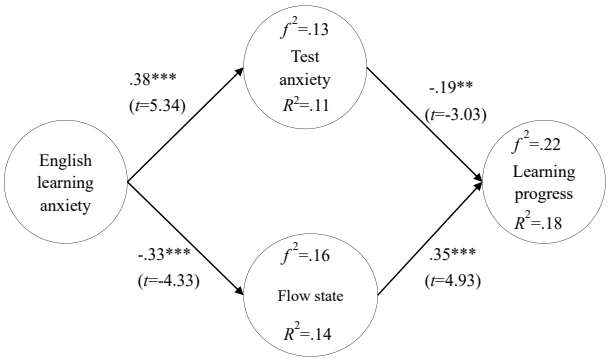

Fig. 3. Research model verification (**$p < .01$, ***$p < .001$).

VIII. Discussion

Schmidt *et al*. defined embodiment as the bodily states (such as arm movements and postures) that occur as a result of interactions with the semiotic world, and explained that it can trigger cognitive processing [8]. In other words, motor and cognitive abilities are strongly interrelated, and influence young people's academic achievement [73]. For example, the number of questions answered in a quiz reflects retrieval and generation success [62]. Moreover, time pressure when responding to a number of questions can influence the progression of game playing [63]. Accordingly, for the present study, we designed 35-40 quiz items to be completed in 15 minutes each time the students used Shaking-On.

Considering this time pressure, which can create a certain degree of anxiety, the learning effect of students moving their arms during the quiz was explored, as this is a topic that has not previously been extensively studied [74]. Thus, the present study explored the correlates between two types of anxiety, flow state, and learning progress.

A. English Learning Anxiety was Positively Related to Test Anxiety

Trait anxiety plays a critical role in perceiving information about the state of the body and then integrating this information to produce subjective emotional experience [33]. It has been found that people can have a large number of attentional and interpretive biases when they show high levels of anxiety [31]. However, working memory comprises complex cognitive operations including manipulation, retrieval, and transformation of visual input. Cognitive processing centers on individual working memory and affects anxiety [75]. While past studies on state anxiety (e.g., reading anxiety) tapped into trait anxiety (i.e., general anxiety in learning English) [75], the current study is the first to examine how Taiwanese junior high school students' test anxiety is predicted by ELA when using Shaking-On to take English grammar quizzes. The result of this study verified H1, indicating that the higher level of ELA participants had, the higher level of test anxiety they had. That is to say, the anxiety as part of cognitive processes in time-limited interventions [76]. Accordingly, by using Sharking-On, test anxiety was expected to occur, and the results revealed that individuals' ELA affected their working memory and was grounded in their test anxiety. The result confirms Salehi and Marefat's research finding that English learning anxiety and test anxiety are positively correlated to each other [77]. In other words, the higher a student's level of anxiety about learning language, the higher the level of test anxiety he or she will feel when playing educational games of a testing nature.

B. English Learning Anxiety was Negatively Related to Flow State

Anxiety and stress are considered to be the only negative results of absent-minded use of smartphones and the only negative predictors of flow [39]. Stress would cause negative impacts on individuals' physical and psychological states. If participants do not feel pressured to do a task, they would be more likely to experience positive emotions [75]. In their study, Zuniga and Payant found that the repetition of oral tasks was able to significantly enhance learners' flow experience [78]. This is an example of a trait anxiety influencing a positive experiential state characterized by intense focus and task engagement. When singled out to answer questions, inadequate time pressure affects the reactions of making errors in which ELA could have effects on flow experience [79]. Accordingly, when participants were using Shaking-On to answer quiz questions, they were under pressure to answer 35-40 questions in 15 minutes in an activity which included "on the move" processing (shaking the device) and non-move processing (looking at the questions and thinking of the answers). Thus, how their ELA related to their flow state when using Shaking-On to answer English grammar questions was explored. The result revealed that H2 was not supported. This confirms a previous study which found that language anxiety is a form of cognitive anxiety that could affect flow experience [40]. In other words, the higher the level of language learning anxiety, the more difficult it is for students to become immersed in the process of playing educational games with language learning.

C. Test Anxiety was Negatively Related to Learning Progress

It is suggested in attentional control theory that stress could disrupt some functional activities in working memory [45]. Also, the central executive area, inhibitory function, displacement function, and processing efficiency of working memory of the brain tend to be less efficient when people are anxious [46]. Meanwhile Cassady's study revealed that test anxiety blocks learners' processing functions related to learning tasks and leads to a lower level of learning achievement [80]. It has also been discovered in many studies that anxiety is particularly associated with poor academic performance [47]. That is to say, in the exact mechanism by which emotions interact with working memory, anxiety would have negative impacts on working performance. For example, when interacting with a game involving verbal-analytical and motor control, participants' cognitive anxiety was negatively related to their learning progress [40]. Accordingly, using Shaking-On to answer quiz questions, participants engaged in "on the move" motor-control, and it was revealed that test anxiety could negatively predict their learning progress. Thus, H3 was supported, in line with the above studies. Briefly, a higher level of test anxiety has negative influences on learning performance.

D. Flow State Was Positively Related to Learning Progress

Csikszentmihalyi asserted that a flow state arises from the optimal balance of challenge and skill [38]. Therefore, positive gaming experience provides students with the motivation to continue learning, which in turn helps them to improve their knowledge. Studies have also found that flow experience affects learners' memory and understanding of the learning outcome [52]. In language learning, MacIntyre and Gregersen suggested that learners could be more focused on classes and be better able to understand learning content, if students had better absorbance when learning foreign language knowledge [81]. Moreover, motor behavior has been found to play a significant role in flow experience [82]. For example, when interacting in a game involving motor control, participants' flow experience was found to positively predict their learning progress [40]. However, flow not only occurs when using information systems, but also occurs in physical activities [50]. Consistent with this, in this study's participants were engaged in motor-control as embodied responses when using Shaking-On to answer quiz questions, and the results revealed that flow state could positively predict their learning progress. From this, we can see that H4 was positively supported, showing that flow had the greatest impact on improving the learners' academic performance [62]. That is, the more immersed students are in the educational game experience, the better their learning progress will be.

E. Challenges of Game-Based Learning

Game-based learning, as implemented in this study using the Shaking-On app, is an effective way of learning. Game-based learning is widely recognized as a method that can help students learn in a meaningful way. However, there are still some challenges that need to be recognized. All meaningful learning methods need to be carefully designed or they will be severely compromised. For example, Rezapour pointed out that in order to effectively maintain the state of mind of student players, the educational gaming industry must adopt automated, flexible, scalable and accurate methods for assessing changes in player skills over time, so that game challenges can be instantly adjusted according to player ability [51].

In addition, due to the high cost of customized educational games, open source educational games are needed to popularize the game-based learning approach. Meanwhile, due to the influence of educational concepts, game-based learning or teaching methods are not widely implemented in schools in Chinese regions.

F. Implications

This dynamic answering method was designed in Shaking-On to help learners activate their brains to stimulate the cognitive processing mechanism, so as to enhance the learning effects. The results of this research show that in game-based learning, game apps with test characteristics would still have negative impacts on learners' academic performance. Therefore, it is suggested that when planning learning content, game designers should also consider whether the content difficulty would trigger users to have a high level of test anxiety.

Previous research on embodied cognition has mainly explained the influences of physical activity on cognitive processes and learning [83]. In the classroom, learning with physical activity has effects on cognitive functioning [84]; for example, the physiological changes brought about by gross motor exercise with arm movement have been found to affect academic achievement [85]. However, there is often a lack of physical activity during the learning process, such as when using Kahoot! [86]. Thus, to enhance students' embodying cognition, teachers can apply Shaking-On as a formative assessment instrument.

In addition, most of the studies on embodied learning in the past were on whole body movement or large body movement, with few studies on small body or simple movement embodied learning. Therefore, this study validated the learning benefits of embodied learning games based on simple movements through teaching experiments, and the results can thus be useful for educational game designers and teachers as a reference in game design or lesson plan design.

Although the research shows that flow state and learning progress are positively correlated, the participants did not generate a high level of flow state (M = 2.35, SD = 0.85). According to Csikszentmihalyi, an important prerequisite for generating flow state is a good balance between human skills and the ability to cope with challenges [87]. Although this study adopted the simulated test questions of the National High School Examination that have expert validity, there may still be an imbalance between learners' ability and challenge difficulty. Thus, it is suggested that game designers should carefully evaluate whether the game difficulty suits learners' level of ability.

G. Limitations and Future Study

Mayer divided game studies into i) value-added research, in which specific game functions that could help promote learning effectiveness were discussed; ii) cognitive consequences research, discussing whether game-playing promotes cognitive ability; and iii) media comparison research, which compares the effects of traditional teaching materials and game-based teaching materials, exploring more detailed explanations of game utility [88]. Since this research was a confirmatory study that focused on the relationship between cognition, affection, and learning effect when the learners were using the Shaking-On app, follow-up studies could adopt the perspective of the three comparative studies mentioned by Mayer for further analysis.

The results of this study indicated that using Shaking-On can activate students' flow state, but their flow state may fluctuate when they encounter different learning subjects. To elaborate on the possibility of flow state as a psychological effect of game-based learning, future research may include a quasi-experimental study to involve students in more practice in different learning subjects using Shaking-On to explore the change of flow state along with the activation of embodied learning.

Based on mapping learning styles [89], the components of the VARK technique – Visual, Aural, Read, and Kinesthetic - correspond to the four channels that are used to receive and process information. "On the move" may work for some people, but not for others. Therefore, it is suggested that in the follow-up research, we can conduct an in-depth study on students' preferences for educational games, playing styles, and game mechanisms through qualitative interviews, and summarize the elements required for educational games, so as to design more educational games that can teach, entertain, and motivate learning.

In addition, artificial intelligence's high degree of interactivity and feedback capabilities are thought to be useful for educational practices. However, it is still unknown how AI technology can be effectively applied to game-based learning. This is an important research gap, and clarifying this issue will help game-based learning to enter the next stage of development.

IX. Conclusion

The game-based learning mode of educational computer games has been recognized as a beneficial approach for learners to gain knowledge while having fun. In recent years, the emergence of various technologies that require human body interaction and somatosensory movement has also prompted educators to adopt somatosensory learning approaches in various learning environments. The learning tool, Shaking-On, used in this research incorporates human-computer interaction through shaking a device with an expectation of activating the brain and flow by somatosensory operation, thus improving cognitive mechanisms and further supporting learners' language

learning.

Digital game-based language learning can stimulate motivation and enable learners to feel immersed in learning. Nonetheless, different learners can be affected in different ways by certain game elements or learning content. Thus, this research explored the relationship between English learning anxiety, test anxiety, flow state, and learning progress based on the theory of cognitive affection in multimedia learning. The result shows that English learning anxiety is positively related to test anxiety, but negatively related to learning interest, whereas test anxiety is negatively related to learning progress, and flow state is positively related to learning progress when shaking the mobile devices.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

J.-C.H.: Conceptualization, Methodology, Supervision, Project administration, Funding acquisition, and Writing - Original Draft; J.-H.Y.: Conceptualization, Methodology, Formal analysis, Data Curation, Writing - Original Draft, and Writing - Review & Editing; L.-P.M.: Data Curation, and Writing - Review & Editing; J.-Y.F.: Writing - Original Draft, and Writing - Review & Editing; J.-N.Y.: Validation, Formal analysis, and Investigation; all authors had approved the final version.

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REFERENCE

[1] L. Mejia-Puig and T. Chandrasekera, "The virtual body in a design exercise: A conceptual framework for embodied cognition," *International Journal of Technology and Design Education*, vol. 33, no. 5, pp. 1861–1882, 2023. https://doi.org/10.1007/s10798-022-09793-8

[2] S. A. Licorish, H. E. Owen, B. Daniel, and J. L. George, "Students' perception of Kahoot!'s influence on teaching and learning," *Research and Practice in Technology Enhanced Learning*, vol. 13, no. 1, p. 9, 2018. https://doi.org/1.1186/s41039-018-0078-8

[3] D. O. Göksün and G. Gürsoy, "Comparing success and engagement in gamified learning experiences via Kahoot and Quizizz," *Computers & Education*, vol. 135, pp 5–29, 2019. https://doi.org/1.1016/j.compedu.2019.02.015

[4] J.-H. Ye, N. Watthanapas, and Y.-F. Wu, "Applying Kahoot in Thai language and culture curriculum: Analysis of the relationship among online cognitive failure, flow experience, gameplay anxiety and learning performance," *International Journal of Information and Education Technology*, vol. 10, no. 8, pp. 563–572, 2020. https://doi.org/10.18178/ijiet.2020.10.8.1425

[5] J. C. Hong, K. H. Tai, W. L. Low, Y. J Sher, and Y. W. Kao, "Comparing the Taiwanese learning effects of Shaking-On and Kahoot!" *Journal of Computer Assisted Learnin*, vol. 38, no. 3, pp. 892–905, 2022. https://doi.org/10.1111/jcal.12655

[6] J. Adler, "The collective body," in P. Pallaro (Ed.), *Authentic movement: Essays by Mary Stark Whitehouse, Janet Adler and Joan Chorodow*, London: Jessica Kingsley, 1994.

[7] R. Alberto, A. Shvarts, P. Drijvers, and A. Bakker, "Action-based embodied design for mathematics learning: A decade of variations on a theme," *International Journal of Child-Computer Interaction*, vol. 32, 100419, 2022. https://doi.org/10.1016/j.ijcci.2021.100419.

[8] M. Schmidt, V. Benzing, A. Wallman-Jones, M. F. Mavilidi, D. R. Lubans, and F. Paas, "Embodied learning in the classroom: Effects on primary school children's attention and foreign language vocabulary learning," *Psychology of Sport & Exercise*, vol. 43, pp. 45–54, 2019. https://doi.org/1.1016/j.psychsport.2018.12.017

[9] A. Alipova, A. Turganbayeva, L. Alimzhanova, V. Savelyeva, and R. Malybayev, "Evaluating the effectiveness of gaming practices in enhancing computer science terminology learning among primary school students," *International Journal of Information and Education Technology*, vol. 14, 6, pp. 865–875, 2024. https://doi.org/10.18178/ijiet.2024.14.6.2112.

[10] L. Shapiro and S. Spaulding, "Embodied cognition," in *The Stanford Encyclopedia of Philosophy*, E. N. Zalta, (Ed.), Metaphysics Research Lab, Stanford University, 2021.

[11] K. R. Allen, K. A. Smith, L. A. Bird, J. B. Tenenbaum, T. R. Makin, and D. Cowie, "Lifelong learning of cognitive styles for physical problem-solving: The effect of embodied experience," *Psychonomic Bulletin & Review*, vol. 31, no. 3, pp. 1364–1375, 2024. https://doi.org/10.3758/s13423-023-02400-4

[12] L. Pessoa, "A network model of the emotional brain," *Trends in Cognitive Sciences*, vol. 21, no. 5, pp. 357–371, 2017. https://doi.org/1.1016/j.tics.2017.03.002

[13] N. Schwarz and G. L. Clore, "Mood as information: 20 years later," *Psychological Inquiry*, vol. 14, pp. 296–303, 2003. https://doi.org/1.1207/S15327965PLI1403&4_20

[14] C. D. Spielberger and R. L. Gorsuch, *State-Trait Anxiety Inventory for Adults: Manual and Sample: Manual, Instrument and Scoring Guide*, Consulting Psychologists Press, 1983.

[15] A. Bradley, *Trait and State Anxiety: Assessment, Predictors and Outcomes*, Nova Publishers, 2016.

[16] P. Weeks, A. Hayley and C. Stough, "Do individual differences in state and trait anxiety predict sleep difficulties in healthy older adults?" *Personality and Individual Differences*, vol. 144, pp. 141–146, 2019. https://doi.org/1.1016/j.paid.2019.03.004

[17] C. Chen, P. Liu, F. Wu, H. Wang, S. Chen, Y. Zhang, W. Huang, Y. Wang, and Q. Chen, "Factors associated with test anxiety among adolescents in Shenzhen, China," *Journal of Affective Disorders*, vol. 323, pp. 123–130, 2023. https://doi.org/10.1016/j.jad.2022.11.048

[18] H. A. Gibson, "A conceptual view of test anxiety," *Nursing Forum*, vol. 49, no. 4, pp. 267–277, 2014. https://doi.org/1.1111/nuf.12069

[19] J. N. Prinz, E. Bar-Kalifa, E. Rafaeli, H. Sened, and W. Lutz, "Imagery-based treatment for test anxiety: A multiple-baseline open trial," *Journal of Affective Disorders*, vol. 244, pp. 187–195, 2019. https://doi.org/1.1016/j.jad.2018.1.091

[20] L. A. T. Kenny, T. Gaston, K. Powers, and A. Isaac-Dockery, "Anxiety in nursing students: The impact of using mobile technology with quick response codes," *Nurse Education Today*, vol. 89, 104382, 2020. https://doi.org/1.1016/j.nedt.202.104382

[21] M. Gómez-Rico, M. L. Santos-Vijande, A. Molina-Collado, and A. Bilgihan, "Unlocking the flow experience in apps: Fostering long-term adoption for sustainable healthcare systems," *Psychology & Marketing*, vol. 40, no. 8, pp. 1556–1578, 2023. https://doi.org/10.1002/mar.21824

[22] B. Maraza-Quispe, L. C. Traverso-Condori, S. B. Torres-Gonzales, R. E. Reyes-Arco, S. T. Tinco-Túpac, E. Reyes-Villalba, and J. R. Carpio-Ventura, "Impact of the use of gamified online tools: A study with Kahoot and Quizizz in the educational context," *International Journal of Information and Education Technology*, vol. 14, no. 1, pp. 132–140, 2024. https://doi.org/10.18178/ijiet.2024.14.1.2033

[23] J. C. Hong, K. H. Tai, and J. H. Ye, "Playing a Chinese Remote Associated Game: The correlation among flow, self-efficacy, collective self-esteem, and competitive anxiety," *British Journal of Educational Technology*, vol. 50, no. 5, pp. 2720–2735, 2019. https://doi.org/1.1111/bjet.12721

[24] J. C. Kimiecik and G. L. Stein, "Examining flow experiences in sport contexts: conceptual issues and methodological concerns," *Journal of*

Applied Sport Psychology, vol. 4, pp. 144–160, 1992. https://doi.org/10.1080/10413209208406458
[25] P. C. Jackman, E. J. Dargue, J. P. Johnston, and R. M. Hawkins, "Flow in youth sport, physical activity, and physical education: A systematic review," *Psychology of Sport & Exercise*, vol. 53, 101852, 2021. https://doi.org/10.1016/j.psychsport.2020.101852
[26] N. Watthanapas, Y.-W. Hao, J.-H. Ye, J.-C. Hong, and J.-N. Ye, "The effects of using virtual reality on Thai word order learning," *Brain Sciences*, vol. 13, no. 3, 517, 2023. http://dx.doi.org/10.3390/brainsci13030517
[27] M. W. Eysenck and M. G. Calvo, "Anxiety and performance: The processing efficiency theory," *Cognition and Emotion*, vol. 6, pp. 409–434, 1992. https://doi.org/1.1080/02699939208409696.
[28] P. Kosmas, A. Ioannou, and P. Zaphiris, "Implementing embodied learning in the classroom: Effects on children's memory and language skills," *Educational Media International*, vol. 56, no. 1, pp. 59–74, 2019. https://doi.org/1.1080/09523987.2018.1547948
[29] M. Johnson, *Embodied Mind, Meaning, and Reason: How Our Bodies Give Rise to Understanding*, Chicago, Illinois: The University of Chicago Press, 2017.
[30] R. Pekrun, "The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice," *Educational Psychology Review*, vol. 18, pp. 315–341, 2006. https://doi.org/1.1007/s10648-006-9029-9.
[31] M. W. Eysenck, "Trait anxiety, repressors and cognitive biases," in J. Yiend (Ed.), *Cognition Emotion and Psychopathology: Theoretical, Empirical and Clinical Directions*, Cambridge University Press, 2004, pp. 49–67)
[32] H. S. Park, "Factors associated with foreign language anxiety from learners' perspective," *The New Studies of English Language & Literature*, vol. 64, pp. 253–274, 2016. https://doi.org/1.21087/nsell.2016.08.64.253
[33] J. Ernst, H. Böker, J. Hättenschwiler, D. Schüpbach, G. Northoff, E. Seifritz, and S. Grimm, "The association of interceptive awareness and alexithymia with neurotransmitter concentrations in insula and anterior cingulate," *Social Cognitive and Affective Neuroscience*, vol. 9, no. 6, pp. 857–863, 2014. http://dx.doi.org/1.1093/scan/nst058
[34] D. A. Robson, S. J. Johnstone, D. W. Putwain, and S. Howard, "Test anxiety in primary school children: A 20-year systematic review and meta-analysis," *Journal of School Psychology*, vol. 98, pp. 39–60, 2023. https://doi.org/10.1016/j.jsp.2023.02.003
[35] H. T. D. Huang, "Modeling the relationships between anxieties and performance in second/foreign language speaking assessment," *Learning and Individual Differences*, vol. 63, pp. 44–56, 2018. https://doi.org/1.1016/j.lindif.2018.03.002
[36] N. Watthanapas, J.-C. Hong, J.-H. Ye, J.-N. Ye, and Y.-W. Hao, "Applying motion sensing gaming to learning Thai syntax: Relationship among Thai learning attitudes, language anxiety, gameplay flow, test anxiety and self-confidence enhancement in Thai syntax," *Journal of Research in Education Sciences*, vol. 66, no. 3, pp. 213–246, 2021. https://doi.org/10.6209/JORIES.202109_66(3).000
[37] Q. Wen, "The production-oriented approach to teaching university students English in China," *Language Teaching*, vol. 51, no. 4, pp. 526–54, 2016. https://doi.org/1.1017/S026144481600001X.
[38] M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*, New York: Harper & Row, 1990.
[39] J. Marty-Dugas and D. Smilek, "The relations between smartphone use, mood, and flow experience," *Personality and Individual Differences*, vol. 164, 109966, 2020. https://doi.org/1.1016/j.paid.202.109966
[40] J. C. Hong, K. H. Tai, M. Y. Hwang, and Y. C. Kuo, "Internet cognitive failure affects learning progress as mediated by cognitive anxiety and flow while playing a Chinese antonym synonym game with interacting verbal-analytical and motor-control," *Computers & Education*, vol. 100, pp. 32–44, 2016. https://doi.org/10.1016/j.compedu.2016.04.009
[41] A. I. Wang, "The wear out effect of a game-based student response system," *Computers & Education*, vol. 82, pp. 217–227, 2015. https://doi.org/1.1016/j.compedu.2014.11.004
[42] C. Li, J. Huang, and B. Li, "The predictive effects of classroom environment and trait emotional intelligence on foreign language enjoyment and anxiety," *System*, vol. 96, 102393, 2021. https://doi.org/10.1016/j.system.2020.102393
[43] W. Kwon and H. Lee, "How does stadium atmosphere affect spectator behavior, flow, and revisit intentions? Implications from embodied cognition theory and environmental psychology," *Korean Journal of Sport Management*, vol. 20, no. 4, pp. 67–80, 2015.
[44] H. W. Lee, C. Gipson, and C. Barnhill, "Experience of spectator flow and perceived stadium atmosphere: Moderating role of team identification," *Sport Marketing Quarterly*, vol. 26, no. 2, pp. 87–98, 2017.
[45] M. W. Eysenck, N. Derakshan, R. Santos, and M. G. Calvo, "Anxiety and cognitive performance: Attentional control theory," *Emotion*, vol. 7, no. 2, pp. 336–353, 2007. https://doi.org/1.1037/1528-3542.7.2.336
[46] M. W. Eysenck and N. Derakshan, "New perspectives in attentional control theory," *Personality and Individual Differences*, vol. 50, no. 7, pp. 955–96, 2011. http://dx.doi.org/1.1016/j.paid.201.08.019
[47] U. Aydin, "Test anxiety: Gender differences in elementary school students," *European Journal of Educational Research*, vol. 8, no. 1, pp. 21–30, 2019. https://doi.org/1.12973/eu-jer.8.1.21
[48] A. Krispenz, C. Gort, L. Schültke, and O. Dickhäuser, "How to reduce test anxiety and academic procrastination through inquiry of cognitive appraisals: Investigating the role of academic self-efficacy," *Frontiers in Psychology*, vol. 10, 1917, 2019. https://doi.org/1.3389/fpsyg.2019.01917
[49] K. Kiili, T. Lainema, S. Freitas, and S. Arnab, "Flow framework for analyzing the quality of educational games," *Entertainment Computing*, vol. 5, no. 4, pp. 367–377, 2014. https://doi.org/1.1016/j.entcom.2014.08.002
[50] R. Agarwal and E. Karahanna, "Time flies when you're having fun: Cognitive ab-sorption and beliefs about information technology usage," *MIS Quarterly*, vol. 24, no. 4, pp. 665–694, 2000. https://doi.org/1.2307/3250951.
[51] M. M. Rezapour, A. Fatemi, and M. A. Nematbakhsh, "Learning experience assessment through players chat content in multiplayer online games," *Computers in Human Behavior*, vol. 151, 108003, 2024. https://doi.org/10.1016/j.chb.2023.108003
[52] S. Erhel and E. Jamet, "Improving instructions in educational computer games: Exploring the relations between goal specificity, flow experience and learning outcomes," *Computers in Human Behavior*, vol. 91, pp. 106–114, 2019. https://doi.org/1.1016/j.chb.2018.09.020
[53] J. C. Hong, M. Y. Hwang, and K. H. Tai," Intrinsic motivation of Chinese learning in predicting online learning self-efficacy and flow experience relevant to students' learning progress," *Computer Assisted Language Learning*, vol. 30, no. 6, pp. 552–574, 2017. https://doi.org/1.1080/09588221.2017.1329215
[54] R. E. Mayer and G. Estrella, "Benefits of emotional design in multimedia instruction," *Learning and Instruction*, vol. 33, pp. 12–18, 2014. https://doi.org/10.1016/j.learninstruc.2014.02.004
[55] M. Mavilidi, F. Paas, A. Okely, and P. Chandler, "Embodying cognition in the classroom: A new approach to foster physical activity and learning," *Journal of Science and Medicine in Sport*, vol. 18S, pp. e72–e107, http://dx.doi.org/1.1016/j.jsams.2014.11.364
[56] D. Abrahamson, "Building educational activities for understanding: An elaboration on the embodied-design framework and its epistemic grounds," *International Journal of Child-Computer Interaction*, vol. 2, no. 1, pp. 1–16, 2014.
[57] S. R. G. Jones, "Was there a Hawthorne effect?" *American Journal of Sociology*, vol. 98, no. 3, pp. 451–468, 1992. https://doi.org/10.1086/230046.
[58] M. Chiesa and S. Hobbs, "Making sense of social research: How useful is the Hawthorne effect?" *European Journal of Social Psychology*, vol. 38, no. 1, pp. 67–74, 2008. https://doi.org/10.1002/ejsp.401
[59] R. F. Schmid, R. M. Bernard, E. Borokhovski, R. M. Tamim, P. C. Abrami, M. A. Surkes, C. A. Wade, and J. Woods, "The effects of technology use in postsecondary education: A meta-analysis of classroom applications," *Computers & Education*, vol. 72, pp. 271–291, 2014. https://doi.org/10.1016/j.compedu.2013.11.002
[60] R. G. Butler, *Exploratory vs Confirmatory Research*, 2014.
[61] C. Nachtigall, U. Kroehne, F. Funke, and R. Steyer, "(Why) should we use SEM? Pros and Cons of structural equation modeling," *Methods of Psychological Research Online*, vol. 8, no. 2, pp. 1–22, 2003.
[62] S. Heitmann, A. Grund, S. Fries, K. Berthold, and J. Roelle, "The quizzing effect depends on hope of success and can be optimized by cognitive load-based adaptation," *Learning and Instruction*, vol. 77, 101526, 2022. https://doi.org/10.1016/j.learninstruc.2021.101526
[63] P. Anunpattana, M. N. A. Khalid, H. Iida, and W. Inchamnan, "Capturing potential impact of challenge-based gamification on gamified quizzing in the classroom" *Heliyon*, vol. 7, e08637, 2021. https://doi.org/10.1016/j.heliyon.2021.e08637
[64] T. H. Wang, "Web-based quiz-game-like formative assessment: Development and evaluation," *Computers & Education*, vol. 51, pp. 1247–1263, 2008. https://doi.org/10.1016/j.compedu.2007.11.011
[65] J. C. Hong, M. Y. Hwang, K. H. Tai, and Y. L. Chen, "Using calibration to enhance students' self-confidence in English vocabulary learning relevant to their judgment of over-confidence and predicted by smartphone self-efficacy and English learning anxiety," *Computers*

& Education, vol. 72, pp. 313–322, 2014. https://doi.org/1.1016/j.compedu.2013.11.011
[66] E. K. Horwitz, "Preliminary evidence for the reliability and validity of a foreign language anxiety scale," *Tesol Quarterly*, vol. 20, no. 3, pp. 559–562, 1986. https://doi.org/10.2307/3586302
[67] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis* (8th ed.), Cengage, 2019.
[68] D. A. Kenny, B. Kaniskan, and D. B. McCoach, "The performance of RMSEA in models with small degrees of freedom," *Sociological Methods & Research*, vol. 44, no. 3, pp. 486–507, 2015. https://doi.org/10.1177/0049124114543236
[69] L. A. McClure, M. L. Boninger, H. Ozawa, and A. Koontz, "Reliability and validity analysis of the transfer assessment instrument," *Archives of Physical Medicine and Rehabilitation*, vol. 92, pp. 499–508, 2011. https://doi.org/1.1016/j.apmr.201.07.231
[70] B. Park, J. L. Plass, and R. Brunken, "Cognitive and affective processes in multimedia learning," *Learning and Instruction*, vol. 29, pp. 125–127, 2014. https://doi.org/10.1016/j.learninstruc.2013.05.005
[71] R. Pekrun, S. Lichtenfeld, H. W. Marsh, and K. Murayama, "Achievement emotions and academic performance: Longitudinal models of reciprocal effects," *Child Development*, vol. 88, no. 5, pp. 1653–1670, 2017. https://doi.org/10.1111/cdev.12704
[72] G. Abedi, F. Rostami, and A. Nadi, "Analyzing the dimensions of the quality of life in hepatitis B patients using confirmatory factor analysis," *Global Journal of Health Science*, vol. 7, no. 7, pp. 22–31, 2015. https://doi.org/1.5539/gjhs.v7n7p22
[73] M. Schmidt, F. Egger, V. Benzing, K. Jager, A. Conzelmann, C. M. Roebers, and C. Pesce, "Disentangling the relationship between children's motor ability, executive function and academic achievement," *PLoS One*, vol. 12, no. 8, e0182845, 2017. https://doi.org/1.1371/journal.pone.0182845
[74] M. F. Mavilidi, M. Ruiter, M. Schmidt, A. D. Okely, S. Loyens, P. Chandler, and F. Paas, "A narrative review of school-based physical activity for enhancing cognition and learning: The importance of relevancy and integration," *Frontiers in Psychology*, vol. 9, 2079, 2018. https://doi.org/1.3389/fpsyg.2018.02079
[75] B. W. Y. Chow, J. Mo, and Y. Dong, "Roles of reading anxiety and working memory in reading comprehension in English as a second language," *Learning and Individual Differences*, vol. 92, 102092, 2021. https://doi.org/10.1016/j.lindif.2021.102092
[76] Y. Jin, J. M. Dewaele, and P. D. MacIntyre, "Reducing anxiety in the foreign language classroom: A positive psychology approach," *System*, vol. 101, 102604, 2021. https://doi.org/10.1016/j.system.2021.102604
[77] M. Salehi and F. Marefat, "The effects of foreign language anxiety and test anxiety on foreign language test performance," *Theory & Practice in Language Studies*, vol. 4, no. 5, pp. 931–94, 2014. https://doi.org/1.4304/tpls.4.5.931-940
[78] M. Zuniga and C. Payant, "In flow with task repetition during collaborative oral and writing tasks," *Canadian Journal of Applied Linguistics*, vol. 24, pp. 48–69, 2021. https://doi.org/10.37213/cjal.2021.31365
[79] J.-M. Dewaele, "Online questionnaires," in *The Palgrave Handbook of Applied Linguistics Research Methodology*, A. Phakiti, P. De Costa, L. Plonsky and S. Starfield (Eds.), Palgrave Macmillan, 2018, pp. 269-286.
[80] J. C. Cassady, "The influence of cognitive test anxiety across the learning-testing cycle," *Learning and Instruction*, vol. 14, pp. 569–592, 2004. https://doi.org/1.1016/j.learninstruc.2004.09.002
[81] P. D. MacIntyre and T. Gregersen, "Emotions that facilitate language learning: The positive broadening power of the imagination," *Studies in Second Language Learning and Teaching*, vol. 2012, no. 2, pp. 193–213, 2012. https://doi.org/1.14746/ssllt.2012.2.2.4
[82] C. Swann, L. Crust, and S. A. Vella, "New directions in the psychology of optimal performance in sport: Flow and clutch states," *Current Opinion in Psychology*, vol. 16, pp. 48–530, 2017. https://doi.org/10.1016/j.copsyc.2017.03.032
[83] S. Goldin-Meadow and S. L. Beilock, "Action's influence on thought: The case of gesture," *Perspectives on Psychological Science*, vol. 5, no. 6, pp. 664–674, 2010. https://doi.org/1.1177/1745691610388764
[84] D. Lubans, J. Richards, C. Hillman, G. Faulkner, M. Beauchamp, M. Nilsson, P. Kelly, J. Smith, L. Raine, and S. Biddle, "Physical activity for cognitive and mental health in youth: A systematic review of mechanisms," *Pediatrics*, vol. 138, no. 3, e20161642, 2016. https://doi.org/1.1542/peds.2016-1642
[85] J. E. Donnelly, C. H. Hillman, J. L. Greene, D. M. Hansen, C. A. Gibson, D. K. Sullivan, J. Poggio, M. S. Mayo, K. Lambourne, A. N. Szabo-Reed, S. D. Herrmann, J. J. Honas, M. R. Scudder, J. L. Betts, K. Henley, S. L Hunt, and R. A. Washburn, "Physical activity and academic achievement across the curriculum: Results from a 3-year cluster-randomized trial," *Preventive Medicine*, vol. 99, pp. 140–145, 2017. https://doi.org/1.1016/j.ypmed.2017.02.006.
[86] S. Y. Chien, G. J. Hwang, and M. S. Y. Jong, "Effects of peer assessment within the context of spherical video-based virtual reality on EFL students' English-Speaking performance and learning perceptions," *Computers & Education*, vol. 146, 103751, 2020. https://doi.org/1.1016/j.compedu.2019.103751
[87] M. Csikszentmihalyi, "Play and intrinsic rewards," *Journal of Humanistic Psychology*, vol. 15, pp. 41–63, 1975. https://doi.org/1.1177/002216787501500306
[88] R. E. Mayer, "Computer games in education," *Annual Review of Psychology*, vol. 70, pp. 531–549, 2019. https://doi.org/1.1146/annurev-psych-010418-102744
[89] N. D. Fleming, *Teaching and Learning Styles: VARK Strategies*, Christchurch, NZ: Neil Fleming, 2001.