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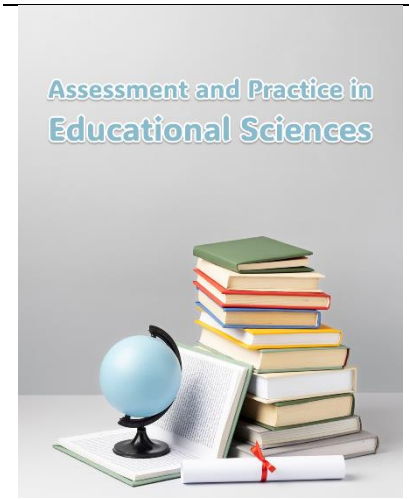

A Structural Equation Modeling Approach to Iranian EFL Learners' Willingness to Communicate: The Mediating Roles of Foreign Language Enjoyment and L2 Grit

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ABSTRACT

Willingness to communicate (WTC) has been recognized as a crucial construct in second language acquisition, reflecting learners' readiness to initiate communication in the target language. Although previous studies have investigated the relationships among L2 Motivational Self System (L2MSS), achievement goal orientation, Foreign Language Enjoyment (FLE), grit, and WTC, these constructs have largely been examined independently, leaving the integration of motivational and positive psychological perspectives insufficiently explored. The present study aimed to develop and test an integrated model explaining Iranian EFL learners' WTC by examining the direct and indirect effects of L2MSS and achievement goal orientation through the mediating roles of L2 grit and FLE. A sequential explanatory mixed-methods design was employed. In the quantitative phase, questionnaire data were collected and analyzed using descriptive statistics, reliability analysis, confirmatory factor analysis, correlation analysis, and structural equation modeling (SEM). The qualitative phase involved semi-structured interviews to provide deeper insights into the quantitative findings. Results indicated that L2MSS and achievement goal orientation significantly predicted WTC. Moreover, their effects were partially mediated by L2 grit and FLE, demonstrating that motivational factors contribute to communicative willingness by enhancing learners' perseverance and positive emotional experiences in language learning. Qualitative findings further showed that WTC is shaped not only by linguistic competence but also by learners' self-perceptions, emotional engagement, and sustained effort. This study contributes to second language research by integrating motivational and positive psychological dimensions into a unified framework. The findings emphasize the importance of supportive classrooms that foster motivation, resilience, and enjoyment to facilitate effective communication.

Keywords: Willingness to Communicate (WTC); L2 Motivational Self System (L2MSS); Achievement Goal Orientation; Foreign Language Enjoyment (FLE); L2 Grit

Introduction

Communication constitutes one of the principal purposes of second language learning because the acquisition of linguistic knowledge gains practical value when learners are prepared to use the target language for meaningful interaction. Nevertheless, possessing grammatical knowledge, vocabulary, pronunciation ability, or even relatively advanced communicative competence does not necessarily ensure that learners will voluntarily initiate or sustain interaction in a second or foreign language. Some

learners actively seek opportunities to communicate despite limited linguistic resources, whereas others with stronger proficiency avoid speaking even when communication opportunities are readily available. This discrepancy has placed willingness to communicate (WTC) at the center of research on individual differences in second language acquisition. L2 WTC broadly concerns learners' readiness to enter into discourse at a particular time with particular interlocutors using the second language and therefore represents an important link between underlying linguistic competence and actual communicative behavior. Early work demonstrated that WTC is associated not only with language competence but also with learners' social support, motivational orientations, and situational experiences, suggesting that communicative participation emerges from the interaction of multiple psychological and contextual processes (1). Evidence from EFL environments has likewise indicated a meaningful relationship between learners' WTC and success in English learning, reinforcing the educational significance of understanding why some students readily communicate while others remain reluctant (2). The construct is particularly consequential in foreign language settings such as Iran, where learners frequently have limited opportunities to use English beyond formal educational environments. Under such circumstances, willingness to participate in classroom communication may substantially determine the amount of meaningful L2 use available to learners and, consequently, their opportunities to develop fluency, confidence, and interactional competence.

Research has progressively moved away from viewing WTC as a stable personality characteristic and toward understanding it as a dynamic outcome of learner-internal and learner-external conditions. Classroom WTC can vary according to motivational states, interlocutor characteristics, social support, task conditions, perceived competence, emotions, and the broader classroom environment. In this regard, Dewaele and Dewaele demonstrated that foreign-language classroom WTC is shaped by a combination of internal learner characteristics and external contextual predictors, emphasizing that communication readiness cannot be adequately explained by a single psychological variable (3). Earlier research also linked integrative motivation to willingness to communicate, indicating that learners who attach greater personal and social meaning to L2 learning may be more prepared to engage communicatively (4). Such findings are compatible with the broader individual-differences perspective in language learning, according to which motivation, personality, self-related beliefs, affective experiences, and behavioral persistence jointly contribute to differences in learners' engagement and achievement (5). Consequently, contemporary investigation of WTC increasingly requires integrative explanatory models capable of representing both distal motivational orientations and more immediate psychological mechanisms through which those orientations are translated into communicative action.

Among the motivational frameworks relevant to this issue, the L2 Motivational Self System (L2MSS) has become particularly influential. The L2MSS conceptualizes language-learning motivation in terms of learners' self-related future representations and experiences and emphasizes the motivational power of discrepancies between current and desired future selves (5). Of particular relevance is the Ideal L2 Self, which reflects the image of the person learners would ideally like to become as users of the target language. When this future image is vivid and personally meaningful, learners may invest greater effort in language learning because current learning behaviors are interpreted as steps toward a desired future identity. Such motivational self-guides may also influence communicative behavior. Learners who imagine themselves as competent and active English users are theoretically more likely to perceive communication not merely as a classroom requirement but as behavior consistent with an important future self. Recent research further supports the broader significance of ideal-L2-self processes in sustained engagement. Derakhshan and Fathi found that the Ideal L2 Self, together with growth mindset, predicted EFL student engagement, while L2 grit served as an important mediating mechanism (6). This evidence suggests that motivational visions may influence observable engagement partly by strengthening perseverance, raising the possibility that similar mechanisms operate when learners decide whether to communicate in English.

Achievement goal orientation represents another important motivational dimension that may contribute to WTC. Whereas the L2MSS primarily addresses future self-guides and motivational identity, goal orientation concerns the purposes and standards learners adopt when approaching achievement situations. Learners may differ in the extent to which they strive to develop competence, demonstrate competence, avoid appearing incompetent, or prevent failure. Such orientations can influence effort, persistence, emotional responses, strategy use, and reactions to difficulties, all of which are relevant to communication in an additional language. Speaking English publicly exposes learners to uncertainty, errors, evaluation, and possible communication breakdown, making their interpretation of achievement and failure especially important. Learners who regard challenging interaction as an opportunity for improvement may be more inclined to participate than those who perceive mistakes primarily as evidence of inadequacy. Research on closely related motivational and self-regulatory processes has shown that future-oriented self-conceptions and adaptive beliefs can contribute to achievement through sustained effort. For example, Fathi, Pawlak, and Hejazi demonstrated that ideal L2 writing self, growth L2 writing mindset, and L2 writing grit were interconnected in explaining L2 writing achievement, illustrating the importance of combining motivational cognition with perseverance-related mechanisms (7). These findings provide a basis for examining goal orientation alongside L2MSS rather than treating motivational processes as isolated antecedents of communication.

A particularly relevant mechanism connecting motivation with sustained communicative behavior is grit. General positive psychology conceptualizations emphasize strengths that allow individuals to pursue valued goals, adapt constructively to difficulty, and maintain engagement despite obstacles (8). Within second language research, however, perseverance may take domain-specific forms because language learning involves repeated exposure to errors, slow progress, communicative uncertainty, and extended periods of effort. Teimouri, Plonsky, and Tabachnick therefore conceptualized L2 grit specifically in relation to perseverance and sustained passion for learning a new language, thereby adapting the construct to the distinctive demands of second language development (9). L2 grit may be especially important for WTC because communication often requires learners to continue speaking despite lexical gaps, grammatical errors, misunderstanding, embarrassment, or unsuccessful attempts to express meaning. A learner who persists through such challenges is more likely to remain communicatively engaged rather than withdraw when difficulties arise. Evidence across EFL settings increasingly demonstrates the importance of grit for adaptive educational outcomes. Theiyab Alazemi and colleagues identified meaningful relationships among L2 grit, academic buoyancy, academic emotion regulation, and personal-best goals, indicating that persistence is embedded within a wider network of motivational and emotional resources (10). Similarly, Hong and Sun showed that L2 grit is meaningfully associated with growth mindset, conscientiousness, and foreign-language performance, further supporting its role as an important individual-difference variable in EFL achievement (11). Although some of this evidence concerns performance rather than communication itself, it suggests that perseverance may constitute an important pathway through which motivational orientations become sustained language-learning behavior.

The relevance of grit also extends beyond learner achievement to broader forms of engagement in language education. Azari Noughabi and colleagues reported associations among EFL teachers' immunity, L2 grit, and work engagement, demonstrating that grit is connected with sustained professional involvement even within demanding instructional environments (12). Fathi, Zhang, and Arefian similarly found that professional identity, L2 grit, and foreign language teaching enjoyment contributed to explaining EFL teachers' work engagement (13). Although teachers and learners operate within different psychological and professional contexts, these findings collectively reinforce the idea that grit functions most meaningfully when examined in relation to other motivational and affective resources. For learners, therefore, L2 grit may not independently generate willingness to communicate; rather, it may mediate the influence of stronger motivational systems such as L2MSS and goal orientation by converting aspirations and achievement goals into sustained effort during communicative challenges. From this

perspective, learners with clearer future L2 selves or stronger achievement orientations may become more willing to communicate partly because these motivational resources enhance their readiness to persevere when communication is effortful.

At the same time, persistence alone is unlikely to explain why learners willingly approach communicative opportunities. Second language communication is inherently emotional, and learners' participation decisions are often shaped by whether the classroom is experienced as threatening, supportive, frustrating, or enjoyable. The emergence of Positive Psychology marked an important shift in psychological research from an almost exclusive focus on dysfunction and negative states toward systematic investigation of strengths, well-being, positive emotions, and optimal functioning (14). This movement subsequently influenced second language acquisition by encouraging researchers to investigate not only language anxiety but also positive emotional experiences that may broaden engagement and promote successful language use. MacIntyre, Gregersen, and Mercer emphasized that Positive Psychology offers a productive framework for SLA because positive emotions, strengths, and supportive conditions may shape language-learning trajectories alongside negative affective variables (15). Foreign Language Enjoyment (FLE) has become one of the most prominent constructs within this perspective. FLE reflects positive experiences arising from successful engagement, interest, interpersonal connection, accomplishment, and the stimulating challenges of learning and using another language. Importantly, enjoyment should not simply be understood as the absence of anxiety; learners may experience enjoyment and anxiety simultaneously, and each can make a distinctive contribution to language-learning behavior.

The classroom origins of FLE further underscore its relevance to WTC. Positive emotions may be influenced by teachers, peers, task design, learner personality, and perceptions of progress. Dewaele and MacIntyre demonstrated that foreign language enjoyment and anxiety are associated with a combination of learner characteristics, multicultural personality traits, and teacher-related variables, highlighting the socially situated nature of emotional experience in language classrooms (16). When learners perceive the classroom as supportive, engaging, and tolerant of mistakes, communication may become emotionally rewarding rather than psychologically risky. This matters directly for WTC because learners who enjoy classroom interaction may be more willing to initiate speech, respond spontaneously, participate in discussions, and tolerate the uncertainty accompanying real-time L2 communication. Indeed, Lee specifically examined grit and classroom enjoyment in relation to EFL learners' willingness to communicate and demonstrated that these positive psychological resources play important roles in explaining communicative readiness (17). This finding is especially important because it suggests that grit and enjoyment may constitute complementary mechanisms: grit may sustain participation when communication becomes difficult, whereas enjoyment may make learners more inclined to approach and repeat communicative experiences.

The potential interplay between motivation, grit, FLE, and WTC therefore warrants integrated investigation. Motivational self-guides and goal orientations may establish why learners invest in English, but the translation of such motivation into actual communication may depend on learners' capacity to persist and their emotional experience of participation. A learner with a strong Ideal L2 Self may aspire to become a proficient English speaker, yet this aspiration may fail to result in classroom communication if the learner withdraws after errors or consistently experiences communication as unpleasant. Conversely, a learner who enjoys English activities may eagerly participate in the short term but show inconsistent engagement without enduring motivational commitments and perseverance. Accordingly, combining L2MSS, goal orientation, L2 grit, and FLE within a single explanatory framework may provide a more complete account of WTC than examining each construct independently. Existing research supports several components of this framework: motivation has been associated with WTC (4); learner-internal and learner-external variables jointly predict classroom WTC (3); grit and classroom enjoyment are related to WTC (17); and motivational self-processes can operate through grit in predicting engagement and achievement (6, 7).

Nevertheless, these relationships have seldom been tested simultaneously in a unified structural model in which L2 grit and FLE operate as parallel mediators between motivational antecedents and WTC.

Gender adds another layer of complexity to this issue. The influence of motivational and emotional variables may not necessarily operate with identical strength across male and female learners because communication is embedded in social, affective, and educational experiences that can vary between learner groups. Rather than assuming gender differences a priori, an empirical multi-group approach can determine whether the same measurement structure and structural relationships are supported across groups. Establishing measurement invariance is particularly important because meaningful comparison requires evidence that the underlying constructs are measured in equivalent ways. Once equivalence is established, differences in structural pathways can be examined to determine whether L2MSS, goal orientation, grit, and FLE contribute similarly or differently to WTC. Such analysis is particularly valuable in the Iranian EFL context, where comparatively little integrated evidence is available concerning gender-conditioned relationships among motivational self-guides, achievement orientations, positive emotions, perseverance, and communication readiness. A multi-group SEM approach can therefore extend previous correlational findings by simultaneously estimating direct and indirect relationships while identifying whether specific pathways differ across male and female learners.

A further limitation of exclusively quantitative models is that statistically significant paths indicate whether variables are related but do not fully explain how learners themselves experience these mechanisms during communication. For example, an indirect relationship between L2MSS and WTC through grit may suggest that perseverance transmits part of the motivational effect, but quantitative coefficients alone cannot reveal whether learners perceive this process as continuing after mistakes, overcoming embarrassment, repeatedly practicing difficult forms, or remaining committed to future communication goals. Similarly, mediation through FLE may reflect multiple experiential processes, including reduced fear, supportive teacher behavior, enjoyable activities, peer acceptance, or satisfaction derived from successful communication. A mixed-methods approach is therefore useful for connecting statistical relationships with learners' lived interpretations. Such integration is consistent with contemporary positive-psychological perspectives in SLA, which emphasize that positive learner functioning emerges from complex interactions among internal strengths, affective states, social relationships, and contextual affordances (15). It also responds to the broader conceptual position that individual differences should be understood as interacting components of language-learning behavior rather than isolated predictors (5). By incorporating learners' qualitative accounts after structural modeling, it becomes possible to explain not only whether grit and enjoyment mediate motivational influences on WTC but also the classroom experiences through which these processes become meaningful to learners.

Taken together, the existing literature establishes a strong theoretical foundation for examining WTC through an integrated motivational and positive-psychological framework, yet several gaps remain. WTC has been linked to communicative success, social support, motivation, and classroom conditions (1, 2); Positive Psychology has highlighted the importance of strengths and adaptive emotional experiences in human functioning and SLA (8, 14); FLE has emerged as an important positive emotion shaped by both learner and classroom factors (16); and L2 grit has increasingly been associated with achievement, engagement, resilience-related variables, and communication (9-11). Furthermore, recent studies demonstrate that grit can act as an explanatory mechanism connecting motivational or identity-related variables with engagement and performance (6, 7), while research involving language teachers also illustrates the joint importance of grit, enjoyment, identity, and sustained engagement (12, 13). However, insufficient attention has been devoted to a single model that simultaneously examines L2MSS and goal orientation as motivational antecedents, L2 grit and FLE as parallel mediators, and WTC as the communicative outcome, while also comparing the structural relationships across gender and qualitatively exploring how learners understand the roles of persistence and enjoyment in their communicative behavior.

Accordingly, the present study aimed to develop and test an integrated model of Iranian EFL learners' L2 willingness to communicate by examining the direct and indirect effects of the L2 Motivational Self System and goal orientation through the mediating roles of L2 grit and Foreign Language Enjoyment, comparing the proposed structural relationships across male and female learners, and qualitatively exploring learners' perceptions of how L2 grit and FLE shape their willingness to communicate.

Methods and Materials

This study adopted a mixed-methods research design, specifically an explanatory sequential design, to obtain a comprehensive understanding of the factors influencing Iranian EFL learners' willingness to communicate (WTC). In the first phase, quantitative data were collected to examine the structural relationships among L2 Motivational Self System (L2MSS), goal orientation, L2 grit, Foreign Language Enjoyment (FLE), and L2 WTC. The quantitative findings subsequently informed the qualitative phase, in which semi-structured interviews were conducted to provide a deeper explanation of the statistical results. This design was selected because it allows qualitative findings to elaborate, clarify, and extend the interpretation of quantitative outcomes, thereby providing a more comprehensive understanding of the proposed conceptual model.

The target population comprised Iranian learners of English as a Foreign Language (EFL) enrolled in private language institutes in Tabriz, Iran. Considering Boomsma's (1985) recommendation that a minimum sample size of 200 participants is appropriate for structural equation modeling (SEM), a total of 326 learners participated in the quantitative phase of the study. The participants, aged between 15 and 30 years, were recruited from the male and female branches of Iran Language Institute (ILI), Goldis Language Institute, Chitsazan Language Institute, and Safir-e Danesh Language Institute. Their English proficiency ranged from upper-intermediate to advanced levels according to the ACTFL Proficiency Guidelines, as determined by the placement tests routinely administered by the participating institutes. Convenience sampling was employed for the quantitative phase because the participants were readily accessible and met the inclusion criteria.

Consistent with the explanatory sequential mixed-methods design, a subset of the quantitative sample participated in the qualitative phase. Following the completion of the quantitative analyses, 25 learners were purposefully selected for semi-structured interviews to provide richer explanations for the statistical findings. To ensure variation in participants' experiences and perceptions, the interviewees were selected according to both gender and academic achievement. The final qualitative sample consisted of five higher-achieving male learners, five higher-achieving female learners, five lower-achieving male learners, five lower-achieving female learners, and five learners with average achievement levels. This stratified selection procedure enabled the study to capture a broad range of perspectives regarding learners' motivation, goal orientation, grit, enjoyment, and willingness to communicate.

Prior to the main data collection, all research instruments were carefully reviewed by three university experts in applied linguistics and educational psychology to evaluate their content appropriateness, clarity, and suitability for the target population. Based on their comments, minor modifications were made to improve the wording of several items. Subsequently, the questionnaires were piloted with a sample of 30 Iranian EFL learners from language institutes similar to those participating in the main study. The pilot study was conducted to evaluate the internal consistency and preliminary validity of the instruments before the large-scale administration. Reliability was examined using Cronbach's alpha coefficient, while construct validity was assessed through confirmatory factor analysis (CFA) and the Average Variance Extracted (AVE) indices. The results confirmed that all instruments possessed satisfactory psychometric properties and were therefore appropriate for the main study.

After obtaining permission from the participating language institutes, the researcher contacted the institute administrators and English teachers to arrange the data collection process. The participating teachers were informed about the objectives of

the study, the administration procedures, and the ethical considerations so that standardized instructions could be provided to all participants. Before completing the questionnaires, the participants were informed about the purpose of the study and assured that their participation was entirely voluntary. They were also informed that they could withdraw from the study at any stage without any negative consequences. Anonymity and confidentiality of the collected data were guaranteed throughout the research process.

The questionnaire package, including the L2 Motivational Self System, Goal Orientation, Foreign Language Enjoyment, L2 Grit, and L2 Willingness to Communicate scales, was distributed to the participants electronically through their English teachers. Participants completed the questionnaires individually outside class and returned the completed forms within a two-week period. After the questionnaires had been collected, the responses were carefully screened for missing values, incomplete questionnaires, response inconsistencies, and careless answering patterns. Cases with incomplete or invalid responses were excluded from further analyses. Upon completion of the questionnaire administration, the participants' final English examination scores were obtained from the participating institutes with the approval of the institute administrators.

Following the quantitative phase, qualitative data were collected to provide a deeper explanation of the statistical findings. Based on the quantitative results, 25 learners representing different achievement levels and both genders were purposefully selected for semi-structured interviews. The interviews were conducted individually in Persian to ensure that participants could express their perceptions freely and accurately. Each interview followed a semi-structured interview guide while allowing sufficient flexibility to explore issues emerging during the conversation. After all interviews had been completed, the audio recordings were transcribed verbatim and subsequently translated into English to facilitate qualitative analysis.

Six instruments were employed to collect the quantitative and qualitative data required for the study, including five standardized questionnaires and one semi-structured interview protocol.

L2 Motivational Self System (L2MSS): Learners' L2 Motivational Self System was measured using an adapted version of Taguchi et al.'s (2009) questionnaire. The original instrument comprises 27 items representing three dimensions: Ideal L2 Self, Ought-to L2 Self, and L2 Learning Experience. Since the present study focused on learners' motivational self-guides, only the 18 items assessing Ideal L2 Self (9 items) and Ought-to L2 Self (9 items) were retained, whereas the L2 Learning Experience dimension was excluded. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Previous research has provided substantial evidence supporting the reliability and validity of the instrument across different EFL contexts. In the present study, the questionnaire demonstrated satisfactory internal consistency (Cronbach's $\alpha = .87$) and construct validity (AVE = .78), confirming its suitability for the proposed measurement model.

Goal Orientation: Achievement goal orientation was assessed using Elliot and Murayama's (2008) Achievement Goal Questionnaire–Revised (AGQ-R). The instrument consists of 12 items measuring four dimensions of the 2 × 2 achievement goal framework: mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance goals. Participants responded using a five-point Likert scale ranging from 1 (not at all true of me) to 5 (extremely true of me). Higher scores indicate stronger endorsement of the corresponding achievement goal orientation. In the present study, the questionnaire demonstrated satisfactory psychometric properties, with a Cronbach's alpha coefficient of .85 and an Average Variance Extracted (AVE) value of .81.

Foreign Language Enjoyment (FLE): Foreign Language Enjoyment was measured using the 14-item FLE Scale developed by Dewaele and MacIntyre (2016). The instrument assesses learners' positive emotional experiences during foreign language learning and has been extensively validated in previous SLA research. Participants rated each statement on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores representing greater levels of enjoyment. In the present study, the scale showed acceptable reliability ($\alpha = .82$) and construct validity (AVE = .67).

L2 Grit: Learners' perseverance and sustained effort in second language learning were measured using Teimouri et al.'s (2020) L2 Grit Scale. The instrument consists of nine items assessing learners' persistence and long-term commitment to language learning goals. Responses were recorded on a five-point Likert scale ranging from 1 (not like me at all) to 5 (very much like me). The instrument demonstrated satisfactory psychometric properties in the present study, yielding a Cronbach's alpha coefficient of .88 and an AVE value of .86.

L2 Willingness to Communicate (L2 WTC): Learners' classroom willingness to communicate was assessed using the 27-item questionnaire developed by MacIntyre et al. (2001). The instrument evaluates learners' willingness to participate in a variety of English classroom communication activities, including speaking, listening, reading, and writing. All items were rated on a five-point Likert scale ranging from 1 (almost never willing) to 5 (almost always willing). Higher scores reflected greater willingness to communicate in English. The instrument demonstrated satisfactory reliability ($\alpha = .89$) and construct validity (AVE = .71) in the present study.

Semi-Structured Interview: To complement the quantitative findings, qualitative data were collected through semi-structured interviews. An interview guide, developed based on the theoretical framework of the study, focused on learners' perceptions of the relationships among L2 Motivational Self System, goal orientation, L2 grit, Foreign Language Enjoyment, and willingness to communicate. Semi-structured interviews were selected because they provide sufficient flexibility for participants to elaborate on their experiences while ensuring that all key topics are addressed (Patton, 2002). All interviews were conducted individually in Persian to facilitate participants' comprehension and encourage more detailed responses. Subsequently, the interview transcripts were translated into English for analysis.

The data analysis was conducted in two main phases: quantitative and qualitative analyses. First, the quantitative data obtained from the questionnaires were analyzed. To estimate the internal consistency reliability of the four questionnaires, Cronbach's alpha coefficients were calculated. Subsequently, descriptive statistics, correlation analysis, confirmatory factor analysis (CFA), and structural equation modeling (SEM) were conducted.

The statistical analyses were performed using SPSS 24.0 and AMOS 24.0. Descriptive statistics were used to report the mean scores and standard deviations of the main variables, including goal orientation (GO), L2 motivational self-system (L2MSS), L2 grit, foreign language enjoyment (FLE), and willingness to communicate (WTC). Confirmatory factor analysis was conducted to examine the factor structure, construct validity, and reliability of the measurement models.

Before conducting the structural analyses, the data were examined to identify potential errors and ensure the appropriateness of the dataset for further analysis. The structural relationships among the variables were then tested using structural equation modeling. After confirming the proposed models and examining the significance of the hypothesized relationships, the moderating effect of gender was investigated through multi-group analysis (MGA) within the SEM framework. The differences between male and female groups were examined to determine whether gender significantly influenced the relationships among the study variables.

To address the qualitative research question, interview data were analyzed using thematic content analysis. The qualitative analysis aimed to identify underlying patterns, categories, and themes that could provide further explanations for the quantitative findings.

The quantitative data analysis was conducted in several stages. First, confirmatory factor analysis (CFA) was performed to evaluate the reliability and construct validity of each measurement model. Next, Cronbach's alpha coefficients and Pearson correlation coefficients were calculated to examine internal consistency reliability and the relationships among the study variables.

To assess different aspects of construct validity, including convergent and discriminant validity, several indices were calculated, including Composite Reliability (CR), Average Variance Extracted (AVE), Maximum Shared Variance (MSV), and Average Shared Variance (ASV). For constructs modeled as second-order factors, the validity of the second-order measurement models was also examined.

Following the validation of the measurement models, the hypothesized relationships among the variables were tested using Structural Equation Modeling (SEM). Two conceptual models were evaluated in this study. First, model fit was assessed using commonly accepted fit indices, including the chi-square statistic (χ^2), the ratio of chi-square to degrees of freedom (χ^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Non-Normed Fit Index (NNFI), Goodness-of-Fit Index (GFI), and Adjusted Goodness-of-Fit Index (AGFI). After establishing acceptable model fit, the significance of the hypothesized paths was examined using t-values.

Furthermore, in the second model, which included additional relationships among the variables, bootstrapping procedures were applied to estimate indirect and total effects. The statistical significance of these effects was evaluated using empirical p-values. All quantitative analyses were conducted using SPSS 24.0 and AMOS 24.0.

To address the qualitative research question and provide a deeper explanation of the quantitative findings, the interview data obtained from 25 male and female EFL learners were analyzed using thematic content analysis. Following the completion of the semi-structured interviews, all audio-recorded interviews were transcribed verbatim and carefully reviewed several times to ensure familiarity with the dataset.

The analysis began with repeated readings of the transcripts to identify meaningful units, recurring ideas, and emerging patterns related to learners' L2 motivational self-system (L2MSS), goal orientation (GO), L2 grit, foreign language enjoyment (FLE), and willingness to communicate (WTC). Subsequently, the transcripts were systematically coded, and similar codes were grouped into broader categories based on conceptual similarities. Through this process, the researcher identified the major themes representing participants' perceptions and experiences regarding the factors influencing their willingness to communicate in English.

The coding and categorization procedures were conducted inductively to ensure that the identified themes emerged from the participants' accounts rather than from predetermined assumptions. The initial codes and categories were repeatedly reviewed, compared, and refined to eliminate redundancy, improve conceptual clarity, and ensure consistency within and across themes. The final themes were then interpreted in relation to the quantitative findings so that the qualitative results could explain, support, and enrich the statistical outcomes.

To enhance the trustworthiness of the qualitative analysis, detailed records of the coding process were maintained, and the consistency between the original interview excerpts and the extracted themes was continuously examined. Moreover, representative excerpts from participants' responses were selected and reported in the findings section to provide evidence for the identified themes and strengthen the credibility of the interpretations.

Overall, the purpose of this qualitative phase was to achieve a more comprehensive understanding of how learners with different achievement levels and gender backgrounds perceived the roles of L2MSS, goal orientation, L2 grit, and FLE in shaping their classroom willingness to communicate.

Findings and Results

The first stage of the quantitative analysis examined the internal consistency of the five instruments used to measure willingness to communicate (WTC), the L2 Motivational Self System (L2MSS), goal orientation (GO), L2 grit, and Foreign

Language Enjoyment (FLE). The reliability coefficients are presented in Table 1. These analyses were consistent with the study design and measurement procedures described for the quantitative phase of the research.

Table 1. **Reliability Indices of the Instruments**

Instrument	Cronbach's α	Cronbach's α Based on Standardized Items
WTC Questionnaire	.89	.895
L2MSS Questionnaire	.87	.876
GO Questionnaire	.88	.887
Grit Questionnaire	.81	.819
FLE Questionnaire	.85	.857

As shown in Table 1, all Cronbach's alpha coefficients exceeded .80, ranging from .81 for the grit questionnaire to .89 for the WTC questionnaire. Similarly, the coefficients based on standardized items ranged from .819 to .895. These findings demonstrated satisfactory to strong internal consistency for all five instruments and indicated that the measures were sufficiently reliable for use in the subsequent confirmatory factor analysis (CFA) and Multi-Group Structural Equation Modeling (SEM). Before estimating the structural relationships among L2MSS, GO, L2 grit, FLE, and WTC, CFA was conducted to determine whether the proposed five-factor measurement model adequately represented the observed data. The overall goodness-of-fit statistics for the measurement model are reported in Table 2.

Table 2. **Overall Fit of the Five-Factor Measurement Model**

Fit Index	Value	Interpretation
χ^2	812.45	—
df	224	—
χ^2/df	3.63	Acceptable (< 5)
CFI	.965	Excellent (> .95)
TLI	.957	Very good (> .95)
RMSEA	.046	Good (< .06)
RMSEA 90% CI	[.041, .051]	Precise
SRMR	.039	Excellent (< .08)

As presented in Table 2, the measurement model demonstrated an adequate overall fit. The χ^2/df ratio was 3.63, remaining below the criterion of 5. More importantly, the incremental and residual-based fit indices showed particularly favorable values, with CFI = .965, TLI = .957, RMSEA = .046 with a 90% confidence interval of [.041, .051], and SRMR = .039. Taken together, these indices indicated that the proposed five-factor measurement structure represented the empirical covariance matrix satisfactorily and therefore supported proceeding with the structural analyses.

The standardized factor loadings, composite reliability (CR), Average Variance Extracted (AVE), Cronbach's alpha coefficients, and the information required to evaluate discriminant validity were subsequently examined. Table 3 combines the principal measurement-quality results to avoid unnecessary fragmentation of closely related psychometric evidence.

Table 3. **Measurement-Model Reliability, Convergent Validity, and Discriminant Validity**

Construct	Standardized Indicator Loadings	CR	AVE	Cronbach's α	√AVE	Correlations with Other Constructs
L2MSS	L2MSS1 = .81; L2MSS2 = .87	.89	.72	.87	.85	GO = .42; Grit = .48; FLE = .50; WTC = .60
GO	GO1 = .76; GO2 = .84; GO3 = .79; GO4 = .72	.88	.65	.86	.81	L2MSS = .42; Grit = .40; FLE = .37; WTC = .55
Grit	Grit1 = .85; Grit2 = .79	.87	.69	.84	.83	L2MSS = .48; GO = .40; FLE = .45; WTC = .52
FLE	FLE1 = .88; FLE2 = .83	.90	.75	.88	.87	L2MSS = .50; GO = .37; Grit = .45; WTC = .58
WTC	WTC1 = .77; WTC2 = .80; WTC3 = .83; WTC4 = .75	.88	.62	.85	.79	L2MSS = .60; GO = .55; Grit = .52; FLE = .58

All standardized factor loadings were greater than .70. For L2MSS, the loadings were .81 and .87; those for GO ranged from .72 to .84; the two grit indicators loaded at .85 and .79; FLE loadings were .88 and .83; and WTC loadings ranged from .75 to .83. Thus, each observed indicator showed a substantial relationship with its intended latent construct.

The reliability and convergent-validity statistics provided additional support for the measurement model. CR values were .89 for L2MSS, .88 for GO, .87 for grit, .90 for FLE, and .88 for WTC. The respective AVE values were .72, .65, .69, .75, and .62, while Cronbach's alpha coefficients were .87, .86, .84, .88, and .85. Hence, every construct exceeded the conventional criteria of CR > .70, AVE > .50, and $\alpha > .80$.

Discriminant validity was also supported according to the Fornell–Larcker criterion. The square roots of AVE were .85 for L2MSS, .81 for GO, .83 for grit, .87 for FLE, and .79 for WTC. All of these values exceeded the corresponding inter-construct correlations. Specifically, the correlations were .42 between L2MSS and GO, .48 between L2MSS and grit, .50 between L2MSS and FLE, .60 between L2MSS and WTC, .40 between GO and grit, .37 between GO and FLE, .55 between GO and WTC, .45 between grit and FLE, .52 between grit and WTC, and .58 between FLE and WTC. Consequently, the constructs demonstrated sufficient empirical distinctiveness.

Modification indices were then inspected for possible localized areas of model misfit. The largest modification index concerned the correlated residuals of GO2 and GO3 (MI = 23.5), with an expected χ^2 reduction of 2.1; this association was considered theoretically defensible because the two items shared similar wording or thematic content. The residual association between WTC1 and WTC2 produced MI = 18.2 and an expected χ^2 reduction of 1.9 because both indicators represented classroom WTC. Similarly, correlating the residuals of FLE1 and FLE2 yielded MI = 15.7 and an expected χ^2 reduction of 1.5 because both indicators assessed closely related positive emotional experiences. A proposed cross-loading of Grit1 on GO had MI = 9.3 and an expected change of −0.44; however, this modification was not incorporated because it would violate the theoretical unidimensionality of the constructs. Thus, only theoretically defensible within-construct residual correlations were considered, and no cross-loadings or theoretically inappropriate modifications were introduced.

The assumptions underlying CFA and subsequent SEM analyses were also examined. Multivariate normality was considered satisfactory because absolute skewness values were below 2, absolute kurtosis values were below 7, and Mardia's multivariate kurtosis was 4.92, $p = .19$. Inspection of the relationships among the indicators supported linearity, and no problematic multivariate outliers were detected according to Mahalanobis distance at $p > .001$. Multicollinearity was likewise not problematic, as all VIF values were below 2.5. Finally, the sample size of 326 exceeded 300 and satisfied the adopted rule of thumb concerning the number of participants relative to estimated parameters. Consequently, the dataset was considered suitable for Multi-Group SEM.

Following validation of the measurement model, Multi-Group SEM was conducted to evaluate the hypothesized structural relationships and determine whether these relationships differed between male and female Iranian EFL learners. Figure 1 represents the structural model tested across the two gender groups.

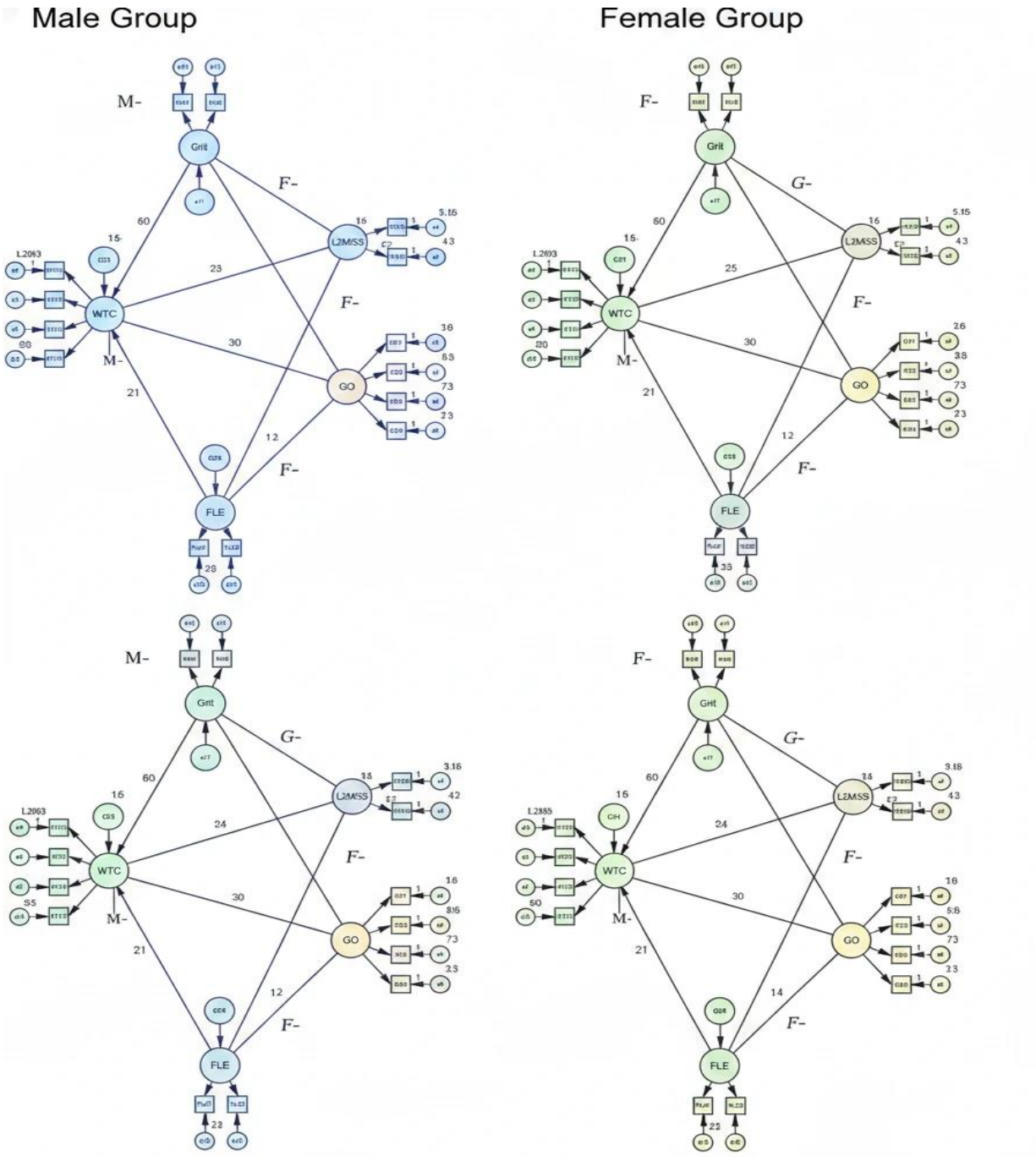

Figure 1. **Multi-Group SEM Model of the Interrelationships among Male and Female EFL Learners' WTC, L2MSS, GO, Grit, and FLE**

The standardized path coefficients demonstrated positive relationships among the motivational variables, mediators, and WTC for both male and female learners. Table 4 presents the coefficients for the two groups within a single comparative framework and additionally reports the calculated indirect and total effects of L2MSS and GO on WTC.

Table 4. **Standardized Structural Effects for Male and Female EFL Learners**

Structural Effect	Male β	Female β	Interpretation
L2MSS → Grit	.50	.45	L2MSS positively predicted grit in both groups.
L2MSS → FLE	.40	.55	The relationship was stronger among female learners.
GO → Grit	.45	.40	GO positively predicted grit in both groups.
GO → FLE	.30	.45	GO showed a stronger relationship with FLE among females.

Grit → WTC	.35	.30	Grit positively predicted WTC in both groups.
FLE → WTC	.40	.50	The coefficient was numerically larger among females.
L2MSS → WTC, direct	.40	.30	The direct coefficient was larger among males.
GO → WTC, direct	.50	.35	The direct coefficient was larger among males.
L2MSS → Grit → WTC	.175	.135	Positive indirect effect through grit.
L2MSS → FLE → WTC	.160	.275	FLE mediation was particularly prominent among females.
L2MSS → WTC, total	≈ .74	≈ .71	Strong total effect in both groups.
GO → Grit → WTC	.158	.120	Positive indirect effect through grit.
GO → FLE → WTC	.120	.225	FLE pathway was stronger among females.
GO → WTC, total	≈ .78	≈ .72	Strong total effect in both groups.

Among male learners, L2MSS positively predicted grit (β = .50) and FLE (β = .40), whereas GO predicted grit (β = .45) and FLE (β = .30). Both mediators subsequently contributed positively to WTC, with β = .35 for grit and β = .40 for FLE. The direct effects of L2MSS and GO on WTC were also substantial, at β = .40 and β = .50, respectively. The indirect effect of L2MSS through grit was .50 × .35 = .175, while its indirect effect through FLE was .40 × .40 = .160. Together with the direct effect of .40, these effects produced an approximate total L2MSS effect of .74. For GO, the indirect pathway through grit was .45 × .35 = .158, and the pathway through FLE was .30 × .40 = .120. When combined with the direct coefficient of .50, the approximate total effect was .78. Both total effects therefore exceeded .70.

Among female learners, L2MSS predicted grit at β = .45 and FLE at β = .55, whereas GO predicted grit at β = .40 and FLE at β = .45. Grit subsequently predicted WTC at β = .30, while FLE predicted WTC at β = .50. The direct effects of L2MSS and GO on WTC were β = .30 and β = .35, respectively. For L2MSS, the indirect effect through grit was .45 × .30 = .135 and the indirect effect through FLE was .55 × .50 = .275. Combined with the direct path of .30, the approximate total effect was .71. For GO, the indirect effects through grit and FLE were .120 and .225, respectively; combined with the direct effect of .35, these values yielded an approximate total effect of .72. Thus, the component-based calculation reported in the structural results yielded .72 for the female GO total effect, although the subsequent hypothesis summary supplied for the study reported this total effect as approximately .70. Overall, direct motivational pathways appeared comparatively stronger among male learners, whereas the indirect pathway through FLE was more pronounced among female learners.

To determine whether valid comparisons could be made between male and female learners, overall multi-group model fit and measurement invariance were subsequently evaluated. Structural path invariance was then examined to identify the individual relationships that differed between the groups. These analyses are summarized in Table 5.

Table 5. Multi-Group Model Fit, Measurement Invariance, and Structural Path Invariance across Gender

Analysis	Model/Path	χ^2	df	CFI	TLI	RMSEA	SRMR	$\Delta\chi^2$	Δdf	ΔCFI	ΔRMSEA	*p*	Decision/Conclusion
Overall fit	Configural model	1340.21	252	.962	.955	.048 [.044, .052]	.038	—	—	—	—	—	Acceptable/good fit
Measurement invariance	M1: Configural	1340.21	252	.962	—	.048	—	—	—	—	—	—	Accept
Measurement invariance	M2: Metric	1365.78	266	.961	—	.047	—	—	—	−.001	−.001	—	Invariance holds
Measurement invariance	M3: Scalar	1398.32	280	.959	—	.047	—	—	—	−.002	.000	—	Invariance holds
Structural invariance	L2MSS → WTC constrained equal	1408.55	281	—	—	—	—	10.23	1	—	—	.001	Stronger for males

Structural invariance	GO → WTC constrained equal	1412.74	281	—	—	—	—	14.42	1	—	—	< .001	Stronger for males
Structural invariance	FLE → WTC constrained equal	1400.12	281	—	—	—	—	1.80	1	—	—	.18	No significant difference
Structural invariance	Grit → WTC constrained equal	1402.05	281	—	—	—	—	3.73	1	—	—	.054	Marginally stronger for males

The configural model produced $\chi^2 = 1340.21$, $df = 252$, $\chi^2/df = 5.32$, CFI = .962, TLI = .955, RMSEA = .048, 90% CI [.044, .052], and SRMR = .038. Although the χ^2/df value was comparatively high, the CFI, TLI, RMSEA, and SRMR indices supported an acceptable-to-good overall model fit.

Measurement invariance was supported at successive levels. Relative to the configural model, the metric model yielded ΔCFI = −.001 and ΔRMSEA = −.001, while the scalar model yielded ΔCFI = −.002 and ΔRMSEA = .000. Because the absolute changes in CFI remained below .01 and changes in RMSEA remained below .015, configural, metric, and scalar invariance were supported. The measurement structure could therefore be regarded as sufficiently equivalent across male and female learners for meaningful comparison of the structural coefficients. The supplied results subsequently identify the first null hypothesis as rejected, although the reported invariance statistics themselves indicate equivalence of the measurement model across gender.

The structural path comparisons nevertheless revealed differences in specific relationships. Constraining the L2MSS → WTC relationship to equality produced $\Delta\chi^2 = 10.23$, $\Delta df = 1$, $p = .001$, demonstrating that the direct relationship was significantly stronger among male learners. Similarly, constraining the GO → WTC path produced $\Delta\chi^2 = 14.42$, $\Delta df = 1$, $p < .001$, again indicating a stronger direct coefficient for males. By contrast, the FLE → WTC comparison was nonsignificant, $\Delta\chi^2 = 1.80$, $p = .18$, despite the numerically higher standardized coefficient for females. The Grit → WTC difference approached but did not reach the conventional .05 threshold, $\Delta\chi^2 = 3.73$, $p = .054$, and was characterized as marginally stronger among males.

The remaining hypotheses were examined using the direct, indirect, and total structural effects. Regarding H02, which stated that there was no causal relationship between L2MSS and L2WTC, the results showed a direct coefficient of $\beta = .40$ and an approximate total effect of .74 among males, compared with $\beta = .30$ and a total effect of .71 among females. Thus, higher L2MSS was associated with higher L2WTC in both groups, with the direct relationship being stronger among males. H02 was therefore rejected.

Regarding H03, the indirect L2MSS → Grit → WTC effect was .175 among males and .135 among females, and both effects were reported as significant. L2 grit consequently functioned as a partial mediator in both groups: stronger motivational self-guides were associated with greater perseverance in L2 learning, which in turn corresponded to greater WTC. H03 was therefore rejected.

For H04, the indirect L2MSS → FLE → WTC effect was approximately .16 among males but approximately .28 among females. Thus, FLE partially mediated the L2MSS–WTC relationship in both groups but represented a substantially stronger indirect mechanism among female learners. H04 was consequently rejected.

H05 concerned the direct relationship between GO and L2WTC. Among male learners, the direct effect was $\beta = .50$ and the total effect was approximately .78. Among females, the direct effect was $\beta = .35$. The component-based calculation reported earlier produced an approximate total effect of .72, whereas the supplied hypothesis summary reported the corresponding value

as approximately .70. Irrespective of this minor numerical discrepancy, the results consistently showed a strong positive relationship between GO and WTC in both groups and a larger direct coefficient among male learners. H05 was therefore rejected.

H06 and H07 examined the mediating roles of L2 grit and FLE in the relationship between GO and WTC. Among male learners, the indirect effect through grit was .158 and that through FLE was .120; both were reported as significant but were smaller than the direct GO → WTC effect of .50. Among females, the corresponding indirect effects were .120 through grit and .225 through FLE. The latter result indicated that the GO → FLE → WTC pathway played a comparatively important role among female learners. Thus, GO appeared to promote female learners' WTC substantially by enhancing positive emotional experience, whereas its direct association with WTC was more prominent among male learners. Accordingly, H06 and H07 were rejected.

The qualitative phase addressed RQ8: *Given the Iranian EFL learners' perceptions, how could the role of L2 grit and FLE in L2 WTC be explained?* Semi-structured interviews with 25 learners were analyzed thematically to elaborate on the quantitative relationships identified through SEM. The analysis generated six major themes concerning persistence, confidence, emotional comfort, enjoyable classroom experiences, social support, and the joint contribution of grit and enjoyment to sustained communication. The study's qualitative procedure involved verbatim transcription, repeated reading, coding, categorization, refinement of themes, and interpretation of the themes in relation to the quantitative findings.

Table 6. Codes and Themes Derived from the Qualitative Analysis

Codes	Theme
Perseverance in speaking; not giving up; continuing after mistakes; repeated effort; persistence despite difficulty	Theme 1: L2 grit as perseverance in communication
Confidence from effort; gradual improvement; sense of progress; mastery through practice; courage to try again	Theme 2: Grit strengthens self-confidence and communicative readiness
Fear reduction; enjoyment replacing anxiety; relaxed classroom atmosphere; comfort in speaking	Theme 3: FLE reduces anxiety and facilitates communication
Interesting tasks; fun activities; humor; games; engaging discussions; enjoyable classroom experiences	Theme 4: Enjoyable classroom experiences stimulate WTC
Teacher support; peer encouragement; acceptance of mistakes; positive feedback; friendly interaction	Theme 5: Social support enhances enjoyment and willingness to speak
Future goals; personal investment; meaningful English use; communication as achievement; sustained engagement	Theme 6: Grit and enjoyment jointly sustain long-term willingness to communicate

The first theme, L2 grit as perseverance in communication, reflected participants' repeated emphasis on continuing to speak despite mistakes, linguistic difficulties, or unsuccessful communicative attempts. Learners perceived willingness to communicate not simply as an immediate desire to speak but as a behavior that required persistence. Grit appeared to prevent temporary communication problems from resulting in withdrawal from classroom interaction. Learners who were willing to continue after errors or misunderstandings therefore described themselves as more capable of remaining communicatively engaged.

The second theme, grit strengthens self-confidence and communicative readiness, showed that persistence could gradually translate into greater communicative confidence. Continued effort, repeated practice, perceptions of improvement, and experiences of mastery encouraged learners to attempt further communication. Consequently, the contribution of grit to WTC appeared to extend beyond persistence itself. By enabling learners to observe gradual progress arising from sustained effort, grit contributed to the confidence and readiness necessary to initiate subsequent communication.

The third theme, FLE reduces anxiety and facilitates communication, represented the affective mechanism through which enjoyment appeared to promote WTC. Participants associated enjoyable language-learning experiences with lower fear, greater relaxation, and increased comfort when speaking English. Enjoyment was therefore perceived as creating an emotional context

in which communication felt less threatening. Rather than approaching classroom communication primarily as a source of possible embarrassment or failure, learners experiencing greater FLE appeared more capable of approaching speaking opportunities positively.

The fourth theme, enjoyable classroom experiences stimulate WTC, concerned specific classroom features that generated positive affect and encouraged participation. Interesting tasks, humorous interactions, games, engaging discussions, and generally enjoyable learning experiences were repeatedly associated with stronger willingness to participate orally. The findings therefore indicated that FLE was not experienced as an abstract emotional state disconnected from instruction; instead, it was closely tied to the design and interpersonal quality of classroom activities.

The fifth theme, social support enhances enjoyment and willingness to speak, highlighted the importance of the classroom's interpersonal environment. Teacher support, encouragement from peers, acceptance of mistakes, positive feedback, and friendly interaction created conditions under which learners felt more comfortable participating. Participants' accounts suggested that perceived acceptance reduced the interpersonal risk attached to speaking in another language. Social support thereby contributed to FLE while simultaneously increasing learners' readiness to communicate.

Finally, the sixth theme, grit and enjoyment jointly sustain long-term willingness to communicate, demonstrated that the two mediating constructs were not perceived as independent mechanisms. Future goals, personal investment in language learning, meaningful English use, perceptions of successful communication as an achievement, and sustained engagement connected persistence with positive emotional experience. Grit appeared to provide the psychological resources required to endure communicative difficulty, whereas FLE provided the positive affective incentive to approach communication voluntarily. Together, they helped sustain WTC across both challenging and successful classroom experiences.

Overall, the qualitative findings complemented the SEM results by showing how the statistical relationships could be understood from the learners' own perspectives. L2 grit contributed to WTC mainly by sustaining perseverance, encouraging repeated effort, and strengthening confidence after difficulties or mistakes. FLE contributed by reducing fear, increasing emotional comfort, making classroom activities more engaging, and strengthening the supportive interpersonal conditions surrounding communication. Most importantly, participants perceived grit and enjoyment as mutually complementary rather than isolated influences: grit enabled learners to continue communicating when language use became difficult, while enjoyment made continued participation emotionally rewarding and desirable. This convergence between the quantitative and qualitative findings indicated that Iranian EFL learners' WTC emerged through the combined operation of motivational commitment, sustained effort, and positive emotional engagement.

Discussion and Conclusion

The findings of the present systematic review demonstrate that cognitive competencies in technical and engineering education should not be conceptualized as isolated, independent abilities; rather, they constitute an interconnected system of cognitive and self-regulatory resources that jointly support effective learning, problem solving, adaptation, and professional performance. Across the reviewed studies, critical thinking, problem solving, cognitive flexibility, self-regulation, working-memory-related processes, decision-making, and the capacity to manage complex learning demands repeatedly emerged as central dimensions of effective engineering learning. This finding supports broader conceptualizations of competency as an integrated combination of knowledge, skills, abilities, attitudes, and personal resources that become meaningful through their coordinated application in authentic situations (18-21). From this perspective, cognitive competency cannot be reduced to a single mental ability or assessed solely through performance on decontextualized tasks. Rather, it represents the capacity to mobilize several interrelated cognitive resources in response to complex educational and professional demands. This

interpretation is consistent with contemporary approaches that reconceptualize knowledge, skills, and abilities as interacting components of aptitude and professional readiness (22).

One of the most important findings of the review was the central position of critical thinking within engineering cognition. The analyzed studies consistently indicated that engineering students must be capable of evaluating evidence, questioning assumptions, generating and testing hypotheses, recognizing alternatives, and making reasoned judgments in situations for which no single predetermined solution is available. This conclusion is strongly supported by previous studies demonstrating a reciprocal relationship between critical thinking and engineering design. Engagement in engineering design can promote analytical reasoning and hypothesis evaluation, while critical thinking can simultaneously improve the quality of engineering problem solving (23). The findings are also consistent with evidence indicating that critical thinking contributes to students' capacity to cope with academic challenges and is associated with lower tendencies toward academic procrastination and burnout (24). Nevertheless, the review also revealed difficulties in the systematic assessment of this competency. Previous literature has similarly identified considerable inconsistency among critical-thinking assessment approaches in engineering education, suggesting that different studies may measure different components of the construct under the same conceptual label (25). Therefore, the present results indicate that critical thinking should be treated as a multidimensional and context-dependent competency that needs to be embedded in authentic engineering learning rather than addressed as an isolated generic skill.

The findings further showed that self-regulation and the management of learning processes are fundamental components of cognitive competency. Engineering students operate within demanding educational environments in which they are expected to understand abstract concepts, integrate information across disciplines, solve open-ended problems, and sustain effort over extended periods. Under such conditions, academic success depends not only on disciplinary knowledge but also on students' capacity to plan their learning, monitor progress, select appropriate strategies, recognize ineffective approaches, and modify their behavior. Research on undergraduate engineering students has similarly demonstrated meaningful differences among students in their use of self-regulated learning strategies and in their ability to manage learning effectively (26). Furthermore, interventions targeting action-state orientation indicate that engineering students can be supported in becoming more effective learners when educational activities explicitly address how intentions are translated into sustained and organized academic behavior (27). These findings reinforce the conclusion that self-regulation should not be viewed merely as a supplementary study habit; it represents a core mechanism through which other cognitive competencies are coordinated and transformed into effective performance.

Another central finding concerned the close association between cognitive competencies and deep, durable, and transferable learning. The reviewed evidence suggested that students may possess substantial theoretical knowledge while remaining unable to apply that knowledge effectively in unfamiliar or ambiguous situations when relevant cognitive capacities have not been sufficiently developed. This result is compatible with the broader literature emphasizing that cognitive competencies play a foundational role in academic performance, adaptation, decision-making, and long-term learning (28, 29). It also supports arguments that optimal educational performance depends on balanced profiles that combine cognitive and non-cognitive competencies rather than privileging one domain exclusively (30). In engineering education, this issue is particularly important because professional problems frequently require students to transfer principles learned in formal instructional settings to situations that differ substantially from textbook examples. Consequently, cognitive competency-based education should prioritize students' capacity to reorganize and use knowledge rather than the mere accumulation of information.

The results also indicated that cognitive competency is inherently contextual and dynamic. Cognitive resources are not expressed identically across all situations; their manifestation depends on interactions among the learner, the nature of the task, the educational environment, and professional expectations. This finding is consistent with contextualized perspectives of

employability, which argue that individual resources produce different outcomes depending on the opportunities, constraints, and demands present within specific environments (31). Evidence from different areas of engineering education further supports this conclusion. In railway engineering, learning quality has been associated with students' satisfaction and familiarity with the discipline, practical learning opportunities, instructional methods, study habits, facilities, and the educational environment (32). Similarly, investigations of competencies required for architectural practice show that the relative importance of specific competencies is shaped by professional demands rather than by academic assumptions alone (33). These findings suggest that cognitive competencies cannot be meaningfully developed or assessed without considering the settings in which they are expected to operate.

A further important result concerned the value of active, experiential, and competency-based educational approaches. The reviewed studies suggested that cognitive competencies develop most effectively when students engage with authentic or simulated professional problems requiring active decision-making, collaboration, design, reflection, and application of disciplinary knowledge. Robotics-centered project-based learning provides one example of how students can integrate conceptual knowledge with design, construction, experimentation, and problem solving within meaningful engineering tasks (34). Similarly, the integration of STEM, competency-based education, and experiential learning has been proposed as a pathway for reducing the gap between theoretical instruction and professional application, including in resource-constrained settings (35). Challenge-based educational models such as Tec21 further demonstrate how learner-centered and interdisciplinary experiences can organize education around complex challenges rather than discrete disciplinary content (36). Together, these studies support the present finding that cognitive competencies are best developed through curricular experiences that require their repeated use rather than through isolated instruction about the competencies themselves.

The findings regarding digital transformation and Industry 4.0 further extend this argument. Engineering students increasingly require competencies for working with complex data, intelligent systems, automated environments, and continuously evolving digital technologies. Previous research has emphasized that cognitive technologies and smart learning environments may support conceptual understanding, personalized learning, problem solving, and self-regulated learning while simultaneously creating demand for new forms of human-machine collaboration (37). The increasing use of generative artificial intelligence in engineering education likewise requires students to develop competencies not only for operating such systems but also for evaluating generated information, making responsible decisions, and integrating AI outputs with disciplinary reasoning (38). Moreover, AI-supported tools for competency-based assessment demonstrate that digital technologies may help educators map and evaluate competencies more systematically (39). However, the present findings suggest that these technological applications will be educationally meaningful only when the competencies being developed or assessed are conceptually well defined and connected to authentic engineering performance.

The review also revealed that cognitive competencies are closely connected with the interpersonal and collaborative requirements of contemporary engineering. Modern engineering practice is rarely an exclusively individual activity; rather, engineers frequently participate in multidisciplinary, geographically dispersed, and culturally diverse teams. Consequently, effective performance requires the interaction of cognitive processes with teamwork, communication, leadership, and conflict-management abilities. Previous research demonstrates that engineering students recognize the importance of team culture, role distribution, responsibility, peer interaction, and constructive responses to underperforming team members (40). Faculty members have similarly identified deficiencies and developmental needs in engineering students' leadership preparedness (41). Globalization further intensifies these demands because engineers increasingly need to collaborate across linguistic, disciplinary, and cultural boundaries (42). Teaching approaches combining flipped learning, cooperative work, and gamification have also demonstrated potential for developing soft skills in engineering students (43). Accordingly, the present

findings imply that cognitive competency development should not be artificially separated from interpersonal learning, because real engineering problems require simultaneous cognitive and social coordination.

Professional identity represents another important dimension for interpreting the results. Competency development occurs not only through acquiring abilities but also through gradually learning what competent professional action means within a particular field. Research on professional identity formation emphasizes the roles of competence, belonging, mattering, recognition, and participation in helping students develop a stable professional self-concept (44, 45). Other scholarship has argued that competency-based education and professional identity formation should be integrated rather than treated as competing educational paradigms (46). Similar patterns of identity development have been reported in professional education more broadly, where exposure to practice settings and professional communities contributes to students' evolving understanding of their roles (47). Civic identity scholarship additionally highlights the importance of values and participation in educational development (48). From this perspective, cognitive competency-based engineering education should help students not only perform tasks successfully but also understand how competent reasoning, judgment, responsibility, and learning are embedded within professional engineering identity.

The results also support the growing importance of employability as an outcome of competency development, while simultaneously indicating that employability should not be understood narrowly. Traditional studies have emphasized the importance of communication, teamwork, professionalism, self-direction, uncertainty management, and transferable skills for graduates' transition to employment (49, 50). More recent evidence confirms that twenty-first-century employability depends upon combinations of technical, cognitive, interpersonal, digital, and adaptive capacities (51). At the same time, the ongoing debate regarding employability as a core responsibility of higher education illustrates that universities cannot simply equate educational quality with short-term labor-market placement (52). Graduate competence should therefore include the capacity for continued learning and adaptation across changing occupational circumstances. Apprenticeship-oriented studies reinforce this developmental perspective by showing how professional growth can occur through sustained participation in authentic occupational environments (53). Similarly, the use of successful graduates as sources of evidence for curriculum improvement demonstrates the value of connecting educational design to actual professional trajectories (54).

The systematic review additionally showed that sustainability-related engineering decisions illustrate the complexity of cognition in professional practice. Engineering decision-making cannot always be represented as a purely technical or mathematically optimized process because environmental decisions may also involve values, perception, framing, and emotional-cognitive responses. Neurocognitive evidence suggests that appropriate priming can influence engineers' thinking and increase their consideration of sustainable design alternatives (55). Broader analyses of engineering education for sustainable development similarly identify institutional and pedagogical obstacles, including fragmented curricula, reliance on traditional methods, inadequate infrastructure, resistance to innovation, and limited awareness among educators (56). Competencies required for sustainable development in the digital age consequently include analytical ability, adaptation, continuous learning, and capacity to address multidimensional problems (57). These findings further substantiate the central conclusion of the present review that engineering cognition is multidimensional and cannot be adequately developed through technical instruction alone.

Finally, the findings indicate that engineering education is undergoing a broader transition from knowledge transmission toward competency development. Internationalization, technological transformation, artificial intelligence, sustainability, and changing labor-market expectations have collectively expanded the responsibilities of engineering programs. International mobility among STEM students reflects the emergence of a global educational and professional knowledge space in which students seek learning opportunities according to perceived academic and occupational possibilities (58). At the macro level,

educational investment, inclusion, and lifelong learning are increasingly regarded as elements of economic and social development (59). Educational institutions must therefore create curricula that allow students to continually develop and renew cognitive competencies throughout their professional lives. The central implication of the present review is that cognitive competency-based technical and engineering education requires a holistic curricular architecture in which critical thinking, problem solving, self-regulation, cognitive flexibility, decision-making, teamwork, and adaptive learning are developed through coherent, progressively challenging, and context-sensitive educational experiences rather than taught as disconnected supplementary skills.

The present systematic review has several limitations that should be considered when interpreting its findings. First, although the search strategy covered several major international and Iranian scientific databases, relevant studies indexed in other specialized, regional, or non-indexed sources may not have been identified. Second, the included studies were heterogeneous in research design, engineering discipline, educational setting, participant characteristics, conceptual definitions, and methods used to evaluate cognitive competencies, which limited the possibility of direct comparison across studies. Third, considerable conceptual overlap was observed among constructs such as cognitive competency, metacognition, self-regulation, critical thinking, employability skills, and professional competencies, making strict classification difficult. Fourth, the limited number of studies meeting the final inclusion criteria restricts the generalizability of the synthesized framework across all technical and engineering disciplines. Finally, because the review synthesized published evidence, its conclusions remain dependent on the methodological quality, conceptual clarity, and reporting practices of the original studies and may also be affected by publication bias.

Future studies should empirically examine the relationships among the cognitive competencies identified in this review rather than investigating them separately. Longitudinal designs are particularly needed to determine how critical thinking, problem solving, cognitive flexibility, self-regulation, working memory, and decision-making develop across different stages of engineering education and how changes in these competencies predict academic and professional outcomes. Researchers should also distinguish more precisely among cognitive, metacognitive, motivational, emotional, and interpersonal competencies and develop validated multidimensional instruments that capture their interrelationships. Comparative research across engineering disciplines, universities, cultural settings, and national higher-education systems would clarify the extent to which cognitive competency models are context-specific or generalizable. Future studies could additionally examine the effects of project-based learning, problem-based learning, artificial intelligence, virtual laboratories, simulation, apprenticeships, and industry-based learning on competency development through experimental or quasi-experimental designs. Particular attention should also be directed toward university-industry relationships and the role of institutional policies, curricular structures, faculty competencies, and organizational resources in facilitating or constraining the development of students' cognitive competencies.

Engineering universities and faculties should explicitly incorporate cognitive competencies into curriculum objectives, course design, teaching strategies, and assessment systems instead of assuming that these abilities will develop automatically through exposure to technical content. Programs should provide progressively complex learning experiences in which students repeatedly practice critical thinking, problem solving, decision-making, self-regulation, teamwork, and adaptation in authentic or simulated engineering situations. Project-based learning, interdisciplinary design problems, case studies, laboratory challenges, industry partnerships, internships, reflective activities, and collaborative assignments can be used to connect theoretical knowledge with professional action. Faculty-development programs should also prepare instructors to teach and assess cognitive competencies using clear performance criteria and authentic assessment tasks. Universities should establish mechanisms for regular feedback from employers, graduates, professional associations, and students so that competency

frameworks remain responsive to technological and occupational change. Finally, cognitive competency development should be approached as a continuous process extending across the entire engineering curriculum, with introductory courses establishing foundational abilities and advanced courses requiring increasingly independent, integrated, and context-sensitive application.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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