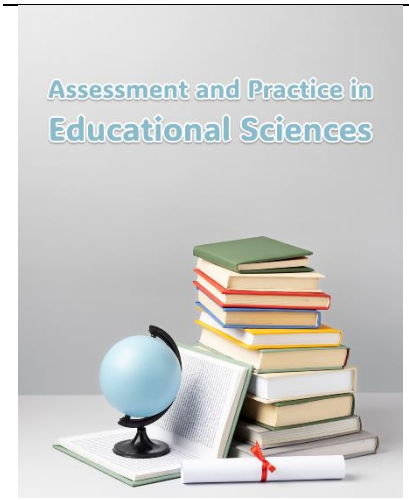
Assessment and Practice in Educational Sciences



Exploring the Nexus of Identity Formation, Student–Teacher Interaction, and TPACK in Virtual and Face-to-Face ESP Instruction

ABSTRACT

This study aimed to examine the relationships among identity formation, student–teacher interaction, perceived ESP instructional qualities and competencies, TPACK, and digital competence and to compare these constructs across virtual and face-to-face ESP instruction. An exploratory sequential mixed-methods design was employed at Islamic Azad University in Tehran, Iran. In the qualitative phase, semi-structured interviews were conducted with 35 ESP students to explore experiences of identity formation, interaction, and technology-mediated instruction. The findings informed the quantitative phase, in which researcher-developed and adapted questionnaires were administered to 308 participants, including 152 participants exposed to virtual instruction and 156 participants exposed to conventional instruction. The instruments assessed identity formation, ESP instructional qualities and competencies, identity perceptions, TPACK, and digital competence. Reliability and construct validity were examined using Cronbach's alpha and exploratory factor analysis. Inferential analyses included chi-square tests, independent-samples t-tests, multivariate analysis of variance, and Pearson correlation coefficients. Virtual and conventional groups differed significantly on overall identity formation, Pillai's Trace = .173, $F(4,303) = 15.82$, $p < .001$, partial $\eta^2 = .173$. Virtual participants scored significantly higher on identity moratorium, $F(1,306) = 51.75$, $p < .001$, partial $\eta^2 = .145$; identity foreclosure, $F(1,306) = 12.73$, $p < .001$, partial $\eta^2 = .040$; and identity diffusion, $F(1,306) = 33.74$, $p < .001$, partial $\eta^2 = .099$, but not identity achievement, $p = .138$. No significant differences emerged for overall ESP qualities and competencies, $t(306) = .537$, $p = .592$, or identity perceptions, $t(306) = .452$, $p = .651$. Virtual participants significantly outperformed conventional participants on combined TPACK and digital competence, Pillai's Trace = .721, $F(2,305) = 393.37$, $p < .001$, partial $\eta^2 = .721$. All principal constructs were positively correlated, with coefficients ranging from $r = .580$ to $r = .814$, all $p < .001$. Virtual ESP instruction appears to substantially strengthen technology-related competence while producing a more complex pattern of identity exploration and uncertainty, suggesting that effective ESP instruction should integrate technological competence with meaningful student–teacher interaction and identity-supportive pedagogical practices.

Keywords: English for Specific Purposes; identity formation; student–teacher interaction; TPACK; digital competence; virtual learning; face-to-face instruction

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Article type:
Original Research

Article history:
Received 28 May 2026
Revised 22 August 2026
Accepted 01 September 2026
Initial Publish 27 September 2026
Published online 01 March 2027

How to cite this article:
Moradi, P., Golshan, M., Moein, A. A., & Shooraki, F. (2027). Exploring the Nexus of Identity Formation, Student–Teacher Interaction, and TPACK in Virtual and Face-to-Face ESP Instruction. *Assessment and Practice in Educational Sciences*, *5*(2), 1-24. https://doi.org/10.61838/japes.314

Introduction

The expansion of digital technologies in higher education has transformed not only how knowledge is delivered but also how learners and teachers understand themselves, interact with one another, and construct professional and academic identities. In language education, and particularly in English for Specific Purposes (ESP), these transformations are especially significant

because learning is situated at the intersection of linguistic competence, disciplinary knowledge, professional socialization, and communication within specialized communities. ESP classrooms are therefore not merely sites for acquiring technical vocabulary or discipline-specific reading and writing skills; they are environments in which learners develop perceptions of themselves as legitimate users of English within academic and professional domains. The shift between face-to-face and virtual instruction can alter these processes by changing the nature of communication, participation, visibility, feedback, access to technology, and opportunities for social engagement. Consequently, examining identity formation alongside student–teacher interaction and technological pedagogical competence offers an important framework for understanding how ESP education is being reshaped in contemporary higher education. Identity formation is a dynamic developmental process through which individuals construct, evaluate, and revise understandings of who they are in relation to their personal experiences, social environments, cultural contexts, and anticipated future roles. Identity does not develop independently of social context; rather, it is influenced by interpersonal relationships, institutional expectations, sociocultural norms, and exposure to alternative perspectives. Research on identity formation across different developmental and social contexts demonstrates that external environments can substantially affect the process through which individuals explore and commit to particular values, roles, and self-definitions. For example, parental control has been shown to shape identity-related experiences among adolescents and young adults, illustrating how perceived social regulation can influence autonomy, exploration, and self-concept (1). Similarly, early marriage has been associated with psychological and developmental consequences for adolescent girls, demonstrating that externally imposed social transitions can alter trajectories of identity formation (2). Psychosocial educational contexts can likewise contribute to identity development among adolescents experiencing major life challenges, reinforcing the idea that identity is responsive to both developmental pressures and the quality of surrounding social support (3).

Contemporary digital environments have added another layer to this process by creating new settings for self-presentation, social comparison, affiliation, and identity exploration. Digital self-presentation may influence how individuals construct and communicate aspects of themselves, particularly when online environments permit selective representation, feedback, and interaction with broader social networks (4). The role of social media in shaping identity and lifestyle further demonstrates that digitally mediated environments can influence personal values, social positioning, self-expression, and perceptions of belonging (5). These findings are particularly relevant to education because virtual learning similarly requires participants to present themselves, communicate, collaborate, and negotiate social roles through digital interfaces. Whereas conventional classrooms provide embodied interaction, immediate social cues, and physical co-presence, online classrooms rely more heavily on mediated communication, platform-based participation, written interaction, audiovisual presence, and technologically facilitated feedback. These differences may influence the ways in which learners perceive themselves and others within educational communities.

In ESP education, identity formation may be even more complex because students are simultaneously developing language-related, academic, and professional identities. ESP learners are generally expected to acquire forms of English that are directly linked to particular disciplinary or occupational contexts. As a result, successful participation involves more than learning grammar or general communicative competence. Students must become familiar with specialized terminology, rhetorical conventions, genres, communicative norms, and forms of knowledge associated with their fields. Through this process, they may gradually begin to see themselves as competent participants in academic or professional communities. Educational technologies can support this development by providing access to specialized resources, multimodal materials, authentic disciplinary communication, and reflective learning opportunities. Research on ESP instruction has shown that educational technologies can contribute to the development of metacognitive skills, thereby supporting learners' ability to monitor, evaluate, and regulate their own learning processes (6). Such metacognitive development may also have implications for

identity because greater awareness of one's learning strategies, strengths, limitations, and disciplinary capabilities can contribute to a more differentiated academic self-concept.

Identity development in educational settings is also closely connected to reflection. Reflective practice has been identified as an important process in teacher identity formation because it enables educators to examine their beliefs, teaching experiences, professional roles, and changing relationships with learners and institutional contexts (7). This principle is highly relevant to ESP student-teachers and teachers working across different instructional modes. Virtual teaching often requires educators to reconsider established pedagogical routines, redesign classroom interaction, adopt unfamiliar technological tools, and reevaluate their effectiveness as instructors. Face-to-face instruction, by contrast, allows teachers to draw on more familiar forms of classroom presence, verbal immediacy, nonverbal communication, spontaneous feedback, and embodied interaction. Moving between these environments can therefore create opportunities for professional reflection and identity reconstruction. Teachers may come to redefine what it means to be competent, responsive, creative, or effective when instruction is mediated by technology rather than by physical proximity alone.

Among the most important contextual mechanisms involved in identity formation is student–teacher interaction. Interaction is a central feature of effective educational environments because it supports feedback, clarification, participation, motivation, emotional support, engagement, and the development of trust. In language learning, interaction is particularly important because communication is both a means of instruction and an instructional objective. Students develop linguistic competence by participating in dialogue, negotiating meaning, asking questions, receiving corrective feedback, and engaging in authentic communicative activity. In ESP contexts, these processes are further linked to disciplinary socialization because teachers often function as mediators between students and the communicative conventions of specialized academic or professional communities.

Recent scholarship has emphasized that high-quality teacher–student interaction can contribute to creativity, engagement, and more effective learning environments. Innovative forms of teacher–student communication may encourage students to participate more actively, experiment with ideas, and engage in meaningful learning rather than remaining passive recipients of information (8). A systematic review of teacher–student interaction and creativity similarly indicates that supportive and stimulating interpersonal relationships within educational settings can foster learners' creative engagement and learning potential (9). These findings suggest that interaction is not simply a logistical element of teaching but a central mechanism through which learners experience recognition, support, autonomy, intellectual challenge, and belonging.

The importance of interaction becomes particularly pronounced in virtual learning environments, where physical distance may weaken some conventional forms of classroom communication while creating new opportunities for technologically mediated engagement. Online classrooms can facilitate flexible participation, access to diverse resources, asynchronous communication, and interaction across geographical boundaries. At the same time, they can reduce spontaneous conversation, nonverbal immediacy, interpersonal visibility, and opportunities for informal contact. Multimodal research on online classrooms has demonstrated that teacher–student interaction and emotional processes are meaningfully associated with academic performance, highlighting the need to consider both communicative and affective dimensions of virtual instruction (10). Thus, understanding the effects of virtual ESP instruction requires attention not only to technological access and task completion but also to the quality of the social and emotional interactions that occur through digital platforms.

The effectiveness of these interactions is closely linked to teachers' capacity to integrate technology with appropriate pedagogy and disciplinary content. The Technological Pedagogical Content Knowledge framework, commonly referred to as TPACK, provides one of the most influential conceptual models for examining this capacity. TPACK emphasizes that effective technology integration cannot be reduced to technical skill alone. Rather, teachers must understand how technology interacts

with pedagogical approaches and subject-matter knowledge. An educator may be technologically proficient yet unable to select tools that support meaningful learning, just as strong disciplinary knowledge does not guarantee the ability to represent content effectively through digital media. An updated conceptualization of TPACK emphasizes the contextual nature of technological integration and highlights the importance of understanding how technological, pedagogical, and content knowledge operate within particular instructional settings (11). This contextual orientation is especially important in ESP because the appropriateness of technology depends heavily on disciplinary objectives, language needs, learner characteristics, and the communicative demands of specific fields.

For ESP instructors, TPACK may involve selecting technologies that support specialized vocabulary acquisition, disciplinary reading, academic writing, presentations, simulations, authentic communication, collaborative tasks, and access to field-specific materials. Teachers must also determine how to adapt pedagogical strategies to online environments while maintaining meaningful interaction and ensuring that technology serves rather than distracts from instructional goals. Research with pre-service English teachers has shown that digital literacy and TPACK are closely related, suggesting that the ability to navigate digital environments may support teachers' capacity to integrate technology pedagogically (12). This relationship is particularly relevant when comparing virtual and face-to-face instruction because teachers who regularly operate in technology-mediated classrooms may develop different levels of confidence, knowledge, and competence in digital teaching practices.

Evidence also suggests that active engagement with technology-supported professional learning can contribute to TPACK development. Participation in technology-focused learning environments has been associated with changes in educators' technological pedagogical knowledge, indicating that practical engagement may be an important mechanism through which TPACK evolves (13). This is consistent with the view that TPACK is not a static trait but a developmental form of professional knowledge shaped by experience, reflection, instructional context, and opportunities to apply technology to authentic teaching problems. Accordingly, the extensive adoption of virtual education may have accelerated TPACK development among instructors by requiring them to design online activities, manage digital communication, deliver content through multiple media, and solve technology-related instructional challenges.

The increasing integration of artificial intelligence into education further extends the TPACK framework and underscores the importance of technological competence in contemporary teaching. Recent research has begun to investigate how AI-related knowledge, attitudes, self-efficacy, and institutional support interact with TPACK. An AI-TPACK framework has been proposed to explain how teachers' attitudes toward artificial intelligence may mediate the relationship between self-efficacy and competence in integrating AI into teaching (14). Similarly, TPACK has been shown to mediate relationships between teachers' AI competency and teaching performance in higher education, suggesting that technological capability becomes educationally meaningful when it is integrated with pedagogical and content-related knowledge (15). These developments demonstrate that the role of TPACK is expanding beyond conventional educational technologies toward increasingly intelligent and adaptive digital environments.

Teachers' willingness to adopt these technologies may also depend on psychological factors. Research has shown that self-efficacy can mediate the association between TPACK and teachers' intentions to use artificial intelligence, indicating that knowledge alone may not be sufficient to promote effective technological adoption (16). Teachers need not only competence but also confidence in their capacity to use technology productively. This is important in ESP because instructors may face additional challenges when integrating technology into highly specialized content areas. Their sense of efficacy can influence whether they experiment with digital tools, redesign activities, encourage student autonomy, and sustain interactive learning environments.

Institutional and infrastructural support may likewise influence technological pedagogical development. Evidence concerning pre-service teachers indicates that ICT and AI support can operate synergistically in the development of TPACK, suggesting that technological competence is shaped by both personal learning and the quality of the surrounding educational ecosystem (17). Teachers working in environments that provide reliable digital infrastructure, appropriate training, access to relevant tools, and pedagogical support may be better positioned to develop integrated forms of technological knowledge. Conversely, limited technological resources or insufficient institutional support may constrain even highly motivated instructors. These contextual considerations are particularly important when comparing virtual and conventional ESP environments because exposure to digital teaching may vary considerably depending on institutional expectations, available platforms, learner readiness, and instructors' prior technological experience.

The intersection of identity, interaction, and TPACK therefore provides a useful conceptual lens for examining contemporary ESP instruction. Identity formation emphasizes how students and teachers understand themselves as participants in educational and disciplinary communities. Student–teacher interaction captures the relational processes through which support, feedback, recognition, communication, and belonging are produced. TPACK explains the professional knowledge required to integrate disciplinary content, pedagogy, and technology effectively. These constructs are theoretically interconnected. Teachers with stronger TPACK may be better able to design interactive and supportive virtual environments; higher-quality interaction may strengthen students' participation, confidence, and sense of belonging; and these experiences may in turn influence learners' academic, linguistic, and professional identities. Digital competence may further support these relationships by enabling both students and teachers to participate effectively in technologically mediated environments.

At the same time, these relationships should not be assumed to operate identically in virtual and face-to-face classrooms. Virtual instruction can increase flexibility, resource access, digital participation, and technological skill, but it may also reduce physical co-presence and spontaneous social interaction. Face-to-face classrooms can support immediacy and interpersonal connection yet may provide fewer opportunities for intensive use of digital tools. Identity development may therefore be strengthened in some respects and challenged in others depending on instructional modality. Existing research has addressed identity formation in psychological, familial, digital, and professional contexts (1-5), teacher identity through reflective practice (7), teacher–student interaction and creativity (8, 9), online interaction and emotion (10), and technological pedagogical knowledge in relation to digital literacy, professional learning, self-efficacy, artificial intelligence, and institutional support (11-17). ESP-specific scholarship has also demonstrated the potential of educational technologies to support metacognitive development (6). However, comparatively little attention has been devoted to how identity formation, student–teacher interaction, perceived instructional qualities and competencies, TPACK, and digital competence operate together across virtual and face-to-face ESP contexts.

Addressing this gap is important both theoretically and practically. Theoretically, integrating identity formation with instructional interaction and technological pedagogical knowledge can provide a more comprehensive understanding of ESP education as both a social and technologically mediated process. Practically, identifying differences between virtual and conventional classrooms may help universities determine which instructional conditions support stronger educational experiences and where additional support is required. Understanding the relationships among these constructs can also inform teacher development by showing whether technological competence is associated with broader perceptions of instructional quality and identity development. Such evidence is particularly valuable as universities increasingly adopt blended, hybrid, online, and technology-enhanced models of language instruction rather than relying exclusively on conventional classroom formats.

Accordingly, the aim of the present study was to explore the nexus among identity formation, student–teacher interaction, perceived ESP instructional qualities and competencies, TPACK, and digital competence and to compare these dimensions across virtual and face-to-face ESP instruction among Iranian ESP student-teachers.

Methods and Materials

Study Design and Particiapnts

The present study employed a mixed-methods research design to explore the nexus among identity formation, student–teacher interaction, and Technological Pedagogical Content Knowledge (TPACK) in virtual and face-to-face English for Specific Purposes (ESP) instruction. More specifically, an exploratory sequential mixed-methods design was adopted, in which qualitative data collection and analysis preceded the quantitative phase and informed the development and refinement of the quantitative research instrument. This design was considered particularly appropriate because the relationships among ESP learners' identity formation, patterns of student–teacher interaction, and teachers' integration of technological, pedagogical, and content knowledge represent multidimensional phenomena that cannot be adequately understood through a purely quantitative approach. Moreover, the transition between conventional face-to-face instruction and technology-mediated ESP learning, particularly following the extensive use of virtual instruction during the COVID-19 period, created contextual dimensions that required initial qualitative exploration. The qualitative phase therefore served to identify context-sensitive dimensions of the principal constructs, whereas the subsequent quantitative phase was designed to examine the magnitude and statistical relationships among the identified variables in a larger sample. Finally, findings obtained through the two methodological strands were integrated to develop a more comprehensive interpretation of the educational processes under investigation.

The study was conducted at Islamic Azad University in Tehran, Iran, among students enrolled in ESP courses and university instructors involved in the teaching of English for academic and discipline-specific purposes. ESP students constituted the principal population of the study because they had direct experience with both the linguistic and disciplinary requirements of ESP instruction and had been exposed, to varying degrees, to virtual and conventional face-to-face learning environments. The students differed in their levels of general English proficiency, discipline-specific English knowledge, academic background, and previous experience with online learning. Participants of both genders were included in the study in order to obtain a broader representation of ESP learning experiences. The instructional context was similarly heterogeneous, as the university instructors differed in years of teaching experience, levels of English taught, disciplinary specialization, familiarity with educational technologies, and experience in conducting virtual classes. Such diversity was considered valuable because the study sought to examine TPACK and instructional interaction as contextual and experiential constructs rather than as characteristics confined to a single course or teaching profile.

The qualitative phase was implemented first and relied on non-probability purposive and availability-based sampling. This sampling strategy was appropriate because the primary objective of the qualitative strand was not statistical generalization but rather the identification of experiences, perceptions, and meanings associated with ESP learning and teaching across virtual and face-to-face settings. Participants were selected on the basis of their experience with ESP courses and their familiarity with virtual learning environments. A total of 35 ESP students participated in the interview component of the study. Their participation enabled the researcher to examine how learners perceived themselves as users of discipline-specific English, how their academic and linguistic identities developed through participation in ESP courses, and how interactions with their instructors influenced their engagement, confidence, participation, and sense of belonging within their academic disciplines.

The interviews also addressed students' experiences of technology-mediated instruction and their perceptions of the extent to which instructors successfully combined disciplinary content, pedagogical strategies, and technological resources during virtual ESP instruction. Teacher-related perspectives concerning interaction and technology-supported teaching were also considered during the qualitative exploration of the instructional environment so that the conceptualization of the constructs would not be restricted exclusively to student perceptions.

The qualitative phase was followed by a quantitative phase in which the constructs and dimensions identified through the interviews and the relevant conceptual literature were operationalized in questionnaire form. After the questionnaire had been developed and prepared for administration, it was distributed among 309 ESP participants selected from the target university population through non-random sampling procedures. The larger quantitative sample made it possible to examine whether patterns emerging from the qualitative investigation could also be observed systematically across a broader group of participants. The quantitative phase specifically focused on the relationships among identity formation, student–teacher interaction, TPACK-related instructional practices, and mode of instruction. Particular attention was given to whether students' experiences differed according to virtual and face-to-face learning conditions and to the extent to which technology-supported pedagogical practices and the quality of interaction with instructors were associated with students' development of ESP-related academic and linguistic identities.

Ethical considerations were observed throughout both phases of the research. Participation was voluntary, and prospective participants were informed of the purpose and general procedures of the study before taking part. Interview participants were asked to provide informed consent, and they were informed that their responses would be used exclusively for research purposes. Confidentiality and anonymity were maintained during data collection, transcription, coding, and reporting. Participants were also informed that they could refrain from answering any question or withdraw from participation without academic consequences. The interviews were conducted in English in accordance with the linguistic context of the ESP courses, while care was taken to allow participants sufficient opportunity to clarify their intended meanings. The sequential organization of the study consequently enabled the researcher to move from an exploratory understanding of participants' lived instructional experiences toward the quantitative assessment of relationships among the main constructs.

Data Collection Tools

Data were collected through qualitative interviews and a researcher-developed questionnaire. The interviews constituted the primary instrument during the qualitative phase and were designed to generate detailed information concerning participants' experiences of virtual and face-to-face ESP instruction. A semi-structured format was adopted because it provided consistency across interviews while simultaneously allowing the researcher to probe individual experiences in greater depth. The interview questions were formulated around the principal domains of the study, including students' perceptions of themselves as ESP learners, changes in confidence and professional or disciplinary identity associated with learning English, participation in classroom activities, communication with instructors, feedback and support, opportunities for interaction, perceptions of teacher presence, use of digital technologies, accessibility of instructional resources, and differences between online and face-to-face ESP classrooms. Participants were also encouraged to describe the ways in which instructors combined English-language teaching, specialized disciplinary content, pedagogical techniques, and technological tools. These responses were especially important for contextualizing TPACK within ESP instruction, because effective technology integration in an ESP classroom requires not simply technological competence but the coordinated use of technological knowledge, pedagogical knowledge, and specialized content knowledge.

The qualitative interview component also provided the empirical foundation for examining identity formation. Rather than treating learner identity as a fixed personal characteristic, the study approached it as a developing and context-sensitive phenomenon reflected in students' perceptions of themselves as language learners, members of academic communities, and prospective users of English within their professional disciplines. Interview questions therefore explored whether participation in ESP instruction affected students' confidence in communicating about disciplinary knowledge, their perceived legitimacy as users of specialized English, their willingness to participate in academic interactions, and their sense of belonging to their disciplinary communities. Differences between virtual and face-to-face instruction were examined by asking participants to compare the degree of visibility, participation, interaction, autonomy, engagement, and interpersonal connection experienced in the two learning environments. The interview protocol further addressed student–teacher interaction by exploring communication frequency, accessibility of instructors, immediacy of feedback, opportunities to ask questions, perceived emotional and academic support, classroom dialogue, and the extent to which interaction facilitated understanding of specialized English content.

Following completion and analysis of the qualitative phase, a researcher-developed questionnaire was prepared for the quantitative stage. The construction of the questionnaire was informed by the categories and themes emerging from the interviews together with the theoretical dimensions of identity formation, student–teacher interaction, and TPACK. The questionnaire was structured in such a way that the resulting numerical data could be used to examine the conceptual model of the study and statistically test the relationships suggested by the qualitative findings. Items related to identity formation assessed dimensions such as confidence in using ESP, identification with the learner's academic or professional field, willingness to communicate using discipline-specific English, perceived competence, participation, and the extent to which ESP learning contributed to students' academic and professional self-conceptions. The student–teacher interaction component addressed accessibility, feedback, responsiveness, instructional support, opportunities for dialogue, teacher presence, interactional quality, and the degree to which communication with the instructor facilitated students' learning and participation.

The TPACK-related component of the questionnaire was designed to assess students' perceptions of instructors' ability to integrate technology, pedagogy, and discipline-specific content in ESP instruction. Accordingly, items reflected the appropriate selection and use of technological tools, alignment of technology with instructional objectives, presentation of specialized content through appropriate digital resources, adaptation of teaching strategies to online environments, facilitation of interaction through technological platforms, and the effective combination of technological resources with pedagogical and content knowledge. Because the study compared virtual and face-to-face instruction, questionnaire items also enabled respondents to evaluate their experiences across instructional modes. This comparative structure was intended to reveal whether the effects of interaction and technologically integrated instruction on identity-related outcomes differed depending on the learning environment.

Before full quantitative administration, the questionnaire was reviewed for clarity, comprehensibility, relevance, and consistency with the constructs derived from the qualitative phase. The wording of items was examined to ensure that statements could be understood by ESP students from different academic disciplines and different levels of English proficiency. The instrument was subsequently prepared for administration to the quantitative sample of 309 participants. Questionnaire responses provided numerical indicators for the principal study variables and created the basis for investigating the proposed relationships among TPACK, student–teacher interaction, identity formation, and instructional modality. The combination of interviews and questionnaires was therefore central to the methodological logic of the study: interviews provided contextual depth and enabled the emergence of locally meaningful dimensions, whereas questionnaires allowed those dimensions to be examined systematically across a considerably larger sample.

Data Analysis

Data analysis was conducted sequentially in accordance with the exploratory mixed-methods design. The qualitative data were analyzed before the quantitative data so that the categories emerging from the first phase could inform the construction and interpretation of the quantitative component. Following the interviews, participants' responses were transcribed and organized for qualitative analysis. Content analysis, incorporating principles of thematic analysis, was employed to identify recurring concepts, similarities, differences, and meaningful patterns across the interviews. The analytical process began with repeated reading of the interview transcripts to develop familiarity with participants' accounts. Meaningful units related to identity formation, student–teacher interaction, technology use, pedagogical practices, disciplinary content, virtual instruction, and face-to-face instruction were then identified and coded. Conceptually related codes were compared and grouped into broader categories, and the categories were subsequently organized into higher-order themes representing the principal dimensions of participants' ESP experiences. Particular attention was paid to statements illustrating how classroom interaction and technologically mediated teaching practices contributed to or constrained learners' academic, linguistic, and professional identity formation.

During qualitative analysis, comparisons were also made between participants' descriptions of virtual and face-to-face ESP environments. This comparative analysis focused on recurring differences in interactional immediacy, teacher accessibility, classroom participation, feedback, autonomy, technological affordances, technological difficulties, engagement with specialized materials, and students' perceptions of themselves as active participants in ESP learning. TPACK-related data were analyzed by identifying accounts concerning the instructors' use of technological tools, pedagogical adaptation, representation of disciplinary knowledge, and integration of these domains in teaching practice. Rather than considering technology use in isolation, the analysis examined whether technology appeared pedagogically purposeful and appropriately connected to the specialized content of ESP courses. The qualitative results were subsequently used to define the dimensions incorporated into the quantitative instrument and to formulate relationships to be examined statistically.

Quantitative analysis was performed on responses obtained from the 309 participants. Prior to inferential analysis, the dataset was screened for completeness and suitability for statistical analysis. Descriptive statistics were used to summarize participant responses and characterize the distribution of the main variables. Measures of central tendency and variability were examined to provide an overall representation of identity formation, perceived student–teacher interaction, and TPACK-related instructional practices. Where appropriate, distributional characteristics and statistical assumptions were examined before conducting inferential analyses. The internal consistency of the questionnaire dimensions was also assessed to determine whether the items representing each construct demonstrated an acceptable level of measurement coherence.

Inferential statistical procedures were then employed to investigate relationships among the principal variables and differences associated with instructional modality. Correlational analysis was used to determine the direction and magnitude of associations among identity formation, student–teacher interaction, and TPACK-related instructional practices. Linear and multiple regression analyses were used to determine the extent to which student–teacher interaction and TPACK could explain variation in students' identity formation within ESP instruction. In the regression analyses, identity-related outcomes were treated as criterion variables, while interactional and TPACK-related dimensions were entered as explanatory variables according to the conceptual model developed from the qualitative phase. This analysis made it possible to determine the independent and combined contribution of instructional interaction and technologically integrated pedagogical practice to ESP learners' identity development.

Comparative statistical procedures were additionally used to examine virtual and face-to-face instructional conditions. Where the research questions required comparison between two independent instructional groups, independent-samples t-tests were used to determine whether statistically significant differences existed in identity formation, perceived student–teacher interaction, or relevant instructional dimensions. Analysis of variance was employed where comparisons involved more than two categories or where participant characteristics required examination across multiple groups. The statistical analyses were interpreted not only in terms of statistical significance but also in relation to the conceptual patterns identified during the qualitative stage. This was important because the purpose of the quantitative phase was not simply to identify statistically significant relationships, but to test and elaborate the explanatory framework generated from participants' qualitative experiences.

The final stage of analysis involved the integration of the qualitative and quantitative findings. Integration was accomplished by comparing the themes identified through interview analysis with the patterns obtained from the questionnaire data. Areas of convergence were identified when qualitative experiences were supported by corresponding quantitative relationships, whereas areas of divergence were examined to determine why certain experiences evident in the interviews were not reflected as strongly in the statistical findings. The qualitative data were also used to explain the meaning of significant quantitative relationships. For example, if student–teacher interaction emerged as a significant predictor of identity formation, interview accounts concerning feedback, recognition, teacher accessibility, classroom participation, or communicative confidence were used to clarify the mechanisms through which interaction may influence identity development. Similarly, quantitative relationships involving TPACK were interpreted in light of participants' descriptions of how technological tools, pedagogical strategies, and specialized disciplinary materials were integrated in virtual instruction. Through this process of methodological integration, the study sought to move beyond a simple comparison of online and face-to-face ESP classrooms and provide a more comprehensive explanation of how instructional modality, interaction, and technologically informed pedagogy intersect in the formation of ESP learner identity.

Findings and Results

The present study pursued several interrelated objectives concerning identity formation, instructional quality, interaction, and technological competence in English for Specific Purposes instruction. Specifically, the study examined ESP student-teachers' perceptions of identity formation, compared identity formation under virtual and conventional instructional conditions, evaluated perceived qualities and competencies associated with ESP education, investigated participants' understanding of identity-related processes, assessed TPACK and digital competence, and finally examined the relationships among identity formation, perceived educational quality and competence, TPACK, digital competence, and participants' overall perceptions. Because several researcher-administered instruments were employed, their reliability, construct validity, and relevant statistical assumptions were examined before the substantive comparisons were interpreted.

A total of 308 participants provided analyzable data. As shown in Table 1, half of the participants were between 19 and 25 years of age, and approximately three quarters were female. Most participants held a bachelor's degree, while the largest occupational category was students. Regarding experience with virtual education, 49.3% reported having participated in virtual classes, whereas 50.7% reported that they had not. Weekly participation constituted the most frequently reported pattern of virtual learning participation, followed by rare participation. Online courses were by far the most common form of virtual learning. More than half of the participants reported being somewhat satisfied with virtual learning. Flexibility was identified as its principal advantage, whereas lack of face-to-face interaction was the most commonly reported disadvantage, followed by technical difficulties and limited opportunities for interaction or participation.

Table 1. Demographic and Virtual-Learning Characteristics of the Participants

Characteristic	Category	n	%
Age	19–25 years	154	50.0
	26–36 years	70	22.7
	36–46 years	72	23.4
	Above 46 years	12	3.9
Gender	Male	76	24.7
	Female	232	75.3
Education	Some college	12	3.9
	Bachelor's degree	245	79.5
	Graduate degree	51	16.6
Occupation	Not answered	7	2.3
	Prefer not to answer	6	1.9
	Student	86	27.9
	Employed full-time	72	23.4
	Employed part-time	65	21.1
	Self-employed	72	23.4
Participated in virtual classes	Yes	152	49.3
	No	156	50.7
Amount of virtual-class participation	Prefer not to answer	6	1.9
	Daily	30	9.7
	Weekly	120	39.0
	Monthly	43	14.0
	Rarely	101	32.8
	Never	8	2.6
Type of virtual learning	Online courses	232	75.3
	Webinars	44	14.3
	Virtual workshops	24	7.8
	Other	8	2.6
Satisfaction with virtual learning	Not answered	12	3.9
	Prefer not to answer	6	1.9
	Very dissatisfied	56	18.2
	Somewhat dissatisfied	20	6.5
	Neutral	30	9.7
	Somewhat satisfied	172	55.8
	Very satisfied	12	3.9
Advantages of virtual learning	Flexibility	126	40.9
	Convenience	56	18.2
	Cost-effectiveness	26	8.4
	Access to a wider range of resources	88	28.6
	Other	12	3.9
Disadvantages of virtual learning	Lack of face-to-face interaction	95	30.8
	Difficulty staying motivated	50	16.2
	Technical difficulties	78	25.3
	Limited opportunities	73	23.7
	Other	12	3.9

The first research question examined how Iranian ESP student-teachers perceived the influence of virtual learning on their overall identity formation and on specific mechanisms of identity development, including community belonging, social interaction, and sense of self. Five related questions were therefore examined. The distributions and chi-square tests are summarized in Table 2.

Regarding the overall impact of virtual learning on identity formation, the largest proportion of participants, 29.55%, perceived a negative effect. A nearly comparable proportion, 28.90%, reported no impact, whereas only 10.71% regarded virtual learning as having a positive effect. Another 16.23% were unsure and 14.61% preferred not to answer. The distribution

differed significantly from an equal distribution, $\chi^2(4) = 46.15$, $p < .001$, Cramer's V = .19. The magnitude of Cramer's V suggested a relatively weak association.

When participants were asked more specifically how virtual learning had influenced identity formation, the most frequent response was that it had expanded their worldview, selected by 34.09% of respondents. Strengthening cultural identity was identified by 23.38%, challenging existing beliefs by 17.86%, and increasing self-awareness by 15.26%. The response distribution was again statistically significant, $\chi^2(4) = 53.75$, $p < .001$, Cramer's V = .21, although the effect remained modest.

The findings concerning community and belonging were more balanced. A total of 27.60% were neutral regarding whether virtual learning had helped them develop a sense of community and belonging. However, 25.97% agreed and 17.20% strongly agreed, meaning that 43.17% expressed an explicitly positive evaluation. In contrast, 14.94% disagreed and 14.29% strongly disagreed, corresponding to 29.23% with an explicitly negative evaluation. These differences were statistically significant, $\chi^2(4) = 24.56$, $p < .001$, Cramer's V = .14.

With respect to social interaction and relationships, 27.27% of participants reported increased social interaction and 26.30% reported improved relationships. Approximately 11%–14% reported decreases in social interaction, depending on the percentage calculated from the supplied frequency output, while 17.20% selected another form of impact. Based on the reported frequencies, the response distribution differed significantly, $\chi^2(4) = 27.64$, $p < .001$, Cramer's V = .15.

Finally, participants generally demonstrated a somewhat more positive than negative orientation toward the influence of virtual learning on their sense of self. Although 27.60% remained neutral, 28.57% agreed and 17.86% strongly agreed that virtual learning had helped them develop a stronger sense of self. Thus, 46.43% responded positively. Conversely, 13.96% strongly disagreed and 12.01% disagreed, producing a combined negative response of 25.97%. The differences across categories were statistically significant, $\chi^2(4) = 36.35$, $p < .001$, Cramer's V = .17.

Table 2. ESP Student-Teachers' Perceptions of the Effects of Virtual Learning on Identity Formation

Dimension	Response	n	%	χ^2(df)	p	Cramer's V
Overall impact on identity formation	Prefer not to answer	45	14.61	46.15 (4)	<.001	.19
	Positive	33	10.71			
	Negative	91	29.55			
	No impact	89	28.90			
	Unsure	50	16.23			
Ways identity was affected	Prefer not to answer	29	9.42	53.75 (4)	<.001	.21
	Increased self-awareness	47	15.26			
	Expanded worldview	105	34.09			
	Strengthened cultural identity	72	23.38			
	Challenged existing beliefs	55	17.86			
Community and belonging	Strongly disagree	44	14.29	24.56 (4)	<.001	.14
	Disagree	46	14.94			
	Neutral	85	27.60			
	Agree	80	25.97			
	Strongly agree	53	17.20			
Social interaction and relationships	Decreased social interactions	35	11.36*	27.64 (4)	<.001	.15
	No impact	53	17.21*			
	Increased social interactions	84	27.27*			
	Improved relationships	81	26.30*			
	Other	55	17.86*			
Stronger sense of self	Strongly disagree	43	13.96	36.35 (4)	<.001	.17
	Disagree	37	12.01			
	Neutral	85	27.60			
	Agree	88	28.57			
	Strongly agree	55	17.86			

The second research question examined the extent to which the Marcia Identity Questionnaire constituted an appropriate measure of Iranian ESP student-teachers' identity formation and its four theoretically specified dimensions. The relevant section of the instrument consisted of 40 items, corresponding to Items 20–59, and measured identity achievement, moratorium, foreclosure, and diffusion.

Internal consistency was high for both the overall instrument and each of its four dimensions. Cronbach's alpha was .948 for the complete 40-item instrument. The coefficients for identity achievement, moratorium, foreclosure, and diffusion were .917, .919, .900, and .906, respectively. All exceeded the conventional .70 criterion and were at or above .90, indicating excellent internal consistency.

Exploratory factor analysis was subsequently performed using principal axis factoring. The scree solution supported extraction of four factors. Because the factors were substantially correlated, an oblique rather than orthogonal rotation was adopted. Specifically, the factor correlations were .367 between Factors 1 and 2, −.448 between Factors 1 and 3, −.524 between Factors 1 and 4, −.422 between Factors 2 and 3, −.379 between Factors 2 and 4, and .512 between Factors 3 and 4. Because several of these values exceeded the ±.32 criterion, an oblique solution was considered appropriate.

Sampling adequacy was excellent. The Kaiser-Meyer-Olkin index was .955, while Bartlett's test of sphericity was statistically significant, $\chi^2(780) = 8248.863$, $p < .001$. The correlation matrix was therefore suitable for factor extraction. Four factors were retained, jointly accounting for 58.114% of the extracted variance. The first factor explained 36.355%, the second added 9.418%, the third added 6.568%, and the fourth added 5.773%.

The first extracted factor corresponded to Identity Achievement and comprised Items 20–29. Primary factor loadings ranged from .709 to .833. The factor demonstrated composite reliability of .937 and an average variance extracted of .772. The second factor represented Identity Moratorium and consisted of Items 30–39, with primary loadings ranging from .709 to .850, CR = .937, and AVE = .771. The third factor represented Identity Diffusion and comprised Items 50–59. Its primary loadings ranged from .689 to .826. The originally reported summary statistics identified CR and AVE values of .923 and .738 for this factor. The fourth factor corresponded to Identity Foreclosure and comprised Items 40–49. Its primary loadings ranged from .647 to .849, with CR = .916 and AVE = .722. Taken collectively, these coefficients supported the reliability, convergent validity, and four-dimensional structure of the identity measure.

Table 3. Psychometric Properties of the Marcia Identity Questionnaire

Index/Factor	Items	Cronbach's α	Primary loading range	CR	AVE	Extracted variance
Identity Achievement	20–29	.917	.709–.833	.937	.772	36.355%
Identity Moratorium	30–39	.919	.709–.850	.937	.771	9.418%
Identity Diffusion	50–59	.906	.689–.826	.923	.738	6.568%
Identity Foreclosure	40–49	.900	.647–.849	.916	.722	5.773%
Total questionnaire	40 items	.948	—	—	—	58.114% cumulative
KMO	—	—	—	—	—	.955
Bartlett's test	—	—	—	—	—	$\chi^2(780) = 8248.863$, $p < .001$

The detailed loading pattern further supported this structure. For Identity Achievement, loadings were .833 for Q21, .813 for Q23, .801 for Q29, .790 for Q27, .779 for Q24, .777 for Q20, .748 for Q25, .735 for Q22, .731 for Q26, and .709 for Q28. Identity Moratorium loadings were .850 for Q30, .828 for Q39, .814 for Q31, .797 for Q37, .769 for Q35, .756 for Q38, .745 for Q34, .724 for Q33, .721 for Q32, and .709 for Q36. Identity Diffusion was principally defined by Q57 (.826), Q51 (.788), Q55 (.774), Q58 (.733), Q50 (.725), Q54 (.721), Q56 (.717), Q53 (.714), Q52 (.693), and Q59 (.689). Identity Foreclosure was represented by Q41 (.849), Q40 (.779), Q47 (.750), Q48 (.730), Q43 (.723), Q42 (.700), Q46 (.683), Q49 (.682), Q45 (.679),

and Q44 (.647). All primary loadings therefore exceeded .60 and, with only minor secondary loadings, demonstrated clear association with their intended factors.

The third research question examined whether identity formation differed significantly between ESP student-teachers experiencing virtual and conventional instruction. The four identity dimensions were analyzed simultaneously using MANOVA.

The normality assumption was supported. For the virtual group, skewness values ranged from −.763 to .081 and kurtosis values from −.610 to −.200. More specifically, skewness/kurtosis values were −.657/−.552 for achievement, −.763/−.200 for moratorium, −.086/−.610 for foreclosure, and .081/−.229 for diffusion. For the traditional group, corresponding skewness/kurtosis values were −.806/−.220 for achievement, −.264/−.678 for moratorium, −.230/.634 for foreclosure, and −.478/.412 for diffusion. All indices fell within the ±2 criterion, indicating no substantial departure from normality.

The homogeneity-of-variance results were mixed. Median-based Levene tests were nonsignificant for Identity Achievement, $F(1,306) = .425$, $p = .515$, and Identity Moratorium, $F(1,306) = 3.676$, $p = .056$, but significant for Identity Foreclosure, $F(1,306) = 21.850$, $p < .001$, and Identity Diffusion, $F(1,306) = 16.957$, $p < .001$. Therefore, a more conservative .01 criterion was applied to the latter two univariate comparisons. Box's M was also statistically significant, Box's M = 70.395, $F(10, 446971.426) = 6.940$, $p < .001$, indicating violation of equality of covariance matrices. Consequently, Pillai's Trace, which is relatively robust to this violation, was used as the principal multivariate statistic.

The MANOVA revealed a significant overall effect of instructional group on the combined identity dimensions, Pillai's Trace = .173, $F(4,303) = 15.820$, $p < .001$, partial $\eta^2 = .173$. Thus, approximately 17.3% of multivariate variance in the combined identity dimensions was associated with instructional group, representing a substantial effect.

At the univariate level, the virtual group obtained a somewhat higher Identity Achievement score than the traditional group, but the difference was not statistically significant, $F(1,306) = 2.209$, $p = .138$, partial $\eta^2 = .007$. A pronounced difference was observed for Identity Moratorium: participants in virtual instruction scored substantially higher than participants in conventional instruction, $F(1,306) = 51.746$, $p < .001$, partial $\eta^2 = .145$.

The virtual group also obtained a higher Identity Foreclosure score. The corresponding univariate test was $F(1,306) = 12.732$, $p < .001$, partial $\eta^2 = .040$. Because the homogeneity-of-variance assumption was violated for this dimension, the comparison was evaluated using the stricter .01 significance level; it nevertheless remained statistically significant according to the reported p value. Identity Diffusion was likewise higher under virtual instruction, $F(1,306) = 33.744$, $p < .001$, partial $\eta^2 = .099$, and remained significant under the conservative .01 criterion. Thus, the clearest differences between instructional modalities concerned moratorium and diffusion, whereas achievement displayed little evidence of a group difference.

Table 4. Comparison of Identity Formation Between Virtual and Conventional ESP Groups

Identity dimension	Virtual M	SE	Traditional M	SE	F(1,306)	p	Partial η^2
Identity Achievement	25.842	.735	24.308	.725	2.209	.138	.007
Identity Moratorium	25.322	.664	18.609	.656	51.746	<.001	.145
Identity Foreclosure	17.658	.526	15.019	.520	12.732	<.001	.040
Identity Diffusion	19.625	.527	15.321	.521	33.744	<.001	.099
Overall multivariate group effect	—	—	—	—	15.820*	<.001	.173

The fourth research question concerned the validity of the instrument used to measure perceived qualities and competencies in ESP education. The questionnaire consisted of 61 items, corresponding to Items 60–120. The overall Cronbach's alpha was .916, indicating excellent internal consistency.

Exploratory factor analysis using principal axis factoring produced six factors. In contrast to the Marcia questionnaire, an orthogonal Varimax rotation was selected because the component correlations were relatively modest. Specifically, the

correlations were −.136 between Factors 1 and 2, −.183 between Factors 1 and 3, −.192 between Factors 1 and 4, .173 between Factors 1 and 5, .171 between Factors 1 and 6, .190 between Factors 2 and 3, .191 between Factors 2 and 4, −.160 between Factors 2 and 5, −.124 between Factors 2 and 6, .184 between Factors 3 and 4, −.179 between Factors 3 and 5, −.173 between Factors 3 and 6, −.172 between Factors 4 and 5, −.169 between Factors 4 and 6, and .218 between Factors 5 and 6. These coefficients supported use of an orthogonal solution.

The KMO index was .871, indicating good sampling adequacy, and Bartlett's test of sphericity was significant, $\chi^2(1830) = 10144.312$, $p < .001$. The data were therefore suitable for factor analysis. The six-factor solution accounted for 50.418% of extracted variance. The successive extracted contributions were 17.217%, 7.770%, 7.582%, 6.844%, 6.206%, and 4.799%.

The first factor was labeled Creativity and included Items 79–90, with primary factor loadings ranging from .671 to .729, CR = .918, and AVE = .694. The second factor, Social Use of Language, encompassed Items 91–101. Primary loadings ranged from .676 to .741, with CR = .918 and AVE approximately .710–.715. The third factor, Application of Knowledge, included Items 109–120, with loadings ranging from .626 to .726, CR = .905, and AVE = .665. The fourth factor, Knowledge and Abilities, comprised Items 60–69, with loadings ranging from .645 to .750, CR = .912, and AVE = .712. The fifth factor, Materials and Environment, consisted of Items 70–78, with loadings ranging from .611 to .747, CR = .883, and AVE = .674. The sixth factor, Understanding Students' Needs, included Items 102–108, with loadings ranging from .661 to .740, CR = .875, and AVE = .706.

The individual primary loadings further showed a stable structure. Creativity was defined by loadings of .729, .713, .706, .705, .704, .692, .689, .688, .684, .674, .672, and .671 across Items 79–90. Social Use of Language showed primary loadings of .741, .737, .726, .724, .720, .719, .713, .691, .683, .681, and .676. Application of Knowledge loadings ranged from .626 to .726 across its 12 items. Knowledge and Abilities loadings ranged from .645 to .750 across ten items. Materials and Environment loadings ranged from .611 to .747 across nine items, while Understanding Students' Needs loadings ranged from .661 to .740 across seven items. Because a limited number of items showed conceptual overlap with neighboring constructs, the six labels were treated as tentative, and the principal virtual-versus-conventional comparison was therefore conducted using the total questionnaire score.

The fifth research question examined whether virtual and conventional ESP groups differed in their perceptions of educational qualities and competencies. Normality was supported: the virtual group had skewness of −.473 and kurtosis of .447, while the conventional group had skewness of −.320 and kurtosis of .284.

The virtual group obtained a mean total score of 168.00 (SD = 28.504, SE = 2.312), whereas the conventional group obtained a mean of 166.16 (SD = 31.483, SE = 2.521). Levene's test was nonsignificant, $F = 1.361$, $p = .244$, indicating that the assumption of homogeneity of variance was satisfied. The independent-samples t-test did not reveal a significant difference between the two instructional groups, $t(306) = .537$, $p = .592$. The mean difference was only 1.840 points, SE = 3.425, 95% CI [−4.899, 8.579], with an effect-size correlation of approximately $r = .031$. Accordingly, instructional modality was not associated with a meaningful difference in perceived ESP educational qualities and competencies.

The sixth research question addressed whether perceptions of identity were comparable across virtual and conventional ESP instruction. The identity test demonstrated good internal consistency, with Cronbach's $\alpha = .894$. The supplied material describes the test as containing 12 items, although the reliability output reports 16 items; the reliability coefficient reported by the statistical analysis was retained for interpretation. Factor analysis was not conducted because the test was conceptualized as measuring a single construct.

Normality was again supported. The virtual group had skewness of −.345 and kurtosis of −1.200, while the traditional group showed skewness of −.413 and kurtosis of −1.178. Participants in virtual instruction obtained M = 7.30, SD = 3.988, SE = .324,

while participants in conventional instruction obtained M = 7.10, SD = 4.019, SE = .322. Levene's test was nonsignificant, F = .008, p = .928. The resulting independent-samples t-test was also nonsignificant, t(306) = .452, p = .651, mean difference = .206, SE = .456, 95% CI [−.691, 1.104], r = .026. Consequently, the groups were statistically comparable in their scores on the general identity-perception measure.

Table 5. Psychometric Results and Group Comparisons for ESP Qualities/Competencies and the Identity Test

Measure/Result	Virtual group	Conventional group	Reliability/Validity	Inferential result
Qualities and Competencies total	M = 168.00, SD = 28.504	M = 166.16, SD = 31.483	α = .916; KMO = .871; Bartlett $\chi^2(1830)$ = 10144.312, p < .001	t(306) = .537, p = .592, r = .031
Creativity	—	—	CR = .918; AVE = .694; loadings = .671–.729	—
Social Use of Language	—	—	CR = .918; AVE ≈ .710; loadings = .676–.741	—
Application of Knowledge	—	—	CR = .905; AVE = .665; loadings = .626–.726	—
Knowledge and Abilities	—	—	CR = .912; AVE = .712; loadings = .645–.750	—
Materials and Environment	—	—	CR = .883; AVE = .674; loadings = .611–.747	—
Understanding Students' Needs	—	—	CR = .875; AVE = .706; loadings = .661–.740	—
Identity perception test	M = 7.30, SD = 3.988	M = 7.10, SD = 4.019	α = .894	t(306) = .452, p = .651, r = .026

The six-factor qualities-and-competencies solution accounted for 50.418% of the extracted variance. The equal-variance assumption was retained for both principal independent-samples comparisons.

The seventh research question examined the validity of the TPACK and Digital Competence Questionnaire for Iranian ESP student-teachers. The measure consisted of 25 items. Eight items assessed TPACK, while 17 assessed digital competence. Cronbach's alpha for the complete instrument was .931. TPACK demonstrated α = .879, and Digital Competence demonstrated α = .927, indicating good to excellent internal consistency.

Principal axis factor analysis supported a two-factor structure. The correlation between the two extracted factors was .475, exceeding the ±.32 criterion; consequently, an oblique rotation was used. Sampling adequacy was excellent, with KMO = .949. Bartlett's test was statistically significant, $\chi^2(300) = 3382.845$, $p < .001$, confirming that the item correlation matrix was factorable.

The two-factor model accounted for 44.578% of the extracted variance. The first factor accounted for 35.667%, while the second contributed an additional 8.911%. Digital Competence represented the first factor and contained the 17 digital-competence items. Their primary loadings ranged from .598 to .708. Specifically, the loadings were .708, .707, .681, .678, .674, .660, .656, .656, .654, .641, .639, .638, .632, .631, .622, .601, and .598. Composite reliability was .926 and AVE was .652.

The second factor represented TPACK. Its eight items had primary loadings of .761, .714, .697, .692, .675, .668, .653, and .629. Composite reliability was .877 and AVE was .686. The clear segregation of the digital-competence items and all TPACK items into their respective factors supported the construct validity of the measure.

The eighth research question assessed differences in TPACK and digital competence between virtual and conventional ESP groups. Normality was supported for both dependent variables. In the virtual group, TPACK demonstrated skewness of −.968 and kurtosis of .059, while digital competence demonstrated skewness of −.728 and kurtosis of −.632. In the conventional group, corresponding values were .014 and −1.483 for TPACK and −.190 and −1.234 for digital competence.

The homogeneity-of-variance assumption was violated for both dependent variables. Median-based Levene tests yielded $F(1,306) = 20.636$, $p < .001$ for TPACK and $F(1,306) = 155.750$, $p < .001$ for digital competence. Mean-based tests similarly yielded $F = 23.060$ and $F = 176.461$, respectively, both $p < .001$. Accordingly, the univariate comparisons were evaluated at the more stringent .01 significance level.

Box's M was also significant, Box's M = 134.752, $F(3, 17223446.968) = 44.599$, $p < .001$, demonstrating inequality of covariance matrices. Pillai's Trace was therefore selected for the principal multivariate interpretation. The multivariate group effect was substantial and statistically significant, Pillai's Trace = .721, $F(2,305) = 393.366$, $p < .001$, partial $\eta^2 = .721$. Instructional modality was thus associated with a very large multivariate difference across the combined TPACK and digital-competence outcomes.

The virtual group had a mean TPACK score of 6.132 (SE = .214, 95% CI [5.710, 6.553]), compared with 3.904 (SE = .211, 95% CI [3.488, 4.320]) in the conventional group. The univariate difference was statistically significant, $F(1,306) = 54.814$, $p < .001$, partial $\eta^2 = .152$.

An even larger difference emerged for Digital Competence. The virtual group obtained M = 15.836 (SE = .239, 95% CI [15.366, 16.305]), whereas the traditional group obtained M = 6.436 (SE = .236, 95% CI [5.972, 6.899]). This difference was highly significant, $F(1,306) = 785.666$, $p < .001$, partial $\eta^2 = .720$. Approximately 72% of the variance in digital competence was therefore associated with group membership according to the partial eta-squared estimate.

The ninth research question examined the relationships among participants' overall perceptions, ESP educational qualities and competencies, identity formation, TPACK, and digital competence. Pearson correlation coefficients revealed statistically significant positive relationships among all five constructs. All correlations were significant at $p < .001$, and all coefficients exceeded .50.

Participants' overall perception score correlated positively with educational quality and competence, r = .641, identity formation, r = .725, TPACK, r = .814, and digital competence, r = .772. The strongest relationship in the correlation matrix was therefore between overall perceptions and TPACK.

Educational quality and competence also correlated positively with identity formation, r = .691, TPACK, r = .643, and digital competence, r = .647. Identity formation demonstrated significant positive associations with both TPACK, r = .631, and digital competence, r = .580. Finally, TPACK and digital competence were strongly related, r = .691. These findings demonstrated that stronger perceptions of educational quality, greater technological-pedagogical competence, and greater digital competence were consistently associated with stronger identity-related outcomes.

Table 6. Psychometric Properties, Group Differences, and Intercorrelations of TPACK, Digital Competence, Identity, and Educational Competence

Panel A: TPACK/Digital Competence Results				TPACK	Digital Competence
Cronbach's α				.879	.927
Composite reliability				.877	.926
AVE				.686	.652
Primary loading range				.629–.761	.598–.708
Virtual group mean				6.132	15.836
Conventional group mean				3.904	6.436
F(1,306)				54.814	785.666
p				<.001	<.001
Partial η^2				.152	.720
Panel B: Pearson Correlations	Perception	Competence	Identity	TPACK	Digital
Perception	1				
Competence	.641**	1			
Identity	.725**	.691**	1		

TPACK	.814**	.643**	.631**	1	
Digital competence	.772**	.647**	.580**	.691**	1

Overall, the findings demonstrated a complex pattern regarding the role of instructional modality in identity formation and technology-related competence. Participants did not uniformly perceive virtual education as beneficial to identity development: the largest single group described its overall influence as negative, while another substantial proportion reported no effect. At the same time, virtual learning was positively associated with specific developmental experiences, particularly expansion of worldview, stronger self-perceptions among a considerable proportion of participants, and perceived improvements in social interaction or relationships.

The psychometric analyses supported the applicability of the principal instruments. The Marcia Identity Questionnaire demonstrated excellent reliability and a clear four-factor structure corresponding to achievement, moratorium, diffusion, and foreclosure. The Qualities and Competencies Questionnaire showed excellent overall internal consistency and a six-factor structure reflecting Creativity, Social Use of Language, Application of Knowledge, Knowledge and Abilities, Materials and Environment, and Understanding Students' Needs. The TPACK and Digital Competence Questionnaire similarly demonstrated strong internal consistency and a theoretically interpretable two-factor structure.

Comparisons between instructional modalities indicated that the most substantial identity difference concerned Identity Moratorium, followed by Identity Diffusion, both of which were higher among participants exposed to virtual instruction. Identity Achievement did not significantly differ between groups. The virtual and conventional groups were also statistically comparable in their overall evaluations of ESP qualities and competencies and on the general identity-perception test. In contrast, pronounced differences emerged for technology-related variables. Participants in virtual ESP instruction demonstrated significantly higher TPACK and markedly higher digital competence than those in conventional instruction.

Finally, the correlational findings revealed that identity formation was embedded within a broader network of instructional and technological variables. Identity formation was positively associated with perceived ESP educational quality and competence, TPACK, and digital competence. Similarly, perceptions of ESP instruction were strongly associated with TPACK and digital competence. The overall pattern therefore indicates that identity formation, student-teacher educational experiences, technological-pedagogical competence, and digital competence function as interconnected dimensions of ESP instruction rather than as isolated educational outcomes.

Discussion and Conclusion

The present study examined the interrelationships among identity formation, student–teacher interaction, perceived ESP instructional qualities and competencies, TPACK, and digital competence across virtual and face-to-face ESP instruction. The findings revealed a multidimensional pattern rather than a uniformly positive or negative effect of virtual learning. Participants' perceptions of virtual learning and identity formation were mixed, significant differences emerged between instructional modes for several identity dimensions and for technology-related competencies, and strong positive correlations were observed among identity formation, perceived competence, TPACK, digital competence, and overall perceptions of instruction. Taken together, the findings indicate that virtual ESP education may reshape identity-related processes in ways that differ from conventional classroom instruction, while simultaneously strengthening technology-related forms of professional and instructional competence.

The first major finding concerned participants' perceptions of the effect of virtual learning on identity formation. The largest proportion of participants perceived virtual learning as having a negative influence on their identity formation, although a

similarly large group indicated that it had no effect. Only a smaller proportion explicitly described the overall effect as positive. At the same time, when participants were asked about more specific mechanisms, the pattern became more nuanced. The most commonly reported effect was an expanded worldview, followed by strengthened cultural identity, challenged existing beliefs, and increased self-awareness. These results suggest that virtual learning may not necessarily be perceived as uniformly beneficial to identity at a global level, yet it may still stimulate important processes of exploration, reflection, and exposure to alternative perspectives. This interpretation is consistent with research emphasizing that identity formation is shaped by social and contextual experiences rather than developing in isolation (1-3). Identity is particularly sensitive to changes in social environments, perceived autonomy, interpersonal expectations, and opportunities for self-exploration. Virtual education may therefore function as a context that simultaneously challenges established forms of identity while opening new pathways for exploration and reconstruction.

The finding that virtual learning expanded participants' worldview is also compatible with studies emphasizing the identity-shaping role of digital environments. Online platforms expose individuals to broader communities, alternative modes of self-representation, and more diverse social and cultural content than may be available in immediate face-to-face environments. Research on digital self-presentation has shown that online spaces can influence identity development by providing opportunities for individuals to experiment with how they represent themselves and respond to external feedback (4). Similarly, the use of social media has been associated with identity development and lifestyle construction through exposure to different values, norms, images, and social networks (5). Although virtual education differs from social media in purpose and structure, both environments involve digitally mediated interaction and exposure to forms of communication that may alter learners' understanding of themselves and others. In ESP settings, such exposure may be particularly significant because learners are not only constructing personal identities but also developing academic and professional identities associated with their disciplinary fields.

The results regarding community belonging and sense of self further reinforce this interpretation. A considerable proportion of participants agreed or strongly agreed that virtual learning contributed positively to their sense of community and belonging, although a substantial group remained neutral or disagreed. Similarly, almost half of the participants indicated that virtual learning helped them develop a stronger sense of self. These mixed findings suggest that the effect of virtual learning depends partly on how effectively the instructional environment supports participation, recognition, communication, and social integration. Identity development is closely related to opportunities to belong to meaningful social groups and to receive feedback about one's place within those groups. Where virtual ESP classrooms offer collaborative tasks, responsive instructors, visible participation, and opportunities for meaningful disciplinary communication, they may reinforce learners' sense of belonging and professional self-concept. Where interaction is limited or impersonal, the same environment may instead weaken feelings of connection.

This interpretation is supported by the findings concerning social interaction. More participants reported that virtual learning increased social interactions or improved relationships than reported that it reduced interaction. This result is notable because virtual education is often assumed to necessarily weaken interpersonal relationships. The current findings indicate that technology-mediated communication can, under some circumstances, create additional opportunities for interaction. Online discussion platforms, messaging systems, synchronous video classes, shared documents, and digital collaborative activities may extend communication beyond the physical classroom. Research on teacher–student interaction has similarly shown that creative and well-designed interaction can enhance engagement and facilitate more meaningful learning (8, 9). In online environments specifically, teacher–student interaction and emotional experience have been found to play important roles in

learners' academic functioning (10). Thus, virtuality itself may not determine the quality of interaction; rather, the decisive factor may be how digital tools are used to create socially and pedagogically meaningful exchanges.

The psychometric findings also supported the conceptualization of identity formation as multidimensional. The Marcia-based instrument demonstrated excellent overall reliability and a clear four-factor structure corresponding to identity achievement, moratorium, diffusion, and foreclosure. This finding supports the use of a differentiated approach to identity rather than relying on a single global identity score. Identity formation involves differing degrees of exploration and commitment, and virtual and conventional instructional environments may influence these processes differently. The clear factor structure observed in the current study reinforces the idea that identity is not a unitary construct and that educational settings may affect specific identity statuses in distinct ways.

The comparison between virtual and face-to-face groups provided further evidence for this distinction. There was no statistically significant difference between the two groups in identity achievement, whereas the virtual group scored significantly higher on identity moratorium, foreclosure, and diffusion. The strongest difference was observed for moratorium. Higher moratorium scores indicate greater exploration and uncertainty rather than consolidated commitment. One plausible explanation is that virtual learning exposes learners to more diverse ideas, communication modes, disciplinary resources, and forms of participation, thereby encouraging exploration but not necessarily immediately leading to stable identity commitments. This is consistent with research showing that digital environments can expand opportunities for identity experimentation and self-presentation (4, 5). It also corresponds with broader evidence that identity development can become more complex when individuals encounter competing expectations or major contextual changes (1, 2).

The higher diffusion scores among virtual participants can also be interpreted in relation to the ambiguity and reduced structure sometimes associated with online education. Virtual environments may increase autonomy and flexibility but may simultaneously reduce direct social cues, routine classroom structure, and immediate interpersonal feedback. For some learners, these conditions can create uncertainty about academic roles and participation. Consequently, the same digital flexibility that promotes exploration may also contribute to less consolidated forms of identity. The coexistence of higher moratorium and diffusion is therefore theoretically plausible: virtual education may broaden identity possibilities while also weakening some of the external structures that ordinarily support stable commitments. By contrast, the absence of a significant difference in identity achievement suggests that virtual instruction alone may not be sufficient to produce more mature or committed identity outcomes.

The study also found that participants in virtual and traditional environments did not significantly differ in their overall perceptions of ESP educational qualities and competencies. This result suggests that the core qualities associated with effective ESP education may be maintained across instructional modalities. Competencies such as knowledge and abilities, creativity, appropriate materials, awareness of students' needs, social use of language, and application of knowledge may not depend exclusively on whether instruction is delivered virtually or face-to-face. Instead, these qualities may reflect broader pedagogical competence and instructional design. This finding is compatible with contemporary understandings of technology integration, which emphasize that technological tools should complement rather than replace sound pedagogy (11). A competent ESP teacher may therefore be perceived positively in either environment when disciplinary knowledge, instructional methods, interaction, and responsiveness to student needs are appropriately aligned.

The factor structure of the Qualities and Competencies Questionnaire also reinforced the multidimensionality of effective ESP teaching. Creativity, social use of language, application of knowledge, knowledge and abilities, materials and environment, and understanding students' needs all emerged as distinguishable dimensions. These factors align with research emphasizing the importance of creative teacher–student interaction and responsive instructional strategies (8, 9). In ESP education, these

competencies are particularly important because instructors must adapt language instruction to specialized disciplinary contexts, select authentic materials, understand learner needs, and facilitate meaningful communication related to students' academic or professional fields.

A different pattern emerged for TPACK and digital competence. The virtual group significantly outperformed the traditional group on both variables, and the effect for digital competence was especially large. These findings are highly consistent with the assumption that sustained exposure to technology-mediated teaching strengthens educators' ability to use digital resources and integrate technology with pedagogy and content. Previous research has demonstrated a positive relationship between digital literacy and TPACK among pre-service English teachers (12). Similarly, active participation in technology-enhanced professional learning has been shown to contribute to TPACK development (13). The current findings therefore suggest that virtual ESP education functions not only as an instructional environment but also as a context for developing technological pedagogical expertise.

The strong difference in TPACK between virtual and conventional groups can also be understood through the contextual nature of the TPACK framework. Contemporary conceptualizations emphasize that technological pedagogical content knowledge develops through the interaction of teacher knowledge with the particular demands of instructional contexts (11). In virtual ESP classrooms, instructors are required to select digital platforms, adapt teaching strategies, organize online materials, facilitate technology-mediated interaction, and represent specialized disciplinary content through digital formats. Repeated engagement with these tasks may strengthen integrated TPACK more effectively than occasional technology use in traditional classrooms.

Recent developments involving artificial intelligence further support this interpretation. Research has shown that TPACK is related to teachers' AI competence, teaching performance, self-efficacy, and intentions to use emerging technologies (14-16). In addition, ICT and AI-related support have been found to contribute synergistically to pre-service teachers' TPACK development (17). These findings indicate that technological competence develops through both direct experience and supportive technological ecosystems. Virtual ESP instruction may therefore provide conditions in which teachers and student-teachers are repeatedly required to integrate digital tools with disciplinary content and pedagogical objectives, explaining the substantially higher TPACK and digital competence scores observed in the present study.

The positive relationship between TPACK and digital competence found in the current study further supports this explanation. Participants with stronger digital competence also tended to demonstrate stronger TPACK. This relationship is theoretically expected because basic digital competence provides the technological foundation upon which more sophisticated pedagogical integration can develop. However, TPACK goes beyond technical skill by requiring educators to understand when, why, and how technology should be used to teach specific content. The relationship observed in this study therefore supports previous findings linking digital literacy and technological pedagogical knowledge (12).

Finally, the correlational analysis showed that all major constructs were positively associated with one another. Identity formation correlated significantly with educational quality and competence, TPACK, and digital competence. Perceptions of instruction were also strongly related to TPACK and digital competence. These findings suggest that identity development within ESP education cannot be separated from the quality of the learning environment and the technological-pedagogical competence of instructors. When students perceive teaching as effective, interactive, responsive, and technologically appropriate, they may be more likely to participate actively, develop confidence, and see themselves as legitimate members of academic and professional communities. Educational technology can also support metacognitive development in ESP instruction, enabling learners to reflect more systematically on their learning and regulate their academic behavior (6). Such

reflection may contribute to identity formation by strengthening awareness of one's competencies, goals, and disciplinary position.

The strong relationship between overall perceptions and TPACK is particularly noteworthy. It suggests that students may evaluate contemporary ESP instruction partly through the quality of technological integration they experience. Technology that is pedagogically purposeful, aligned with specialized content, and used to facilitate interaction is likely to enhance students' evaluations of instruction. Conversely, technology that is poorly integrated may reduce perceived instructional quality despite high levels of technical sophistication. These results align with the broader TPACK literature, which emphasizes integration rather than technology use alone (11, 15). Overall, the findings support a relational model in which identity formation, student–teacher interaction, instructional quality, and technological competence mutually reinforce one another within ESP education.

The findings should be interpreted in light of several limitations. First, the participants were drawn from a specific higher-education context, which limits the extent to which the results can be generalized to ESP learners and instructors in other universities, regions, or educational systems. Second, much of the quantitative evidence was based on self-report instruments and therefore may have been influenced by social desirability, recall bias, or participants' subjective interpretations of virtual and face-to-face instruction. Third, the non-random sampling procedure restricts population-level generalization. Fourth, the cross-sectional nature of the quantitative phase prevents causal conclusions regarding whether virtual education directly produces changes in identity formation, TPACK, or digital competence. Finally, some constructs, particularly identity development, are complex and developmental in nature and may not be fully captured through questionnaire responses collected at a single point in time.

Future studies should examine these relationships using longitudinal designs that track changes in identity formation, interaction, TPACK, and digital competence across extended periods of virtual, blended, and face-to-face instruction. Replication with larger and more diverse samples from different universities, academic disciplines, geographical regions, and cultural settings would improve the generalizability of the findings. Experimental or quasi-experimental studies could also examine whether specific forms of interaction or targeted TPACK training produce measurable changes in identity-related outcomes. Future research should distinguish more carefully among synchronous, asynchronous, blended, and fully online ESP environments because these formats may generate different patterns of interaction and identity development. Qualitative investigations involving both teachers and students could further clarify why virtual learning promotes identity exploration for some participants while contributing to uncertainty or weaker commitment for others. Studies incorporating classroom observations, learning analytics, and performance-based measures of technological competence would also provide useful alternatives to exclusive reliance on self-report data.

Universities and ESP programs should design virtual and blended courses so that technological integration is accompanied by purposeful interaction, consistent instructor presence, timely feedback, collaborative learning, and opportunities for students to develop a clear sense of academic and professional belonging. ESP teachers should receive professional development that integrates technological skills with pedagogical and discipline-specific knowledge rather than treating digital competence as a separate technical ability. Online activities should encourage students to communicate about authentic disciplinary content, reflect on their learning, collaborate with peers, and receive recognition for meaningful participation. Because virtual instruction may simultaneously promote identity exploration and uncertainty, instructors should also provide clear structure, predictable communication, opportunities for mentoring, and explicit connections between ESP learning and students' future academic or professional roles. Finally, institutions should ensure that technological infrastructure, technical support, and access to appropriate digital resources are sufficiently reliable to allow teachers to concentrate on instructional quality and student engagement rather than on overcoming avoidable technological barriers.

Acknowledgments

We would like to express our appreciation and gratitude to all those who helped us carrying out this study.

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.

Funding

This research was carried out independently with personal funding and without the financial support of any governmental or private institution or organization.

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