International Journal of Assessment Tools in Education
2026, Vol. 13, No. 1, 308–329
https://doi.org/10.21449/ijate.1662535
journal homepage: https://dergipark.org.tr/en/pub/ijate
Research Article

Development and psychometric evaluation of the E-sports Attitude Scale

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ARTICLE HISTORY

Received: Mar. 21, 2025

Accepted: Sep. 28, 2025

KEYWORDS

E-sports,
Attitude,
Scale development,
Validation,
University students.

Abstract: This study aimed to develop and conduct a comprehensive psychometric evaluation of a scale designed to measure university students' attitudes toward e-sports. The research was carried out using a correlational research design. Two independent samples selected using maximum variation sampling were utilized: 797 students participated in the exploratory factor analysis (EFA), while 794 students were included in the confirmatory factor analysis (CFA). The EFA results revealed a four-factor structure -socialization, individualization, career, and risks- explaining 64% of the total variance. The CFA supported this structure with excellent model fit indices (CFI = .99, TLI = .98, RMSEA = .05, SRMR = .06). Reliability analyses demonstrated high internal consistency, with Cronbach's α ranging from .89 to .93, McDonald's ω between .90 and .94, and stratified α (.94) as well as Revelle's ω (.97) for the total scale. Furthermore, measurement invariance across gender was examined and supported, indicating that the scale functions equivalently for male and female respondents. Additionally, Differential Item Functioning (DIF) analysis based on ordinal logistic regression revealed no significant gender-related item bias, reinforcing item-level fairness. These findings provide strong evidence for the validity, reliability, and fairness of the E-sports Attitude Scale, confirming its suitability for measuring attitudes toward e-sports in higher education contexts.

INTRODUCTION

E-sports (electronic sports) has rapidly evolved into a global phenomenon that not only entertains but also influences young people's social, academic, and professional lives. Its growing presence has positioned it as a significant field of inquiry in education and the social sciences. At its core, e-sports refers to organized competitive video gaming, where individuals or teams compete in multiplayer environments mediated by computers or consoles and broadcast online (Hamari & Sjöblom, 2017). What began as single-player games in the 1980s transformed into human-versus-human competitions in the 1990s with the expansion of internet infrastructure, graphics, and computing power, laying the foundation for today's e-sports (Shan

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e-ISSN: 2148-7456

et al., 2023). E-sports now mirrors traditional sports in many ways, featuring professional players, teams, coaches, managers, leagues, tournaments, live broadcasting, sponsorships, and scholarships (Funk *et al*., 2018). Supported by international federations and corporate sponsors, large-scale tournaments attract millions of viewers worldwide. As a result, e-sports has become a global multi-billion-dollar industry that rivals traditional sports in popularity, especially among young adults (Shan et al., 2023). Given this expanding footprint, the development of valid and reliable instruments to measure students' attitudes toward e-sports has become increasingly important.

The rapid rise of e-sports has also drawn significant attention from higher education. Universities, especially in the United States, have launched specialized programs, scholarships, and varsity teams to respond to growing student demand (Salo, 2021). More than 350 institutions worldwide now integrate e-sports into curricula or extracurricular activities. These initiatives recognize its potential to foster teamwork, strategic thinking, and digital literacy, while simultaneously opening career pathways in broadcasting, game design, event management, and professional play. In the literature, e-sports has been investigated from multiple perspectives, such as educational and managerial aspects (Funk *et al*., 2018), health-related risks (Ketelhut *et al*., 2021), student perceptions (Delello *et al*., 2021), sponsorship and branding opportunities (Huettermann *et al*., 2023), and social connectedness (Soares *et al*., 2022). Findings highlight both opportunities and challenges: on the positive side, studies indicate that e-sports participation supports social and academic outcomes, such as stronger friendships and belonging (Akkaya *et al*., 2021) and stress relief and transferable skills like teamwork and problem-solving (Delello *et al*., 2021). However, risks have also been noted, including social isolation, addictive behaviors, and negative impacts on academic performance (Ketelhut *et al*., 2021). Therefore, these results underscore the need for a multidimensional scale that captures both benefits and risks in student populations.

Existing Measurement Tools and Limitations

Although interest in e-sports research is growing, the tools developed to measure related constructs remain limited and fragmented. In the international literature, several instruments have been developed. For example, Qian *et al*. (2019), drawing on Self-Determination Theory, developed the Motivation Scale of Esports Spectatorship and identified eight dimensions of online viewership: entertainment, competition, drama, game knowledge, skill improvement, vicarious sensation, socialization, and friends bonding. Leung *et al*. (2021) developed the TPB-Esports Intention Questionnaire, grounded in the Theory of Planned Behavior, to measure students' intentions to engage in e-sports across four dimensions: attitude, subjective norm, perceived behavioral control, and intention. Ye *et al*. (2021) developed the 5Cs Educational Value Scale for e-sport games to measure students' perceptions of educational value, encompassing five dimensions: cooperative attitude, communication skills, critical thinking, self-confidence, and continuous improvement attitude.

In the Turkish context, several e-sports–related scales have been developed. Gül *et al*. (2019) developed the Participation Motivation Scale for E-sports to measure players' motivation for engaging in e-sports, and identified three dimensions: intrinsic motivation for knowing and achieving, extrinsic regulation, and identification. More directly addressing attitudes, Savaş and Turan (2023) developed the first national E-sports Attitude Scale for university students, comprising 18 items and a three-dimensional structure (cognitive, affective, behavioral) consistent with the classic tripartite model. While this instrument demonstrated adequate reliability, it did not sufficiently capture context-specific aspects such as career considerations or perceived risks. To address this limitation, the present study introduces and validates a new four-factor structure—socialization, individualization, career, and risks—aimed at providing a more comprehensive measurement of the multifaceted nature of e-sports attitudes. Beyond these instruments, other digital game–related scales indirectly address constructs relevant to e-sports. The Digital Game Playing Motivation Scale (Tekkurşun-Demir & Hazar, 2018) and the Digital Game Playing Attitude Scale (Tekkurşun-Demir & Bozkurt, 2019) stand out as related tools.

At the broader international level, attitudes and perceptions have primarily been examined through survey- and review-based approaches in domains such as spectating, social participation, health, and career. For example, Qian *et al*. (2019) examined the dimensions of e-sports online spectator demand through survey data and factor analysis, providing both conceptual and empirical insights. Similarly, Shan et al. (2023) investigated the role of e-sports in fostering social connectedness during the COVID-19 pandemic using adapted instruments, while Cole (2023) examined perceptions of e-sports as a career choice with survey-based tools. In addition, Yin *et al*. (2020) reviewed health risks and benefits of e-sports through existing health and lifestyle measures. Despite these contributions, no specific scale designed to directly and comprehensively measure general attitudes toward e-sports has been identified in the international literature. Overall, existing instruments remain limited, focusing largely on domain-specific constructs such as motivation, intention, or educational value, rather than offering a holistic measurement of attitudes. Consequently, there is a clear need for a validated, multidimensional attitude instrument that integrates cognitive, affective, behavioral, career, and risk dimensions—a gap the present study directly addresses.

Theoretical Framework and Study Rationale

Attitudes are defined in social psychology as psychological tendencies expressed by evaluating an entity with favor or disfavor (Eagly & Chaiken, 1993; Schuman & Johnson, 1976). The classic tripartite model conceptualizes attitudes through cognitive, affective, and behavioral dimensions (Eagly & Chaiken, 1993; Shi & Ren, 2023). However, several studies have demonstrated that this model does not always fully capture the complexity of attitudes. Evaluative tendencies may also be shaped by contextual, social, or identity-related factors that extend beyond the traditional three components (Crites *et al*., 1994; Fabrigar *et al*., 2005; Maio & Haddock, 2014; Petty *et al*., 2019). This suggests that students' attitudes toward e-sports are likely to encompass additional dimensions—such as socialization, individualization, career, and risks—which reflect the socio-cultural and professional significance of e-sports. Accordingly, a four-dimensional model is proposed to guide the process of scale development and validation.

Building on this framework, the first dimension, socialization, highlights teamwork, interaction, and community, as e-sports fosters meaningful connections both online and offline. Studies document peer bonding and a sense of belonging in student populations (Akkaya *et al*., 2021), the role of social motives in spectator engagement (Qian *et al*., 2019), and the importance of online gaming communities for interaction and affiliation (Kaye & Bryce, 2012; Kowert *et al*., 2014). Research on sportification and identity further situates e-sports within broader social practices (Hilvoorde & Pot, 2016), while pandemic-era studies highlight its role in maintaining social connectedness when face-to-face contact was limited (Shan *et al*., 2023). Accordingly, the existing literature positions socialization as a core attitudinal domain in e-sports contexts. The second dimension, individualization (personal development), reflects skill enhancement, problem-solving, decision-making, and confidence building through structured play and competition. Empirical and review evidence links strategic or action gaming with problem-solving and cognitive benefits (Adachi & Willoughby, 2013a; Bediou *et al*., 2018; Granic *et al*., 2014). Additionally, discussions of e-sports in educational and career contexts point to its role in fostering self-development (Cole, 2023), while national-level studies also emphasize positive learning-related attitudes among university students (Savaş & Turan, 2023). The third dimension, career, underscores the potential of e-sports as a gateway to academic and professional opportunities. Universities and industry provide career pathways in areas such as professional play, event management, and digital media. Research in higher education and management frames e-sports as an emerging professional ecosystem and stresses the transferability of competencies—including collaboration, communication, and digital skills to broader career pathways (Hosky & Wibowo, 2023; Rothwell & Shaffer, 2019; Scholz, 2019). Finally, the fourth dimension, risks, addresses potential drawbacks such as gaming disorder, musculoskeletal strain, sleep disruption, and academic decline. The literature discusses ergonomic and health concerns, addictive play patterns, and lifestyle-related risks (Hoffelner *et al*., 2025; King *et al*., 2018; Rochat & Armengol, 2020; Wattanapisit *et al*., 2020; Weinstein & Lejoyeux, 2015). It also emphasizes the classification of "gaming disorder" (WHO, 2019) and integrates reviews that consider both risks and benefits (Yin *et al*., 2020). At the same time, balanced and responsible engagement has been highlighted as a way to mitigate adverse outcomes (Lobel *et al*., 2017).

By systematically situating these four dimensions socialization, individualization, career, and risks—within the broader educational, social, and professional landscape of e-sports, the present study extends classical attitude theory and addresses a critical gap in the literature. Importantly, it also contributes culturally relevant insights by focusing on Turkish university students, offering one of the first multidimensional e-sports attitude scales with a four-factor structure developed in this context. In doing so, the study not only contributes to psychometric measurement practice but also provides practical implications for higher education particularly regarding program design, student support, and evidence-based decision-making.

Research Purpose and Questions

In light of the above discussion, the purpose of the current research is to develop the E-sports Attitude Scale for university students and to examine its psychometric properties, including validity and reliability evidence. The study seeks to answer the following key questions:

1. Do the scores obtained from the E-sports Attitude Scale demonstrate adequate reliability?
2. What is the factor structure of the E-sports Attitude Scale, and does it correspond to the theorized four-factor model (socialization, individualization, career, and risks)? Specifically, do the results yield validity evidence based on internal structure as supported by exploratory and confirmatory factor analyses?
3. Does the factor structure of the E-sports Attitude Scale demonstrate measurement invariance across gender groups (male and female students)?
4. Do the items of the E-sports Attitude Scale function differently across gender groups?

METHOD

Research Design

This study was conducted using a correlational research design, which, as noted by Fraenkel *et al*. (2018) and Creswell (2015), is a quantitative approach used to examine the relationships between two or more variables without researcher intervention. This design is particularly appropriate for scale development studies, as it allows for the investigation of relationships among scale items, the analysis of underlying latent factors, and the comprehensive evaluation of the psychometric properties of the measurement instrument. Within this framework, the study explored the interrelations among the items, identified latent constructs through factor analyses, and rigorously assessed the validity and reliability of the developed scale.

Study Group

In this research, the study sample rather than the entire population was utilized, as it was not feasible to reach all university students in Türkiye. According to Fraenkel *et al*. (2018) and Creswell (2015), a sample is a subset of the population selected to represent its characteristics, enabling researchers to make inferences about the larger group. In line with best practices in scale development, two independent samples were used for the analyses to ensure robust psychometric testing of the scale. The first sample (n = 797) was used to conduct the

Exploratory Factor Analysis (EFA), which aimed to uncover the underlying structure of the scale. To validate this factor structure, Confirmatory Factor Analysis (CFA) was conducted using a second and independent sample (n = 794). Using separate samples for EFA and CFA helps to avoid capitalizing on chance and improves the generalizability and construct validity of the developed scale (Brown, 2015; Worthington & Whittaker, 2006).

The trial study sample consisted of 797 volunteer university students studying at the Faculty of Education and the Faculty of Sports Sciences from three different state universities in Türkiye. University students were selected as the target sample for this study because they represent one of the primary demographic groups actively engaged in e-sports, both as players and spectators. Moreover, they are considered a critical population for understanding youth trends, digital behaviors, and emerging subcultures, particularly in the context of competitive gaming. Maximum variation sampling was adopted to increase the diversity of participants in terms of the variables under investigation, and data were collected from three different universities located in the Eastern Anatolia, Black Sea, and Central Anatolia regions of Türkiye.

In the trial sample, approximately 41% of the participants were female (f = 325), and 59% (f = 472) were male. According to school year distribution, approximately 29% of the students were in the 1st year (f = 230), 35% (f = 281) were in the 2nd year, 19% (f = 153) were in the 3rd year, and 17% (f = 133) were in the 4th year. Approximately 78% (f = 625) of the students making up the trial study sample of the research had e-sports experience at or outside of school. In comparison, about 22% (f = 172) did not have any e-sports experience. About 58% (f = 466) of the students performed e-sports activities at home, approximately 10% (f = 77) in public areas, and 10% (f =82) in private e-sports centers. The examination of the students in terms of the time they spent a week on e-sports showed that approximately 52% (f = 415) spent 0-3 hours, 14% (f = 112) 4-6 hours, 5% (f = 38) 7-9 hours, and 7% (f = 60) 10 hours or more.

The validity study sample consisted of 794 volunteer university students studying at the Faculty of Education, Faculty of Sports Sciences, Faculty of Engineering and Architecture, and Faculty of Health Sciences from five state universities in Türkiye. The maximum variation sampling was used as the aim was to include a sample of students as diverse as possible in terms of the feature examined. Accordingly, data were collected from universities in the Eastern Anatolia, Black Sea, and Central Anatolia regions of Türkiye.

In the validity study sample, about 71% of the validity study sample were female (f = 561) and 29% (f = 233) were male. The examination of the school year distribution indicated that about 37% of the students were in the 1st year (f = 295), 19% (f = 149) were in the 2nd year, 35% (f = 279) were in the 3rd year, and 9% (f = 71) were in the 4th year. Approximately 34% (f = 273) of the students in the sample had e-sports experience at school or outside of school, whereas around 66% (f = 521) did not have any e-sports experience. Approximately 26% (f = 208) of the students performed e-sports activities at home, approximately 3% (f = 22) in public areas, and 5% (f = 43) in private e-sports centers. Additionally, when students were examined in terms of the time they allocated to e-sports a week, it was seen that approximately 22% (f = 174) spent 0-3 hours, 7% (f = 57) 4-6 hours, 2% (f = 15) 7-9 hours, and 3% (f = 27) 10 hours or more.

Scale Development Processes

The 13 steps suggested by Price (2017) were followed in the development of the E-Sports Attitude Scale: (1) establishing the theoretical framework; (2) determining the purpose of the test; (3) determining the behaviors and qualities reflecting the structure; (4) determining the target audience of the test; (5) defining the content of the items; (6) drafting the items; (7) identifying the procedures for the application of the scale; (8) conducting a trial study with a representative sample; (9) conducting factor and item analyses; (10) reviewing the scale; (11) conducting validity studies; (12) determining standards; and (13) creating a technical guide.

During the development process of the E-sports Attitude Scale, firstly a 63-item pool, including six negatives and 57 positives, was created. Then, a draft form was created with the 63 items in the item pool. The draft form was submitted to three linguists, three field experts, and three measurement experts for their opinions to check the suitability of the items in terms of language and meaning, content validity, and the features that a measurement tool needed to have. Gwet's AC1 coefficient was calculated to determine the inter-rater agreement. It is interpreted as follows: .61-.80, good agreement; and .81-1.00, very good agreement (Landis & Koch, 1977). Accordingly, the coefficients calculated showed that there was good agreement (.76) among linguists, very good agreement (.91) among subject area experts, and good agreement (.74) among measurement and evaluation experts. In addition to this, expert evaluations were obtained through the Expert Opinion Form, in which each item was rated as appropriate, should be revised, or not appropriate. Based on these evaluations, the Content Validity Ratio (CVR) for each item was calculated using Lawshe's (1975) method. As a result, 21 items that fell below the critical CVR threshold of 0.750 were excluded from the scale. Subsequently, the Content Validity Index (CVI) for the remaining 42 items was calculated as CVI = 0.948. This result indicates that the scale has an acceptable level of content validity. Moreover, following the pre-test conducted with 20 students, four items were removed from the form, and the remaining items were revised accordingly. As a result, a trial form consisting of 38 items was created to be used in the trial study. Item analysis EFA were performed with the data obtained from the trial study. Accordingly, three more items were removed from the scale and the scale was reduced to 35 items. Within the scope of the validity study conducted after the trial study, the necessary evidence was presented that the scale data obtained from a new sample were valid and reliable through CFA and reliability examinations. Although no focus group discussions were conducted, the draft items were reviewed by a panel of experts in psychology, education, and sports sciences.

Data Collection Process

The trial study data were collected online during the 2023–2024 fall semester, and the data for the validity study were collected in the 2023–2024 spring semester. Prior to data collection, the ethics committee approval of the research was obtained from the Social and Human Sciences Research Ethics Committee of the Fırat University on January 1, 2023 and in the session with number 2023/01 (decision number: 18). A text about e-sports and the purpose of the study was shared with the participants before the application of the scale to increase the validity and reliability of the collected data. At the beginning of the data collection process, it was stated that participation in the study was voluntary and the scores would be kept anonymous.

Data Analysis

The trial form of the E-sports Attitude Scale consisted of 38 items and the trial study included 797 university students. Corrected item-total correlations were examined for item validity, and EFA was performed for construct validity. Within the scope of reliability analysis, McDonald's ω (McDonald, 1999) and Cronbach's α coefficients were calculated for the sub-dimensions, and stratified α and Revelle's ω total coefficients were calculated for the total scale. For this purpose, firstly the data collected were transferred to the licensed SPSS 22.0 software package, paying attention to the reverse coding of the negative items, and then it was checked whether there were missing or incorrectly entered data in the data set, and it was seen that there were no such data problems. Multicollinearity, multivariate extreme values, and multivariate normality were examined for EFA assumptions. Multivariate extreme values were examined using Mahalanobis distances. Since no extreme values were determined in the data set, the data of 797 students were subjected to EFA analysis. Multicollinearity was examined using the tolerance value and variance inflation factor (VIF). As a result, it was found that the tolerance values ranged between .25 and .54, and the VIF ranged between 1.85 and 4.01. A tolerance value of >.10 and a VIF value of <10 indicate no multicollinearity problem in the data (Kline, 2016). It was determined that there was no multicollinearity in the data. Multivariate normality was examined with Mardia’s skewness and kurtosis coefficients (1970). The results indicated that the data did not have multivariate normality (p< .001).

To determine the suitability of the data for EFA, The Kaiser-Meyer-Olkin (KMO) coefficient was examined, and Bartlett’s test of sphericity test results were examined to evaluate whether the correlations between the variables in the correlation matrix were significant. When EFA was performed, the principle axis factoring (PAF) factor extraction method, which is more suitable for scales consisting of Likert-type items and provides strong estimates against violations of multivariate normality, was preferred. The promax oblique rotation method, which uses a rotation assuming that the factors are related to each other, was preferred for this scale, which consisted of four factors and was scored on a five-point Likert-type structure (*strongly disagree* [1], *disagree* [2], *neither agree nor disagree* [3], *agree* [4], *strongly agree* [5]) (Costello & Osborne, 2005; Fabrigar *et al*., 1999). The reason for choosing Promax as the rotation method was that there are often relationships between sub-dimensions in the field of educational sciences. No limitation was imposed on the number of factors when conducting EFA, and factors with an eigenvalue of >1 were considered significant (Büyüköztürk, 2010). To determine the number of factors, a scree plot, eigenvalues, and explained variance ratio were utilized (Çokluk *et al*., 2014). In addition, to determine the number of factors to retain in the EFA, a parallel analysis was conducted using principal axis factoring based on polychoric correlations. The scree plot compares the eigenvalues derived from the actual dataset with those obtained from randomly generated and resampled data (Hayton *et al*., 2004; Horn, 1965). Corrected item-total correlations and reliability examinations were performed on the Jamovi 2.3.26 software, AFA was performed on the SPSS 22.0 software, and inter-rater agreement calculations were performed on the R Studio software by using the irrCAC (Gwet, 2019) and psych (Revelle, 2023) software package.

The validity study was conducted using the responses of 801 university students to 35 items. Since the data were collected online, no missing data were encountered. CFA was conducted for construct validity. Multicollinearity, multivariate extreme values, and multivariate normality were examined for CFA assumptions. Multivariate extreme values were examined using Mahalanobis distances, and seven data sets that were found to be significant at the .001 level were removed, and analyses were conducted on the remaining 794 data sets. Multicollinearity was examined using the tolerance value and VIF. As a result, it was found that the tolerance values ranged from .26 to .51, and the VIF ranged from 1.96 to 3.77. A tolerance value of >.10 and a VIF value of <10 indicate that there is no multicollinearity problem in the data (Kline, 2016). It was determined that there was no multicollinearity in the data. Multivariate normality was examined using Mardia’s skewness and kurtosis coefficients (1970). The results indicated that the data did not have multivariate normality (p< .001). Accordingly, CFA was performed using the ULS method. The ULS method was found to stand out by outperforming methods such as maximum likelihood (ML) and diagonally weighted least squares (DWLS) in the simulation study conducted by Yang-Wallentin *et al*. (2010). For this reason, ULS was used as the estimation method. For testing reliability, Cronbach’s α and McDonald’s ω coefficients were examined for the sub-dimensions of the scale, and stratified α and Revelle’s ω total coefficients were examined for the total scale. CFA was performed using the AMOS 22 software. Stratified α and Revelle’s ω total coefficients were calculated using the sirt (Robitzsch, 2023) and psych (Revelle, 2023) packages in R software. In addition to the evaluation of factor loadings and model fit indices, convergent and discriminant validity were assessed through Composite Reliability (CR), Average Variance Findings Regarding the Extracted (AVE), Maximum Shared Variance (MSV), and Average Shared Variance (ASV). For convergent validity, AVE values greater than 0.50 and CR values above 0.70 were considered acceptable (Hair *et al*., 2019). Discriminant validity was evaluated by comparing AVE with MSV and ASV values; the condition AVE > MSV and AVE > ASV was used as the criterion (Fornell & Larcker, 1981).

To assess whether the measurement model operated equivalently across gender groups, multigroup confirmatory factor analysis (MG-CFA) was conducted using the lavaan package (Rosseel, 2012) in R Studio. Following the hierarchical approach recommended by Putnick and Bornstein (2016), four levels of measurement invariance were tested sequentially: configural, metric, scalar, and strict. Configural invariance examines whether the same factor structure holds across groups, metric invariance tests the equality of factor loadings, scalar invariance evaluates the equivalence of item intercepts, and strict invariance assesses the equality of residual variances. Establishing these levels of invariance is essential to ensure that the construct is measured equivalently across groups and that the scale allows fair and valid comparisons (Byrne *et al*., 1989; Vandenberg & Lance, 2000). While measurement invariance focuses on group-level structural equivalence, Differential Item Functioning (DIF) analysis provides complementary evidence regarding the presence of potential bias at the item level (Zumbo, 2007). Therefore, following the MG-CFA, DIF analysis was conducted to evaluate item-level fairness. The DIF analysis employed the ordinal logistic regression (OLR) method, which is widely recommended for analyzing Likert-type ordinal items (Agresti, 2010), and was carried out using the lordif package (Choi *et al*., 2011) in the R Studio environment. The OLR procedure involves fitting a series of nested models to determine whether the probability of endorsing an item differs across groups after controlling for the overall trait level. First, a baseline model including only the total test score (matching variable) is estimated. Second, the grouping variable (gender) is added to test for uniform DIF, which reflects consistent differences between groups across trait levels. Finally, an interaction term between the total score and group is introduced to test for non-uniform DIF, which evaluates whether group differences vary across trait levels (Swaminathan & Rogers, 1990). Significant changes in model fit (e.g., χ^2 difference) or meaningful increases in pseudo R^2 (e.g., $\Delta R^2 \geq 0.035$) indicate the presence of DIF (Jodoin & Gierl, 2001). The R^2 change criterion was adopted at a significance level of .01, which is appropriate for detecting both uniform and non-uniform DIF in Likert-type scales. This approach is particularly suitable as it accounts for the ordinal nature of item responses and provides both statistical and practical evidence regarding item fairness across gender groups.

RESULTS

In accordance with established scale development guidelines (Price, 2017), this study followed a systematic procedure to ensure the psychometric quality of the developed instrument. First, the construct of attitude toward e-sports was clearly conceptualized based on a review of relevant literature. Subsequently, an initial item pool was created and refined through expert evaluation to establish content validity. Following trial implementation, item clarity was examined and adjustments were made accordingly. Exploratory factor analysis (EFA) was then conducted to uncover the underlying structure of the scale, and confirmatory factor analysis (CFA) was performed on an independent sample to validate the identified structure. Reliability was assessed using Cronbach's alpha and McDonald's ω coefficients. Finally, DIF analysis based on ordinal logistic regression was conducted to evaluate whether the items operated fairly across gender groups. The findings presented in the following subsections detail the results of these psychometric analyses in the order they were conducted.

Findings for EFA Analysis

The trial study data were obtained from 797 university students. Within the framework of validity evidence, first, these data were subjected to EFA. To determine the suitability of the data for EFA, the Kaiser-Meyer-Olkin (KMO) coefficient was examined to find out the adequacy of the sample, and Bartlett's test of sphericity results were examined to evaluate whether the correlations between the variables in the correlation matrix were significant. As an indicator of the suitability of the data for factor analysis, the KMO value is expected to be >0.60, and Bartlett's test of sphericity needs to be significant (Tabachnick & Fidell, 2013). Accordingly, it was observed that the KMO value calculated in the study (.978) was at a good level and Bartlett's test of sphericity was statistically significant (χ^2 = 25373.752; *df* = 703; *p*< .05). These values indicated that the sample size (797 subjects) was adequate and the data collected were suitable for factor analysis (Hair *et al*., 2019).

In the first application of EFA, a four-factor structure with a total explained variance ratio of 63.26% was obtained. The items were checked in terms of overlapping and factor loadings based on the analysis results. If the difference between the loading values of an item in two or more factors is less than .10, it indicates overlapping and it is recommended to remove this item from the scale (Çokluk *et al*., 2014). In this context, a total of three items were removed from the data set. Two of them were related to individual competencies (such as leadership and stress management) and one was related to social acceptance (such as increasing respect). After these items were removed, EFA was repeated. The result of the second EFA, too, showed a four-factor structure. The scree plot of the factor structure revealed as a result of the analysis is presented in Figure 1, and the eigenvalues and explained variance ratios of the factors are presented in Table 1. According to Figure 1, there were four factors with eigenvalues of >1.

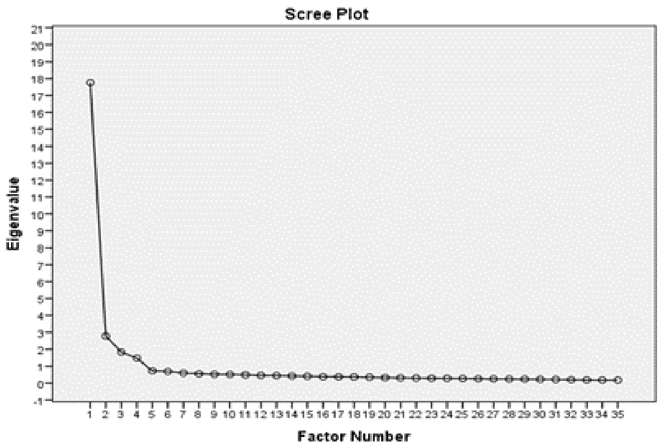

Figure 1. *Scree plot.*

Table 1. *Eigenvalues of factors and explained variance ratios.*

Factor	Eigenvalue	Explained variance	Cumulative variance explained
1	17.76	49.73	49.73
2	2.78	6.92	56.65
3	1.83	4.12	60.77
4	1.47	3.28	64.05

As seen in Table 1, 49.73% of the total variance was explained by the first factor, 6.92% by the second factor, 4.12% by the third factor, and 3.28% by the fourth factor. Accordingly, it was seen that the four-factor structure obtained explained 64.05% of the total variance. The three items removed from the scale had an increasing effect on the total explained variance. Considering the views that a total explained variance ratio of >30% is acceptable (Büyüköztürk, 2010) and that a ratio of 40% to 60% is ideal (Schober *et al*., 2018), it can be said that the total explained variance ratio obtained in the current study was adequate.

Together with this, according to Figure 2, the actual eigenvalues exceeded the simulated eigenvalues for the first four factors, suggesting the retention of four factors. This finding supports the factor retention decision made in the study.

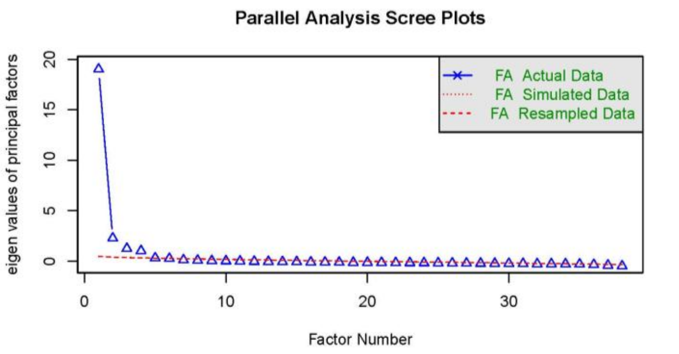

Figure 2. *Parallel analysis scree plot.*

As a result of EFA, the items under the relevant dimensions were examined and it was seen that the items were gathered under the relevant dimensions as theoretically determined during the scale development phase. The distribution of the items obtained as a result of EFA according to their factor loadings is presented in Table 2.

Table 2. *EFA Results of e-sports attitude scale.*

Item	Sub-dimension			
	Socialization	Individualization	Career	Risks
i1	.558			
i2	.641			
i3	.759			
i4	.756			
i5	.759			
i6	.789			
i7	.629			
i8	.846			
i9	.856			
i10	.808			
i11	.779			
i12	.732			
i13	.694			
i14		.892		
i15		.874		
i16		.858		
i17		.897		
i18		.871		
i19		.880		
i20		.719		
i21		.569		
i22		.493		
i23			.518	
i24			.666	
i25			.881	
i26			.856	
i27			.737	
i28			.801	
i29			.666	
i30*				.671
i31*				.721
i32*				.616
i33*				.719
i34*				.828
i35*				.714

*Negative item

As seen in Table 2, the factor loadings of the items under the four dimensions were as follows: .558 to .856 for the 13 items under the first dimension, .493 to .897 for the nine items under the second dimension; .518 to .881 for the seven items under the third dimension; and .616 to .828 for the six items under the fourth dimension. When these values were examined, it was seen that the recommendation that an item should have a factor loading value of >.40 in the EFA was met for all items (Pituch & Stevens, 2016). In addition, the EFA results indicated that the E-sports Attitude Scale consisted of a total of 35 items, including six negative and 29 positive statements. The items under each factor in the four-factor structure obtained through EFA were examined in terms of their content, and the factor naming process was carried out by identifying the common conceptual themes among high-loading items within each factor (DeVellis, 2017; Fabrigar *et al.,* 1999). This process considered not only the statistical loading values but also the semantic meaning of the items, their conceptual correspondence in the literature, and the theoretical framework of the scale. Based on the semantic similarities of the items and relevant literature, the first factor was labeled "socialization," the second "individualization," the third "career," and the fourth "risks." This naming process ensured that each label accurately represented the latent construct reflected by its corresponding set of items, thereby enhancing both the interpretability ant theoretical alignment of the scale.

To examine the reliability of the four-dimensional structure obtained as a result of the EFA for the E-sports Attitude Scale, Cronbach's α and McDonald's ω coefficients were calculated for the sub-dimensions, and stratified α and Revelle's ω total coefficients for the total scale. According to reliability results of trial study, Cronbach's α and McDonald's ω coefficients were calculated as .95 for the socialization dimension, .95 for the individualization dimension, .93 for the career dimension, and .88 for the risks dimension. The stratified α and Revelle's ω total coefficients were .94 and .98 for the total scale. The fact that these coefficients, which express the internal consistency of the scale, are >.80 shows that both the dimension and the total scale scores are reliable (Nájera Catalán, 2019).

Following EFA, item analysis was performed for the E-sports Attitude Scale. Accordingly, the corrected item-total correlations, mean item scores, and standard deviations of the 35 items were calculated to test the discriminating power of the items, and the changes in Cronbach's α and McDonald's ω coefficients were examined for the removal of each item from the relevant dimension. These statistics are presented in Table 3. As seen in Table 3, the corrected item-total correlation value for the socialization dimension was in the range of .69 to .80, the mean item score was in the range of 3.25 to 3.61, and the item standard deviation value was in the range of 1.23 to 1.31. The corrected item-total correlation value for the individualization dimension was in the range of .76 to .85, the mean item score was in the range of 3.06 to 3.43, and the item standard deviation value was in the range of 1.34 to 1.45. The corrected item-total correlation value for the career dimension was in the range of .73 to .82, the mean item score was in the range of 3.15 to 3.43, and the item standard deviation value was in the range of 1.31 to 1.36. The corrected item-total correlation value for the risks dimension was between .64 and .74, the mean item score was between 2.44 and 2.85, and the item standard deviation value was between 1.32 and 1.38. A corrected item-total correlation value of ≥.30 used to test item discrimination is considered good in terms of the feature to be measured (Meyers *et al*., 2016). Therefore, it can be said that item discrimination of the items on all dimensions was at a good level. In addition, the examination of Cronbach's α and McDonald's ω coefficients calculated by removing each item from the scale showed that none of the removed items made a contribution exceeding the reliability coefficient values determined.

Table 3. *Item statistics and item analysis results.*

Sub-dimension	Item	r_{jx}	$\bar{X}$	*SD*	When the item is removed	
					Cronbach α	McDonald ω
Socialization	i1	.722	3.41	1.27	.951	.951
	i2	.751	3.48	1.27	.950	.951
	i3	.795	3.50	1.23	.949	.949
	i4	.803	3.50	1.26	.949	.949
	i5	.788	3.46	1.26	.949	.950
	i6	.801	3.58	1.31	.949	.949
	i7	.687	3.25	1.28	.952	.952
	i8	.776	3.49	1.25	.950	.950
	i9	.770	3.58	1.27	.950	.950
	i10	.772	3.46	1.27	.950	.950
	i11	.741	3.61	1.24	.951	.951
	i12	.737	3.57	1.27	.951	.951
	i13	.778	3.53	1.27	.950	.950
Individualization	i14	.828	3.07	1.42	.945	.945
	i15	.782	3.15	1.45	.948	.948
	i16	.810	3.17	1.39	.946	.946
	i17	.838	3.15	1.44	.945	.945
	i18	.833	3.06	1.41	.945	.945
	i19	.848	3.15	1.39	.944	.944
	i20	.802	3.06	1.38	.946	.947
	i21	.763	3.34	1.40	.948	.949
	i22	.755	3.43	1.34	.949	.949
Career	i23	.728	3.32	1.34	.923	.924
	i24	.735	3.15	1.33	.923	.923
	i25	.819	3.34	1.36	.914	.915
	i26	.760	3.35	1.35	.920	.920
	i27	.802	3.42	1.34	.916	.917
	i28	.816	3.43	1.31	.915	.915
	i29	.764	3.30	1.34	.920	.920
Risks	i30	.698	2.48	1.38	.855	.857
	i31	.653	2.85	1.32	.863	.864
	i32	.637	2.59	1.34	.865	.866
	i33	.670	2.71	1.34	.860	.860
	i34	.743	2.50	1.36	.848	.848
	i35	.707	2.44	1.38	.854	.854

r_{jx}: Item discrimination, $\bar{X}$: Mean, *SD*: Standard deviation

Findings for CFA Analysis

Within the scope of the validation study of the E-Sports Attitude Scale, data were collected from 794 university students. The 35-item, four-factor structure obtained from the EFA was tested using CFA. The CFA was conducted based on the polychoric correlation matrix using the Unweighted Least Squares (ULS) method. The results of the CFA confirmed the proposed four-factor structure of the scale. Furthermore, all factor loadings and error variances of the items were found to be statistically significant at the .001 level. Based on these findings, it can be stated that the construct validity of the data used in the validation study was established. The standardized factor loadings (λ), t-values, R^2 values, and standardized error variances (δ) obtained from the analysis are presented in Table 4. The path diagrams displaying the unstandardized and standardized path coefficients resulting from the CFA are shown in Figures 3 and 4.

Table 4. *Results of the confirmatory factor analysis.*

Sub-dimension	Item	λ	*t*	R^2	δ
Socialization	i1	.681	16.882	.464	.581
	i2	.644	15.971	.414	.607
	i3	.724	17.863	.524	.488
	i4	.762	18.859	.581	.416
	i5	.692	17.431	.479	.517
	i6	.789	19.162	.623	.392
	i7	.660	16.787	.436	.558
	i8	.779	19.344	.606	.377
	i9	.703	18.081	.495	.473
	i10	.719	17.720	.517	.498
	i11	.744	18.609	.553	.434
	i12	.757	19.012	.572	.404
	i13	.751	18.922	.564	.411
Individualization	i14	.819	24.287	.671	.335
	i15	.670	20.615	.449	.500
	i16	.638	18.675	.407	.581
	i17	.806	24.129	.649	.343
	i18	.786	24.360	.619	.332
	i19	.832	25.382	.693	.284
	i20	.842	24.311	.708	.334
	i21	.751	21.170	.564	.476
	i22	.816	24.173	.666	.429
Career	i23	.784	20.946	.615	.513
	i24	.756	18.608	.572	.515
	i25	.759	21.707	.576	.330
	i26	.742	21.534	.550	.341
	i27	.783	20.721	.614	.392
	i28	.811	22.387	.657	.284
	i29	.796	21.275	.633	.358
Risks	i30	.761	21.453	.578	.471
	i31	.721	21.190	.519	.482
	i32	.734	21.055	.538	.488
	i33	.765	22.943	.585	.410
	i34	.844	26.427	.713	.252
	i35	.770	22.997	.592	.377

λ: Standardized factor loading, t: t-value, δ: standardized error variance

According to Table 4, the factor loadings ranged from .64 to .79 for the items under the socialization dimension, from .64 to .84 for the individualization dimension, from .74 to .81 for the career dimension, and from .72 to .84 for the risks dimension. In CFA, standardized factor loadings are expected to be .50 or above (Hair *et al*., 2019). Accordingly, all items in the scale meet this criterion for their respective factors. When the R^2 values were examined, it was observed that they ranged between .41 and .62 for socialization, between .41 and .71 for individualization, between .55 and .66 for career, and between .52 and .71 for risks.

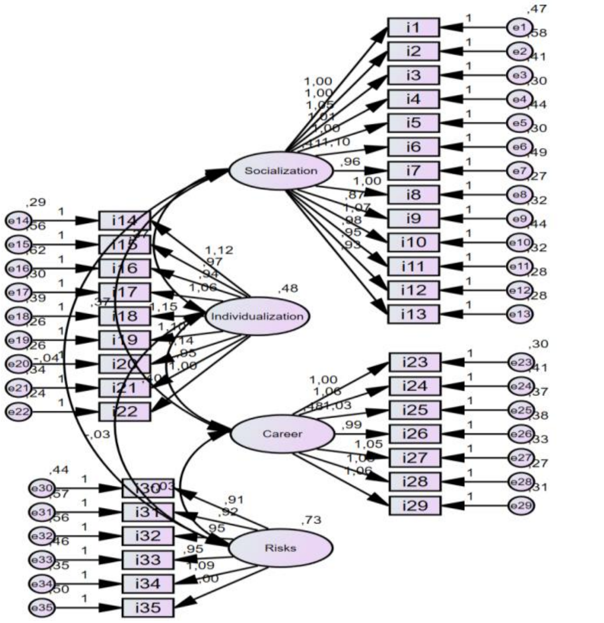

Figure 3. *Path diagram consisting of unstandardized path coefficients.*

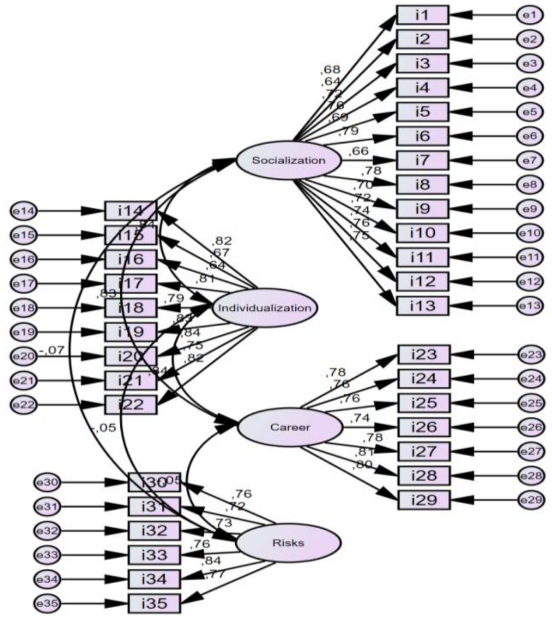

Figure 4. *Path diagram consisting of standardized path coefficient.*

Goodness of fit values were calculated to evaluate the results of the CFA. The goodness of fit values were calculated as follows: χ^2/df, 2.67; CFI, .99; TLI and GFI, .98; PNFI, .91; RMSEA, .05; and SRMR, .06. Of these values, a χ^2/df value of <5, a CFI, TLI, and GFI value of >.90, a PNFI value of >.50, a RMSEA value of <.10, and a SRMR value of <.08 are considered indicators of model fit (Byrne, 2016; Hu & Bentler, 1999; Kline, 2016). The comparison of these values with the CFA results showed that the model fit was achieved for the four-dimensional structure.

In order to evaluate the construct validity of the scale in depth, both convergent and discriminant validity were examined. According to the results, convergent validity was confirmed for all sub-dimensions of the scale, with CR values exceeding the .90 threshold and AVE values above .50 (Hair *et al*., 2019). In addition, discriminant validity was supported for all sub-dimensions, as each sub-dimension's AVE was greater than both its MSV and ASV values, indicating sufficient distinctiveness between the constructs (Fornell & Larcker, 1981). This finding demonstrates that the sub-dimensions are statistically distinct yet conceptually coherent, providing strong evidence for the structural validity and the four-factor solution of the developed scale. To examine the reliability of the data obtained for the validity study of the E-sports Attitude Scale, Cronbach's α and McDonald's ω coefficients were calculated for the sub-dimensions and stratified α and Revelle's ω total coefficients for the total scale.

According to reliability results of validity study, Cronbach's α and McDonald's ω coefficients were calculated as .93 and .94 for the socialization dimension, .93 for the individualization dimension, .91 and .92 for the career dimension, and .89 and .90 for the risks dimension, respectively. The stratified α coefficient for the total scale was .94 and Revelle's ω total coefficient was .97. The fact that these coefficients, which express the internal consistency of the scale, are >.80 indicates that both the dimension and the total scale scores are reliable (Nájera Catalán, 2019).

Measurement Invariance

To determine whether the factor structure of the scale is equivalent across gender groups, measurement invariance was examined using a stepwise MG-CFA. In line with best practices (Milfont & Fischer, 2010; Vandenberg & Lance, 2000), four hierarchical models were tested sequentially: configural, metric, scalar, and strict invariance. The measurement invariance fit indices calculated for gender groups are presented in Table 5.

Table 5. *Measurement invariance fit indexes across gender groups.*

Model	χ^2	*df*	χ^2/df	SRMR	TLI	CFI	RMSEA	ΔCFI	ΔRMSEA
Configural	4379.33	1108	3.95	.068	.830	.842	.086	-	-
Metric	4434.24	1139	3.89	.072	.833	.840	.085	.001	.001
Scalar	4486.97	1170	3.83	.073	.837	.839	.085	.001	.001
Strict	4521.54	1174	3.85	.075	.836	.838	.085	.001	.000

As seen in Table 5, The configural model, which allows parameters to vary freely between groups, exhibited acceptable fit (CFI = .842, RMSEA = .086, SRMR = .068, TLI = .830), indicating that the factor structure was comparable across male and female participants. Next, the metric invariance model constrained the factor loadings to be equal across groups. The model also showed acceptable fit (CFI = .840, RMSEA = .085, SRMR = .072, TLI = .833), and the changes in fit indices (ΔCFI = .001, ΔRMSEA = .001) were within acceptable limits (Chen, 2007), supporting the equivalence of factor loadings. The scalar invariance model imposed equality constraints on both factor loadings and item intercepts. Model fit remained stable (CFI = .839, RMSEA = .085, SRMR = .073, TLI = .837), and the change in fit indices remained negligible (ΔCFI = .001, ΔRMSEA = .001), indicating scalar invariance. Finally, the strict invariance model, which added equality constraints on residual variances, showed a comparable fit to the previous models (CFI = .838, RMSEA = .085, SRMR = .075, TLI = .836), with only marginal changes in fit indices (ΔCFI = .001, ΔRMSEA = .000). ΔCFI values less than .01 and ΔRMSEA values less than .015 are commonly accepted as evidence for invariance (Chen, 2007). Overall, the findings support configural, metric, scalar, and strict invariance across gender groups, demonstrating that the scale functions equivalently for both male and female participants. This allows for meaningful and valid comparisons across gender in further analyses.

In addition to the construct validity and reliability evidence, the results of the DIF analysis provided further support for the scale's measurement fairness across gender groups. In this analysis, each item (i1–i35) was treated as a dependent variable, and gender was used as the grouping (independent) variable, with males as the reference group and females as the comparison group.

The DIF analysis revealed that none of the scale items demonstrated significant DIF based on gender. Specifically, item category distributions, chi-square values, and pseudo R^2 statistics were examined, and no meaningful differences were observed between male and female participants. These findings indicate that the scale items operate similarly across gender groups in terms of measurement.

DISCUSSION and CONCLUSION

This study set out to develop and validate a four-factor, 35-item scale comprising 29 positively worded and 6 negatively worded items to measure university students' attitudes toward e-sports. Evidence from EFA, CFA, reliability indices, measurement invariance, and DIF analyses demonstrates that the instrument is both psychometrically sound and practically applicable.

Psychometric Properties

The EFA results from 797 students confirmed the data's suitability for factor analysis (KMO = .978; Bartlett's $\chi^2(703) = 25373.752$, $p< .05$). A four-factor solution was obtained after three items were removed. These factors—socialization (13 items), individualization (9 items), career

(7 items), and risks (6 items)—explained 64.05% of the total variance. Socialization emerged as the most influential factor, accounting for 49.73% of the variance, followed by individualization (6.92%), career (4.12%), and risks (3.28%).

Factor loadings ranged from .493 to .897, indicating strong relationships between items and their intended constructs. Inter-factor correlations were moderate to high (e.g., socialization-career = .730; individualization-career = .718), supporting the theoretical distinctiveness yet conceptual relatedness of the dimensions. CFA conducted with 794 students further validated this structure. Fit indices showed that the model had strong fit (χ^2/df = 2.67; CFI = .99; TLI = .98; GFI = .98; RMSEA = .046; SRMR = .059).

Convergent and discriminant validity were established. All AVE values were above .50 (e.g., individualization = .60; risks = .59), and each exceeded corresponding MSV and ASV values, confirming that the factors were distinct. Reliability coefficients were also excellent: Cronbach's α and McDonald's ω ranged between .89 and .94 for subscales, and the total scale achieved stratified α of .94 and Revelle's ω of .97.

Comparison with Existing Instruments and Factor Structure

Previous scales on e-sports and gaming attitudes largely emphasized general motivational or affective dimensions (Leung *et al*., 2021; Savaş & Turan, 2023). This study extends the field by introducing two context-specific dimensions—career and risks—while retaining socialization and individualization. This provides a richer account of the multifaceted ways students perceive e-sports.

The strong socialization factor aligns with research noting the community-building and peer support aspects of e-sports (Kaye & Bryce, 2012; Shan *et al*., 2023; Seo, 2016). Nearly half of the variance explained by this factor underscores how students see e-sports primarily as a social phenomenon. The individualization factor resonates with prior work showing that games foster problem-solving, autonomy, and creativity (Adachi & Willoughby, 2013b; Granic *et al*., 2014; Bediou *et al*., 2018). Unlike scales that merged personal and social aspects, the current findings show that students recognize individual growth as an independent component of e-sports attitudes.

The career factor reflects a growing recognition of e-sports as a pathway for professional development, a trend emphasized in both educational and industry contexts (Rothwell & Shaffer, 2019; Qian *et al*., 2019; Scholz, 2019). Including this factor highlights how students increasingly associate e-sports with employability and broader career opportunities. The risks factor is equally critical, capturing concerns about overuse, academic performance, and health consequences. This aligns with evidence from studies documenting negative outcomes of excessive gaming (King *et al*., 2018; Yin *et al*., 2020; Wattanapisit *et al*., 2020). WHO's (2019) formal recognition of gaming disorder further illustrates the importance of accounting for risk perceptions. By integrating this dimension, the scale provides a balanced framework that considers both benefits and challenges.

In addition, this research makes important contributions to both national and international contexts. Internationally, the inclusion of the Risks factor distinguishes the present study from many earlier instruments that emphasized only positive or motivational aspects of gaming (Leung et al., 2021; Savaş & Turan, 2023). The identification of a career dimension also extends prior work by linking e-sports to employability and professional development (Qian *et al*., 2019; Rothwell & Shaffer, 2019; Scholz, 2019). Nationally, this is one of the first validated instruments to measure e-sports attitudes among Turkish university students, addressing a significant gap in the local literature.

Measurement Invariance and DIF Analyses

The robustness of the scale was further demonstrated through invariance testing. Multi-group CFA indicated configural, metric, scalar, and strict invariance across gender, with negligible fit index changes (ΔCFI $\leq$ .001; ΔRMSEA $\leq$ .001). This shows that the factor structure operates equivalently for male and female students. Complementary DIF analyses, performed with ordinal logistic regression, confirmed that no items showed meaningful gender bias (largest ΔR^2 = .012). These findings ensure that the instrument functions fairly across groups.

Practical Implications, Limitations, and Future Research

The validated instrument provides several avenues for practice and policy. Universities can use it to measure baseline attitudes before e-sports initiatives, to highlight positive aspects such as socialization and career, and to identify risk perceptions that need mitigation. Results suggest that interventions should emphasize teamwork and belonging, consistent with existing literature (Shan *et al*., 2023; Seo, 2016). At the same time, programs may incorporate modules on digital health and responsible play to address concerns highlighted in the risks factor.

Limitations should also be acknowledged. The sample consisted solely of Turkish university students, which may limit the generalizability of the findings to other cultural or age groups. The cross-sectional design precludes causal interpretations of relationships among constructs. Moreover, the use of self-reported data introduces the potential for response bias. These limitations suggest that caution should be exercised when extending the results beyond the studied population.

Future studies could replicate this validation in different cultural contexts and across educational levels. Longitudinal approaches may capture changes in e-sports attitudes over time or as programs evolve. Additionally, moderators such as gameplay frequency, academic achievement, digital literacy, and socioeconomic background warrant further study (Granic *et al*., 2014; Qian *et al*., 2019; Delello *et al*., 2021). Such analyses could refine understanding of how e-sports attitudes relate to broader educational and developmental outcomes.

In conclusion, the findings confirm that the 35-item, four-factor E-Sports Attitude Scale demonstrates strong validity, reliability, invariance, and fairness. By addressing both positive (socialization, individualization, career) and negative (risks) dimensions, the scale provides a comprehensive understanding of how students perceive e-sports. Theoretically, this study enriches the literature by introducing two underexplored dimensions—career and risks—into the study of e-sports attitudes (Qian *et al*., 2019; Scholz, 2019), while also confirming the central role of socialization in line with both international and national research (Shan et al., 2023; Seo, 2016; Turan *et al*., 2023). Practically, the instrument offers a robust and fair tool for researchers and higher education institutions to evaluate and guide e-sports-related initiatives, enabling them to emphasize opportunities such as social belonging and career development while also addressing potential risks (Shan *et al*., 2023; Seo, 2016). This balanced framework positions the scale as a valuable resource for advancing scholarly inquiry and guiding evidence-based practice, thereby contributing to the responsible integration of e-sports into higher education and to the broader fields of educational technology and youth development.

Acknowledgments

This research is an outcome of the project titled "Development, Implementation, and Evaluation of E-Sports Teaching Program for University Students (Project No: 122K965)" supported by TUBITAK within the scope of 1001 - Scientific and Technological Research Projects Support Program.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in IJATE belongs to the authors. **Ethics Committee Number**: Fırat University, 10.01.2023-13617.

Data Availability Statement

Research data is available and can be sent with e-mail upon request.

Informed Consent

All participants were informed about the purpose and procedures of the study, and written informed consent was obtained prior to data collection.

Contribution of Authors

Yunus Emre Karakaya: Investigation, Resources. **Seda Demir Ayçiçek**: Methodology, Formal analysis, Validation, and Writing-original draft. **Selahattin Gelbal**: Supervision. **Sebahattin Devecioğlu**: Supervision. **Fazilet Özge Maviş Sevim**: Visualization, Software. **Emin Tamer Yenen**: Visualization, Software, Writing-original draft. **Melih Dikmen**: Methodology, Formal analysis, and Writing-original draft.

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