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# Water Literacy of Secondary School Students: A Scale Development Study

Samet Karakuş*
*Social Studies Teaching, Trabzon University, Trabzon, Türkiye*
*ORCID: 0000-0003-4588-0163*

Yavuz Akbaş
*Social Studies Teaching, Trabzon University, Trabzon, Türkiye*
*ORCID: 0000-0002-3500-4701*

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This study aims to develop a Water Literacy Scale for secondary school students. The study was conducted using a survey model, employing secondary schools located across five distinct districts within Trabzon, a city in northeastern Türkiye. A total of 628 students took part in the study, and the data obtained were analyzed with the help of SPSS, Jamovi, and LISREL software. Expert evaluations were incorporated within the survey research framework to verify the content validity of the scale. Construct validity was assessed through both exploratory and confirmatory factor analysis methods. The reliability of the scale was determined by calculating Cronbach's alpha, McDonald's omega, item-total correlations, and item discrimination indices based on the upper and lower 27% groups. Based on exploratory and confirmatory factor analyses, the scale was finalized with 22 items grouped under three sub-dimensions: water knowledge, water attitude, and water behavior. The relationships among the sub-dimensions were examined using the Pearson correlation coefficient. Confirmatory factor analysis revealed strong fit indices indicating excellent model fit. The scale demonstrated excellent internal consistency, with both Cronbach's alpha and McDonald's omega coefficients. Furthermore, all subscales demonstrated acceptable convergent validity and composite reliability values. The relationships among the sub-dimensions were found to be significant and moderate in strength.

## Introduction

Water is the lifeblood of our planet, and the planet's ecosystems are linked and maintained by water (Acreman, 2004). The Greek scholar Thales claimed that all life depends on water and that water is the first substance. While people can live for weeks without eating, they can live only a few days without water. People are dependent on water in many aspects of daily life (Brody, 1993). In addition to meeting basic health needs, water also plays a crucial role in economic development and food and energy security. (The United Nations, 2024). Two-thirds of Earth's surface is covered with water, but most of that is saltwater. Freshwater is in short supply: 3% of the global total is surface water, of which only 0.06% is readily accessible. Most freshwater is found in polar ice caps, glaciers, deep aquifers, and

*Correspondency: samet_karakus20@trabzon.edu.tr

atmospheric reservoirs, but these systems are difficult to access (Musie & Gonfa, 2023). Climate change, population growth, poor management, and pollution are putting these scarce resources under increasing pressure (Li et al., 2022; UN, 2022; UNESCO, 2020; Salehi, 2021; Schewe et al., 2014). Freshwater is the only viable water source for human use, yet its availability is minimal. As climate change worsens globally, the increasing occurrence and intensity of floods and droughts are becoming significant risks to freshwater security worldwide (Bates et al., 2008). Furthermore, over two billion people worldwide face restricted access to clean, safe water, highlighting the urgency of this crisis (Pichel et al., 2019). Research suggests that global freshwater shortages could reach 40% by 2030, driven by rising demand and inefficient resource management (Li et al., 2022; Yu et al., 2021). Due to inadequate freshwater supplies, nearly half of the global population faces severe water shortages each year (Caretta et al., 2022; Salehi, 2021). The IPCC (2023) reports that around half of the global population experiences severe water scarcity annually. According to the World Economic Forum (WEF) (2020), water scarcity ranks among the world's top five risks. Research suggests that global water demand may increase by 20-30% by 2050 across all sectors (Greve et al., 2018). Meanwhile, alongside persistent threats from freshwater and marine contamination to both human and ecological well-being, antimicrobial pollution is emerging as a critical environmental challenge (WEF, 2025). Waste contamination ranks among the key contributors to this deteriorating situation. A continent made up of waste, known as the 'seventh continent,' is growing day by day in the Pacific Ocean. Projections indicate that delayed action on waste management may result in $640.3 billion in economic losses by 2050, mirroring the seventh continent scenario, with additional unquantified costs to natural systems (UN Environment Programme, 2024). According to the 2025 Global Risks Report (WEF), freshwater scarcity has become the most significant concern for national governments in different geopolitical contexts. Furthermore, while many countries are experiencing water scarcity (e.g. Algeria, Chad, India, Iran), others (e.g. Kosovo, Malta, Ghana, Azerbaijan) face the risk of water pollution (WEF, 2025). Research highlights the fundamental importance of water in the UN Sustainable Development Goals, as water directly and indirectly affects the achievement of each of the 17 goals (Greve et al., 2018; Yu et al., 2021). Acknowledged as a pressing global issue (Sindik & Araya, 2013), water resource management plays a central role in the 2030 Agenda, underpinning efforts to advance sustainable development, reduce poverty, ensure food security, and improve public health (Greve et al., 2018; United Nations, 2023). Many targets have been set for 2030 to make water more accessible, protectable, and usable, including protection, pricing, recycling, use in agriculture, management, and support programmes. Modern water usage practices demonstrate clear unsustainable characteristics, manifesting in increasingly severe ecological consequences and societal challenges (Otaki et al., 2015). Sustainable water management requires populations to possess adequate knowledge, competencies, and pro-environmental attitudes. The United Nations (2012) identifies targeted educational interventions as a fundamental strategy for developing these essential capacities. Even individuals with substantial knowledge of water consumption may lack an understanding of water distribution systems or hold misconceptions about the hydrological cycle, which limits their capacity to adopt water-conscious behaviors (Cho & Kang, 2010; Bar, 1989; Osborne & Cosgrove, 1983). When individuals lack comprehension of resource provision and protection mechanisms, their conservation engagement measurably declines (Jason & Courter, 2020). Comprehensive water education serves as the pedagogical foundation for developing both the intellectual understanding (cognitive domain) and environmental stewardship (affective domain) necessary for sustainable practices. These educational measures should be coordinated with two-way sustainability policies, including behavioral change programs for water conservation alongside technological/political solutions for decarbonization (Cho &

Kang, 2010; Covitt et al., 2009; Yu et al., 2021). Human water use decisions significantly affect riverine ecosystems, economic systems, cultural practices, and spiritual values, necessitating an informed understanding of the normative frameworks, value systems, and knowledge paradigms that shape these decisions (Bresney et al., 2023). As established in the literature (Hoy & Stelli, 2016; Otaki et al., 2015; Wood, 2014), water literacy provides a fundamental foundation for understanding water conservation principles, sustainable management approaches, and their practical application in everyday contexts. Research demonstrates that increased hydrological knowledge correlates with pro-environmental behaviors, including responsible water use that maintains ecosystem health and resource availability for future populations (Bresney et al., 2023; Hoy & Stelli, 2016).

### *Water literacy*

Despite current gaps in public understanding of water's strategic significance, empirical studies confirm that early water education cultivates both environmental awareness and decision-making competencies for sustainable water management (Çoban et al., 2011; Daugs & Israelsen, 1984). Water literacy development through targeted educational programs and hands-on training equips individuals with essential competencies for sustainable water stewardship (Miller et al., 2014). Improved awareness fosters coordinated action among local institutions and citizens, leading to pragmatic responses to intensifying water crises (Dalcanale et al., 2011). Contemporary water resource challenges have underscored the fundamental importance of water literacy in addressing hydrological sustainability (McCarroll & Hamann, 2020). This concept refers to individuals understanding the value of water resources, taking active responsibility for water-related problems, and taking personal ownership of these issues (Sammel et al., 2018). The primary aim of water literacy is to cultivate individuals who demonstrate conscious behaviors toward water conservation and to enhance societal awareness of water's critical importance (McCarroll et al., 2024). The approach systematically fosters: accurate comprehension of aquatic systems, development of water-saving routines, and democratic involvement in resource management decisions (Rogers et al., 2020).

For an individual to be considered water literate, they must know the source and supply processes of water consumed in daily life, be able to evaluate water quality standards, and understand the environmental impacts of water consumption habits (Otaki et al., 2015). Water literacy, as conceptualized by Wood (2014), involves deep knowledge of water systems, problem-solving experience, and practical application skills. According to Özerdinç and Hamalosmanoğlu (2021), this represents a holistic educational domain that integrates water's physicochemical properties, consumption patterns (water footprint), stress indicators, cyclic processes, and socioeconomic dimensions. Daugs and Israelsen (1984) emphasized that water-literate individuals must possess the ability to understand, and effectively express basic concepts related to water, develop responsible behaviors based on their acquired water knowledge, and utilize observation, analysis, and problem-solving skills to protect water resources. The seven fundamental principles set forth by ProjectWET Foundation (2024) clearly outline the scope of water literacy: The unique properties of water in nature, its indispensability for all living things, its role in connecting planetary systems, its being a limited natural resource, the need for effective management, its relationship with social structures, and its place in the cultural context form the basis of these principles. The development of water literacy requires first acquiring basic knowledge about water and then translating this knowledge into attitudes and behaviors. The water literacy paradigm represents a sequential competency model, where the acquisition of hydrological knowledge enables the formation of attitudes, which subsequently predict conservation behaviors, emphasizing the praxis between learning and doing (He, 2018; Tian et al., 2021).

## *Study rationale and objectives*

Educating individuals is crucial for fostering a deeper understanding of water's significance (Brody, 1993). Moreover, water education is key to advancing environmental conservation and supporting sustainable development. Targeted water education programs serve as behavior modification systems, cultivating the acquisition of sustainable practices in learners while establishing the psychological foundations for lifelong resource conservation (Opel & Bogner, 2021). Developing water sustainability competencies requires building individuals' cognitive, affective, and behavioral capacities through targeted education (Küçük, 2022), with particular emphasis on developing personal responsibility for water issues (Gopinath, 2014). Educational institutions serve as the primary catalyst for developing water literacy. Research highlights the crucial importance of developing students' hydrological understanding during their formative academic years to promote long-term environmental stewardship (Imaduddin & Eilks, 2024; Wood, 2014). It is accepted that water education in schools should be provided to students at an early age (Aytaç, 2023; Dieser & Bogner, 2016). Water literacy education can begin as early as preschool (Ursavaş & Aytar, 2018) and continue through primary and secondary school (Mostacedo-Marasovic et al., 2022). Thus, assessing students' water literacy levels at these educational stages is essential.

A review of existing literature indicates that although multiple measurement tools have been created for assessing water-related knowledge and behaviors—such as water attitude scales (Karslı & Tunca-Güçlü, 2023), water literacy instruments (Aytaç, 2023; Sözcü & Türker, 2020), water consumption behavior scales (Çankaya & Filik-İşçen, 2014), and water concern measures (Watkins, 1974)—there remains a lack of validated tools designed explicitly for evaluating water literacy among secondary school students. The present study attempts to fill this important void in current scholarship. A review of existing scale development studies in the literature reveals that the water literacy scale designed by Sözcü and Türker (2020) for high school students was limited to exploratory factor analysis (EFA) and lacked confirmatory factor analysis (CFA) validation. In contrast, Aytaç (2023) performed both EFA and CFA analyses; however, the scale included only the dimensions of 'water behavior' and 'water knowledge,' excluding the 'water attitude' dimension. This study advances water literacy research through three key contributions: (1) operationalizing the tripartite water literacy framework (knowledge-attitudes-behaviors) via a psychometrically validated assessment tool; (2) employing robust quantitative methods, including both EFA and CFA, to establish scale reliability and validity; and (3) focusing on the previously overlooked middle school demographic, thereby addressing a significant measurement gap in the literature. In addition, He (2018) and Tian et al (2021) developed water literacy surveys. He's (2018) study describes the process of designing a survey for individuals aged 6-69. Similarly, Tian et al (2021) also provided information about the design process of a water literacy survey for individuals over the age of 6. However, these studies did not include information on construct validity and reliability. Similarly, this study also addresses the fundamental dimensions of water literacy. Unlike previous studies that omitted psychometric validation and examined only adult populations, this research establishes the reliability/validity of the scale specifically for secondary school students. The present research, which targeted the development of the Water Literacy Scale (WLS) for secondary school students, investigated the following sub-problems.

(1) To what degree is the water literacy scale developed for secondary school students valid?
(2) To what degree is the water literacy scale developed for secondary school students reliable?

## Method

### *Model and participants*

In this study, the general survey model was employed to reveal the opinions, attitudes, and thoughts of a specific group regarding a particular topic (Büyüköztürk et al., 2018). Since the study was designed as a scale development process to measure the water literacy levels of secondary school students quantitatively, this method was deemed appropriate.

The study employed convenience sampling, a method chosen due to its capacity to facilitate data collection (Fraenkel & Wallen, 2008). The study was conducted in June 2024 across five districts (Ortahisar, Akçaabat, Beşikdüzü, Araklı, and Çaykara) in Trabzon province, located in northeastern Turkey. The study engaged 628 learners across secondary school grades (5-8). However, 128 students who did not complete the scale by the prescribed protocol were excluded from the study. The analysis utilized data from 500 participants, who were randomly divided into two subsamples for separate EFA and CFA following established validation procedures (Carpenter et al., 2016). Table 1 presents the demographic characteristics of the participants.

**Table 1.** Demographic Characteristics of Study Participants

| Demographic information | | EFA (n) | CFA (n) |
|---|---|---|---|
| Gender | Female | 168 | 82 |
| | Male | 157 | 93 |
| Class level | 5th class | 67 | 35 |
| | 6th class | 78 | 48 |
| | 7th class | 85 | 48 |
| | 8th class | 95 | 44 |
| Total | | 325 | 175 |

### *Scale development process*

#### *Item pool creation and pilot study*

The study took into account the scale development steps recommended by DeVellis and Thorpe (2022). To assess the water literacy levels of secondary school students, the researchers developed a preliminary item pool comprising 127 statements based on a comprehensive literature review. This item pool was constructed within the context of water literacy and was submitted to five experts, each holding at least a doctoral degree in the field. Experts evaluated each draft scale item using a standardized validation rubric with the following response options:

(1) "Appropriate / Should remain" - Item demonstrates apparent content validity and requires no modification
(2) "Partially appropriate / Should be revised" - Item shows potential relevance but needs substantive refinement
(3) "Not appropriate / Should be removed" - Item lacks conceptual alignment with water literacy constructs

The finalized survey instrument comprised two distinct sections: the first collected demographic data (including gender and grade level), while the second contained items designed to assess water literacy. The draft version utilized a five-point Likert scale with the following response options: “Strongly disagree,” “Disagree,” “Neutral,” “Agree,” and “Strongly agree.” The water literacy scale was designed as a three-dimensional structure, comprising “water knowledge”, “water attitude”, and “water behavior”.

The initial 72-item scale was developed through expert consultation and subsequently evaluated in a two-phase pilot study. First, the draft instrument was administered to a stratified sample of eight participants (two students from each grade level, 5-8). Following completion, in-depth cognitive interviews (average duration: 45 minutes) were conducted with each participant to evaluate item comprehension and identify potential problematic wording through verbal protocol analysis. As a result of the interviews and evaluations, no ambiguous items with broad or unclear content were identified. A Turkish language expert reviewed the scale to ensure that the wording was precise and linguistically appropriate.

Following review, the 72-item draft scale was pilot tested with 29 eighth-grade students. Item discrimination analysis was performed using the collected data, applying the standard threshold of 0.20 (Büyüköztürk, 2023). This process resulted in the elimination of 13 underperforming items that failed to meet the discrimination criterion. The refined 59-item scale was subsequently prepared for the main study. Before data collection, this study received full ethical approval from the Scientific Research and Publication Ethics Committee at Trabzon University's of Social and Human Sciences (Ethics Approval Date: 4 June 2024).

### *Data analysis*

To objectively assess the content validity of the scale, Lawshe’s (1975) method was applied following the collection of expert feedback. To examine the construct validity, both EFA and CFA were performed. EFA was conducted using IBM SPSS Statistics 29.0, while CFA was carried out with LISREL 12. Data suitability for factor analysis was validated using the KMO statistic and Bartlett’s test of sphericity. To assess convergent validity, the Average Variance Extracted (AVE) and Composite Reliability (CR) values were calculated. The AVE and CR values were computed using the AVECR 1.0 software (Aydoğdu, 2023). To ensure the appropriateness of factor analysis for EFA and CFA, skewness and kurtosis values were examined to check the assumptions of normality. The reliability analysis included the calculation of Cronbach’s alpha (α) and McDonald’s omega (ω) coefficients. For reliability analysis, McDonald’s omega (ω) coefficient was calculated using JAMOVI. Item validity was assessed through item-total correlations, while the discriminative power of the items was tested using independent samples t-tests. Furthermore, Intercorrelations among the validated sub-dimensions of the water literacy scale were assessed using Pearson's r correlation coefficients.

## Results

### *Content validity*

The content validity of the scale was thoroughly assessed using the method proposed by Lawshe (1975). To implement this approach, Content Validity Ratios (CVRs) are derived using the formula CVR = (NG / [N/2]) – 1, where NG is the count of experts identifying the item as essential. The resulting CVRs are then compared to the critical CVR values outlined in a standardized table based on the number of experts consulted. In this study, the CVRs obtained for the draft scale items were evaluated against these critical values. According to five experts, the CVR value for the draft scale was calculated as 1.00 (Ayre & Scally, 2014). Consequently, 55 items with CVRs below 1.00 were eliminated from the draft scale. The scale is devoid of any items that are negative or reverse-coded. The final content validity analysis yielded a CVI of 1.00, obtained by averaging the CVRs of retained items following exclusion of problematic measures.

### *Efa*

Before EFA, the normality of the data distribution was assessed. The dataset's distributional properties were rigorously examined through analysis of skewness and kurtosis. According to Huck et al. (2013), skewness and kurtosis values between -1.00 and +1.00 are acceptable; the observed values (-0.620 to 0.321) confirmed the data's normal distribution and suitability for EFA.

Factor analysis assumptions were tested using two established criteria: the KMO measure (threshold > 0.50 for adequate sample size) and Bartlett's Test of Sphericity (requiring significant results at $p < .05$), confirming the data's suitability for dimensional reduction (Field, 2024). Results indicated strong sampling adequacy (KMO = 0.916) and a statistically significant Bartlett's Test of Sphericity ($\chi^2[231] = 2259.829$, $p < 0.001$), validating the factorability of the correlation matrix.

During EFA, the data were analyzed using the principal components method and an oblique rotation technique (Direct Oblimin). This analytical approach was selected based on the theoretical assumption of intercorrelated factors, as oblique rotation methods yield more accurate factor solutions when such relationships exist (Tabachnick & Fidell, 2014). EFA revealed a 22-factor solution with all eigenvalues below 1.00, collectively accounting for 46.09% of the total variance in the measurement model. Factor retention decisions considered both eigenvalues (>1.0 threshold) and variance contribution. The three extracted factors accounted for 46.09% cumulative variance, with Factor 1 (eigenvalue=7.152) explaining 32.51%, Factor 2 (eigenvalue=1.870) 8.50%, and Factor 3 (eigenvalue=1.118) 5.08% of total variance (Çokluk et al., 2023). The eigenvalues and variances of the remaining factors were relatively small. This suggested that the scale may have a three-factor structure, and thus the scree plot was examined (Figure 1).

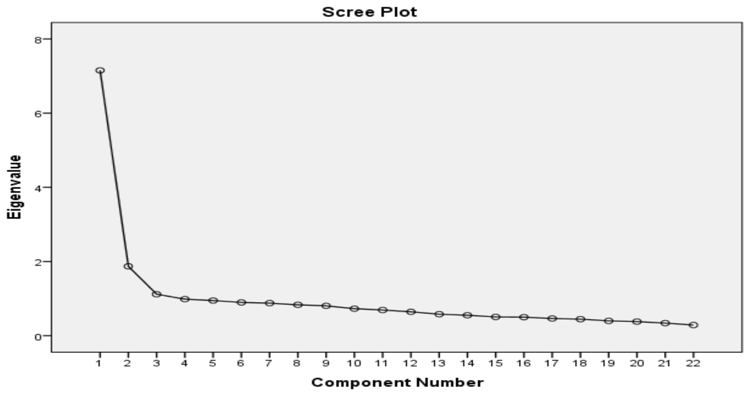


**Figure 1.** 22-item draft form scree plot

When analyzing Figure 1, there are significant decreases after points 1, 2, and 3 but a horizontal curve is observed after point 4. The scree plot's inflection point clearly indicated a three-factor solution, with subsequent components demonstrating both diminishing returns (eigenvalues <1.0) and near-equivalent variance contributions (Δ <2% between factors 4+), supporting the retention of three meaningful dimensions (Büyüköztürk, 2023). Accordingly, the subdimensions were named "Water Attitude (WA)," "Water Knowledge (WK)," and "Water Behavior (WB)" separately. Table 2 presents the final factor structure of the WLS as identified through EFA.

Table 2. Factor loadings of scale items

| | **Factor Load Values** | | |
|---|---|---|---|
| Items | WK | WA | WB |
| 4. A significant part of the world population is experiencing water scarcity. | 0.605 | | |
| 5. Condensation is the transition of water vapor in the air to liquid state. | 0,628 | | |
| 7. Groundwater is part of the water cycle between the earth and the atmosphere. | 0.524 | | |
| 9. Water pollution reduces biodiversity in water resources. | 0.599 | | |
| 11. Water resources have started to decrease with climate change. | 0.497 | | |
| 18. Saving water makes me feel happy. | | 0.517 | |
| 20. I feel sorry for animals that die because of water pollution. | | 0.582 | |
| 22. I believe that access to clean water is a fundamental right for all individuals. | | 0.680 | |
| 25. I believe that problems related to water pollution affect our health very much. | | 0.865 | |
| 27. I would like to increase the number of public service announcements (official advertising films) on water saving. | | 0.675 | |
| 30. I believe that using water economically is important for future generations. | | 0.707 | |
| 33. I am concerned about increasing water problems as a result of global warming. | | 0.564 | |
| 34. I don't find it right to discharge wastewater into water resources without full treatment. | | 0.751 | |
| 49. When I brush my teeth, I take care not to let the tap run in vain. | | 0.727 | |
| 42. I complain to the necessary places about the enterprises (factories, | | | 0.649 |

| | |
|---|---|
| restaurants, hotels, etc.) that discharge their wastes into water resources. | |
| 45. I wash fruit and vegetables in a container instead of a running tap. | 0.535 |
| 46. I participate in waste collection activities near water sources | 0.678 |
| 48. I warn my family members not to run the dishwasher and washing machine before they are full. | 0.605 |
| 51. I show my environment that rainwater can be collected and used for daily cleaning. | 0.617 |
| 53. I prefer to take a short shower rather than a long bath. | 0.490 |
| 57. If I am denied access to clean water, I can take action to claim my water rights. | 0.331 |
| 59. I inform my environment about measures to reduce the water footprint. | 0.501 |

As presented in Table 2, the EFA yielded factor loadings ranging from .331 to .865. Each sub-dimension contains at least three items. Five items (4, 5, 7, 9, 11) in the Knowledge (WK) subscale, nine items (18, 20, 22, 25, 27, 30, 33, 34, 49) in the Attitude (WA) sub-dimension, and eight items (42, 45, 46, 48, 51, 53, 57, 59) in the Behavior (WB) sub-dimension.

### *Cfa*

To confirm the factor structure identified through EFA, CFA was performed on a sample of 175 participants. Skewness (-0.430) and kurtosis (-0.194) values suggested that the data were approximately normally distributed (Tabachnick & Fidell, 2014). As noted by Anderson and Gerbing (1984), a sample size exceeding 100 is deemed adequate for conducting CFA. Furthermore, following Hair et al.'s (2009) 5:1 participant-to-item ratio guideline for CFA, our sample size proved sufficient for robust analysis.

The three-factor model's goodness-of-fit was assessed through CFA using multiple established fit indices: "Root Mean Square Error of Approximation" (RMSEA), "Standardized Root Mean Square Residual" (SRMR), "Comparative Fit Index" (CFI), "Non-Normed Fit Index" (NNFI/TLI), "Adjusted Goodness of Fit Index" (AGFI), and the "chi-square/degrees of freedom ratio" ($\chi^2$/df). Table 3 presents the observed fit indices for this study along with literature-based benchmarks for acceptable and excellent model fit.

Table 3. CFA Goodness-of-Fit Results for the Three-Factor Model

| Indexes of Fit | Perfect Fit Values | Acceptable Values | Measured Values | Conclusion | Referance |
|---|---|---|---|---|---|
| $\chi2/ df$ | $0 \leq \chi2/df \leq 2$ | $2 < \chi2/ df \leq 3$ | 251,5/206 | Perfect fit | (Kline, 2023; Hu & Bentler, 1999 |
| AGFI | .90≤ AGFI ≤ 1.00 | .85≤ AGFI ≤ .90 | 0.86 | Acceptable fit | Kline, 2015; Schumacker & Lomax, 2010 |
| CFI | .95≤ CFI ≤ 1.00 | .90≤ CFI ≤ .95 | 0.96 | Perfect fit | Schumacker & Lomax, 2010 |
| NNFI | .95≤ NNFII ≤ 1.00 | .90≤ NNFI ≤ .95 | 0.95 | Acceptable fit | Hu & Bentler, 1999; Tabachnich & Fidell, 2014 |
| RMSEA | 0≤ RMSEA ≤ .05 | .05≤ RMSEA ≤ .08 | 0.036 | Perfect fit | Jöreskog & Sörbom, 1993; Hu & Bentler, 1999 |
| SRMR | 0≤ SRMR ≤ | .05≤ SRMR ≤ | 0.056 | Acceptable fit | (Browne & Cudeck, 1992; |

| | | | | |
|---|---|---|---|---|
| | .05 | .10 | | Schumacker & Lomax, 2010). |

As shown in Table 3, the χ²/df ratio was calculated as 1.22. A χ²/df value between 0 and 2 is generally interpreted as indicating an excellent model fit. The CFI and NFI values support this conclusion, as values of 0.95 or above are considered indicative of a perfect model fit. The RMSEA value was 0.036, with a 90% confidence interval ranging from .016 to .050, also suggesting an excellent fit. While the AGFI of 0.86 indicates reasonable model approximation (acceptable range: 0.80-0.89), the excellent SRMR value (0.056; <0.08 ideal) suggests particularly strong residual fit. Collectively, these indices support the validity of the theoretical framework, with detailed relationships depicted in Figure 2.

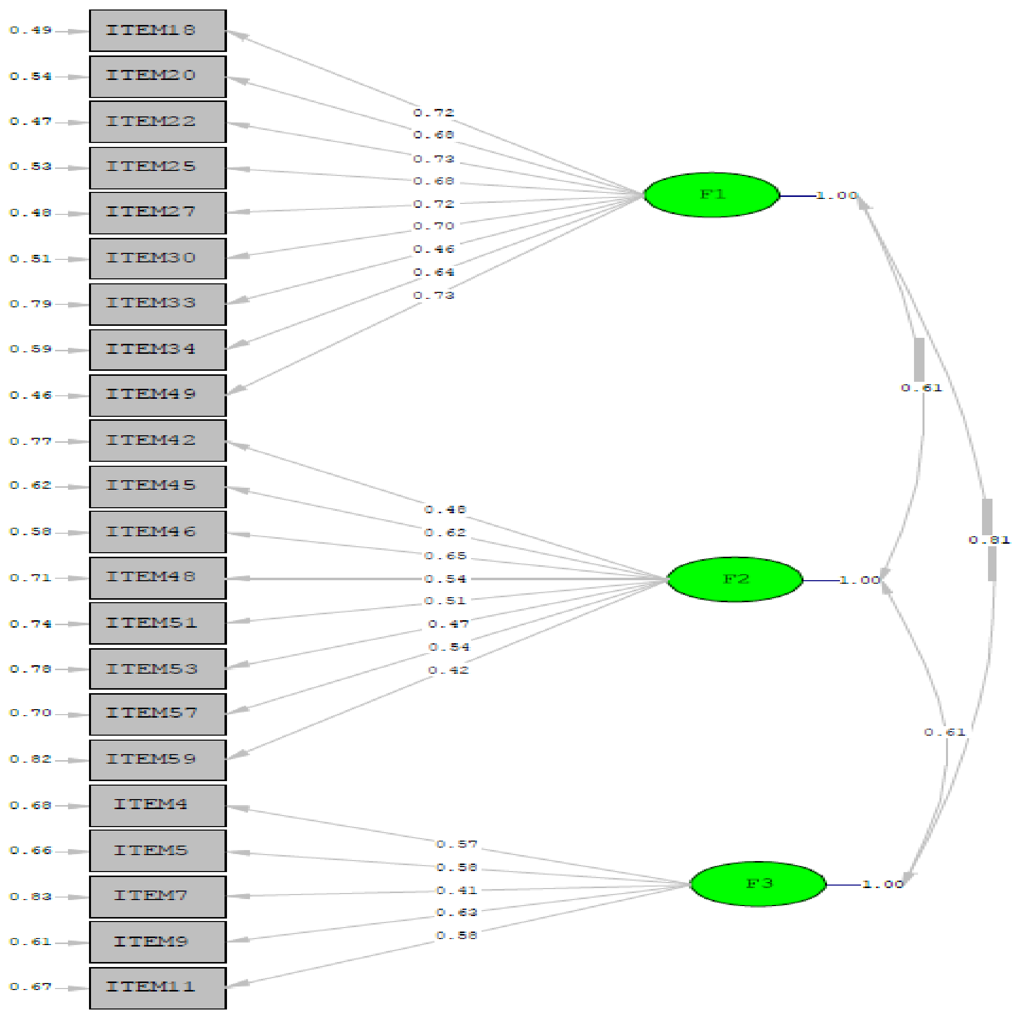


Figure 2: CFA results for the three-factor model

In the measurement model (Figure 2), standardized factor loadings varied from 0.41 to 0.73, all above the suggested 0.30 benchmark for first-order CFA (Hair et al., 2019), thus verifying acceptable item-construct associations. It is also recommended that the correlation coefficients between the scale's factors remain below 0.85 to ensure discriminant validity. Kline (2023) explains that exceeding this threshold suggests the two factors measure the same construct, and thus, one should be removed from the model. However, upon examining the path diagram, the correlation coefficients between the factors are 0.81, 0.61, and 0.61, indicating that the three factors represent distinct constructs.

### *Convergent Validity*

Convergent validity refers to the relationships between items related to variables in a factor and the factor they form (Yaşlıoğlu, 2017). AVE and CR coefficients are key indicators used to assess the validity and reliability of a measurement tool (Shrestha, 2021). The assessment of convergent validity included an evaluation of factor loadings, CR, and AVE for every construct, consistent with methodological recommendations (Hair et al., 2014**).** Table 4 provides the AVE and CR metrics for the relevant factors.

Table 4. AVE and CR Statistics for the Factors

| Factors Number of Items | Number of Items | AVE Value | CR Value |
|---|---|---|---|
| Water Knowledge | 5 | 0.31 | 0.69 |
| Water Attitude | 9 | 0.46 | 0.88 |
| Water Behavior | 8 | 0.28 | 0.75 |

Although the AVE values for all sub-dimensions fell below the recommended threshold (<0.50), composite reliability criteria were satisfied (WA/WB >0.70; WK=0.69). Consistent with Fornell and Larcker's (1981) criteria, the CR values exceeding 0.60 across sub-dimensions demonstrate adequate convergent validity despite suboptimal AVE results.

### *Reliability of the Scale*

The scale's reliability was assessed through both Cronbach's alpha (α) and McDonald's omega (ω) coefficients, which provide complementary perspectives on scale reliability as they offer complementary insights into the scale's reliability (Edwards et al., 2021). Additionally, item-total correlations were examined to assess item quality further. To provide additional evidence of the scale's reliability, a 27% upper-lower group comparison was conducted to evaluate item discrimination. Item discrimination was assessed via independent samples t-tests comparing the upper (top 27%) and lower (bottom 27%) groups' mean scores, per standard psychometric practice (Büyüköztürk et al., 2018). Table 5 presents the reliability coefficients, item-total correlation values, and the t-test results based on the 27% upper-lower group comparison for the scale items and sub-dimensions.

Table 5. Reliability Statistics and Item Discrimination Results for Scale Items and Sub-Dimensions

| Items | Total Item Correlation | t (Lower 27% -Upper 27%)* |
|---|---|---|
| | **WLS (α = 0.89, ω= 0.89)** | |
| | **WK (α = 0.70, ω= 0.70)** | |
| Item 4 | ,461 | 9.33 |
| Item 5 | ,454 | 9.54 |
| Item 7 | ,347 | 7.24 |
| Item 9 | ,499 | 9.78 |

| | | |
|---|---|---|
| Item11 | ,459 | 9.19 |
| | **WA (α = 0.89, ω= 0.89)** | |
| Item 18 | ,646 | 14.44 |
| Item 20 | ,636 | 14.87 |
| Item 22 | ,657 | 16.00 |
| Item 25 | ,599 | 11.44 |
| Item 27 | ,630 | 15.39 |
| Item 30 | ,649 | 14.99 |
| Item 33 | ,573 | 13.23 |
| Item 34 | ,619 | 14.05 |
| Item 49 | ,651 | 16.03 |
| | **WB (α = 0.72, ω= 0.72)** | |
| Item 42 | ,322 | 5.34 |
| Item 45 | ,413 | 10.54 |
| Item 46 | ,443 | 9.04 |
| Item 48 | ,487 | 11.59 |
| Item 51 | ,306 | 6.06 |
| Item 53 | ,308 | 6.63 |
| Item 57 | ,407 | 8.10 |
| Item 59 | ,397 | 8.13 |

p<0.01*

Following the analysis of Table 5, Cronbach's α and McDonald's Omega coefficient (0.89) values were determined for the whole scale, indicating the scale's reliability in terms of internal consistency. The analysis confirms that the scale demonstrates acceptable psychometric properties across all sub-dimensions: the WK sub-dimension meets standard reliability thresholds, the WA sub-dimension shows strong internal consistency, and the WB sub-dimension aligns with established reliability criteria (McDonald, 1985; Yurdugül, 2006).

The psychometric analysis confirms the robust item properties of the scale across multiple validation metrics. First, all 22 items demonstrated appropriate discrimination power, with statistically significant t-values ($p < .01$) in the item analysis (Table 5). Second, item-total correlations ranged from .306 to .657, satisfying the minimum thresholds established by Büyüköztürk (2023) and Nunnally & Bernstein (1994).

The relationships between the sub-dimensions of the scale were analyzed using Pearson correlation analysis. The resulting correlation matrix is presented in Table 6.

Table 6. Relationship between sub-dimensions

| Sub-dimension | | WK | WA | WB |
|---|---|---|---|---|
| WK | Pearson | 1 | .620 | .355 |
| | Sig. | | .000* | .000 |
| | N | 325 | 325 | 325 |
| WA | Pearson | .620 | 1 | .545 |
| | Sig. | .000* | | .000 |
| | N | 325 | 325 | 325 |
| WB | Pearson | .355 | .545 | 1 |
| | Sig. | .000* | .000 | |
| | N | 325 | 325 | 325 |

p<0.01*

As shown in Table 6, all sub-dimensions demonstrate statistically significant positive intercorrelations (r = .355 to .620). Following established interpretation guidelines (Büyüköztürk et al., 2018; Ural & Kılıç, 2013), these coefficients indicate moderate relationships among the scale's constructs.

## Discussion and conclusion

Our research objective focused on the development of WLS. The scale development process identified three distinct factors through EFA, with this structure subsequently confirmed through CFA, supporting the instrument's psychometric adequacy. The three factors in the assessment tool were named “WK”, “WA”, and “WB” by the literature (Amahmid et al., 2018; Daugs & Israelsen, 1984; Imaduddin & Eilks, 2024; Johnson & Courter, 2020; Martínez-Borreguero et al, 2020; McCaroll & Hamann, 2020; Tian et al., 2021; Xu et al., 2019). The scale explained a total variance of 46.09%. It is generally considered that an overall variance of more than 40% is sufficient (Kline, 2023; Tavşancıl, 2019). The results indicated that Cronbach's α and McDonald's ω internal consistency coefficients were 0.89 for the entire scale, and 0.69, 0.89, and 0.72 for the individual sub-dimensions. The scale scores range from 22 to 110, with 22 as the minimum and 110 as the maximum possible score. CFA confirmed the 22-item, three-factor structure identified through EFA. The goodness-of-fit indices from the CFA (RMSEA, AGFI, SRMR, NFI, CFI) indicated an excellent model fit. The scale items effectively measured the intended construct and successfully differentiated between students who possess the trait and those who do not. Collectively, these findings demonstrate that the scale is both valid and reliable. Unlike previous high school-level studies (Aytaç, 2023; Yentür et al.,2022), this research comprehensively addresses all dimensions of water literacy. Furthermore, in contrast to another study (Sözcü & Türker, 2020), the structure reached by EFA was confirmed by CFA. Concerning the reliability results, Cr α values were found to be highly reliable in this study, as in both studies mentioned. Ultimately, the reliability findings align with existing literature on Cronbach's alpha (Cr α). The convergent validity values of the scale's subscales are below 0.50. Bagozzi and Yi (1988) emphasise that the AVE value should be above 0.50. In this case, it can be stated that the AVE values of the scale subscales remain below the desired critical value and that this aspect of the study presents a limitation. On the other hand, the CR values of the sub-dimensions are above 0.60. Fornell and Larcker (1981) state that if the CR value is above 0.60, the AVE is sufficient. Furthermore, especially for a new measurement tool, AVE > 0.25 can be considered acceptable (Hair et al., 2006; Hsu & Wu, 2013; Mayerl, 2016). Despite the AVE values falling below the conventional threshold, the satisfactory Composite

Reliability (CR) values provided evidence for the scale's convergent validity in this initial development phase. AVE values below 0.50 in this study are also found in studies by Akbağ et al. (2025), Jung & Jin (2014), and Kanchanapibul et al. (2014). Water literacy is rich in terms of the topics it covers (McCarroll & Hamann, 2020). In this study, topics related to water literacy include water conservation (ProjectWET Foundation, 2024; TEMA Foundation, 2024), global warming and climate change (Bates et al, 2008; Boon, 2024; TEMA Foundation, 2024), water footprint (Colegrove, 2017; TEMA Foundation, 2024), water scarcity (Mekonnen & Hoekstra, 2016), water pollution (Hui, 2023), and the water cycle (Ben-Zvi-Assarf & Onion, 2005; Daugs & Israelsen, 1984; ProjectWET Foundation, 2024; Robertson, 2021; TEMA Foundation, 2024; Ursavaş & Genç, 2021), water rights (Çakır, 2023; Firidin, 2015; 2018; Tian et al, 2021; Topçu, 2008; Watkins, 1974). Additionally, Maniam et al. (2021) also mention other sub-dimensions of water literacy, such as water resources, water management, and water-related issues. Consistent with these points, the study's results support prior research in the field**.**

The study is limited to the sub-dimensions aligned with the first level of water literacy (knowledge, attitude, and behavior) as defined by He (2018) and is based on a Turkish sample. A number of recommendations can be drawn from the findings of the scale developed in this research. First, it can be utilized to assess water literacy levels across different variables and diverse sample groups**.** Second, since this is the first scale developed to measure water literacy at the secondary school level, its validity and reliability can be re-examined with different student groups. Third, the scale can be adapted to different cultures in various countries. Furthermore, in the future, researchers could concentrate on expanding and validating the higher levels of water literacy. Finally, the sensitivity of the scale could also be examined by applying it before and after curricular water education interventions.

**Declarations**

***Note:*** This study was presented as an oral presentation at the VI. International Congress of Geography Education held in Istanbul, Türkiye, on 19-22.09.2024.

***Ethical Declarations***: The study adhered to ethical principles, including voluntary participation and anonymity. Although AI writing assistants (ChatGPT, DeepSeek) were utilized for language refinement, all content was meticulously reviewed by the authors.

***Conflict of Interest***: The author declares that there is no conflict of interest regarding the publication of this research.

***Data Availability***: The data are available upon request.

***Funding:*** There is no funding.

***Informed Consent:*** Informed consent was obtained from the study participants. They were informed of the study's purpose, the procedures to be used, and their right to withdraw from the study at any time.

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