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VALIDITY AND RELIABILITY OF A WATER LITERACY INSTRUMENT FOR LOWER SECONDARY STUDENTS IN MALAYSIA

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Abstract:

Water literacy is increasingly recognised as a crucial component of environmental sustainability, particularly in strengthening students' understanding of water resources, pollution, and basic water treatment processes. Effective water literacy education depends on the availability of scientifically sound, contextually appropriate measurement instruments. In Malaysia, however, locally evaluated instruments for assessing water literacy among lower secondary students remain limited, particularly those aligned with water science and water management perspectives. This study reports an initial psychometric evaluation of a multidimensional water literacy instrument developed for Malaysian lower secondary students. The instrument was adapted from established water literacy studies and comprised 50 items across three domains: water knowledge (20 multiple-choice items), water attitudes (15 items), and water-related behaviours (15 items). Knowledge items assessed fundamental concepts related to water resources, water pollution, and basic water treatment, while attitude and behaviour items were measured using a five-point Likert scale. Content validity was examined through expert judgement from six subject-matter experts in water treatment, environmental chemistry, sustainable water infrastructure, environmental education, and secondary-level pedagogy, using item- and scale-level Content Validity Index (CVI). A pilot study involving 30 Malaysian lower secondary students was conducted to assess internal consistency reliability. The findings demonstrated high overall content validity ($S-CVI/Ave = 0.953$). Reliability results indicated high internal consistency for the knowledge

domain (KR-20 = 0.864), good reliability for attitudes ($\alpha = 0.805$), and acceptable reliability for behaviours ($\alpha = 0.702$). Overall, the results provide preliminary psychometric evidence supporting the instrument's suitability for continued validation and use in assessing water literacy among Malaysian lower secondary students

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Content Validity, Instrument Development, Lower Secondary Students, Malaysia, Water Literacy



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Introduction

In recent decades, global concern over water scarcity, pollution, and unsustainable consumption has intensified alongside rapid population growth and increasing climate variability (UNESCO, 2021; WWAP, 2023). In parallel, scholarly attention has increasingly focused on water literacy as a critical educational outcome. Water literacy is widely regarded as essential for promoting informed decision-making, responsible water use, and long-term sustainability, particularly among younger generations who will inherit complex socio-hydrological challenges (Saad & Mahmud, 2023; Maniam et al., 2021). Within educational contexts, water literacy is increasingly positioned not merely as scientific knowledge but as a component of environmental citizenship that supports sustainability goals and national environmental priorities (Norkhaidi et al., 2021; Gökce, 2025). Accordingly, strengthening water literacy among lower secondary students has become an important focus of research in environmental and sustainability education.

From an educational and policy standpoint, water literacy development among adolescents aligns with broader sustainability priorities, including SDG 6 (Clean Water and Sanitation), which emphasises informed public engagement, conservation practices, and responsible water use. In school settings, these aims require not only instruction but also credible assessment tools that enable educators and researchers to evaluate learning outcomes, identify gaps across the knowledge–attitude–behaviour dimensions, and design targeted interventions. Therefore, establishing a valid and reliable water literacy instrument for Malaysian lower secondary students is practically relevant for curriculum evaluation, programme monitoring, and evidence-based water education initiatives.

Conceptually, water literacy has evolved from a narrow emphasis on technical or factual knowledge to a multidimensional construct encompassing cognitive understanding, affective dispositions, and behavioural practices related to water resources (Mostacedo-Marasovic et al.,

2022; Kang, 2022). This perspective recognises that sustainable water behaviour is shaped not only by what individuals know but also by their values, attitudes, and everyday practices (Tian et al., 2022; Saad & Mahmud, 2023). Contemporary scholarship, therefore, emphasises the integration of knowledge, attitudes, and behaviours as core components of water literacy (Mostacedo-Marasovic et al., 2022). Consequently, effective assessment requires instruments that capture these interrelated dimensions coherently and in ways that are appropriate for the target learner population.

Despite growing conceptual clarity, empirical research indicates that water literacy assessment practices remain uneven and fragmented. Many instruments prioritise cognitive or knowledge-based measures, while affective and behavioural domains are underrepresented or assessed with limited depth (Saad & Mahmud, 2023; Maniam et al., 2021). Evidence also suggests that knowledge gains do not necessarily translate into sustainable water-related behaviours, highlighting the limitations of knowledge-centric measurement approaches (Malek & Halim, 2023; Tian et al., 2022). As a result, reliance on cognitively focused instruments can constrain comprehensive evaluation of students' water literacy.

In response to increasing interest in water literacy, a range of instruments has been developed across international educational contexts, including multidimensional questionnaires, literacy indices, and domain-specific assessment tools designed to evaluate water-related knowledge, attitudes, and behaviours (Kang, 2022; Fernandes et al., 2023). However, many instruments were developed for specific populations and contexts, limiting transferability when applied elsewhere without systematic adaptation (LaDue et al., 2021; Moon, 2022). Moreover, validation rigor varies considerably, with some studies reporting limited psychometric evidence beyond basic reliability statistics (Saad & Mahmud, 2023; Erbaş et al., 2023). These inconsistencies underscore the need for context-sensitive, rigorously validated measurement tools.

Within Malaysia, research on water literacy among school-aged learners remains limited and unevenly developed. Existing studies suggest that Malaysian students generally demonstrate basic water-related knowledge, yet gaps persist in attitudes, behavioural intentions, and water-use practices (Saad & Mahmud, 2023; Wahab & Mapa, 2020). Importantly, many local studies rely on instruments adapted from other cultural or disciplinary contexts, often without comprehensive content validation or robust reliability testing (Maniam et al., 2021; Saad & Mahmud, 2023). This raises concerns about contextual relevance and measurement accuracy when instruments are adopted without systematic refinement for Malaysian lower secondary learners.

Additionally, prior work suggests that sociocultural and gender-related factors may influence the development of water literacy, indicating that water literacy is not uniform across student populations (Saad & Mahmud, 2023; Meilinda et al., 2023). However, cultural contextualisation and sensitivity to learner variation are not consistently reflected in the design and validation of available measures, limiting their capacity to capture nuanced differences in students' water-related understanding and practices (Erbaş et al., 2023; Maniam et al., 2021). These limitations reduce the utility of existing instruments for informing targeted educational interventions and policy decisions.

Taken together, there is a clear need for a multidimensional, contextually appropriate water literacy instrument with sound validity and reliability for Malaysian lower secondary students. In particular, two gaps require attention. First, locally developed and content-validated water

literacy instruments in Malaysia remain limited, creating uncertainty about contextual fit and measurement accuracy when instruments are imported without systematic validation. Second, many existing instruments are framed broadly around environmental awareness and conservation, with comparatively less emphasis on water science and water management fundamentals (e.g., water resources, pollution processes, and basic water treatment concepts) that underpin water-related decision-making.

Addressing these gaps, this study develops and reports initial evidence of content validity and internal consistency reliability for a multidimensional water literacy instrument grounded in water science-related domains and tailored to Malaysian lower secondary learners. Accordingly, the present study aims to examine the content validity and internal consistency reliability of a water literacy instrument designed to assess water knowledge, attitudes, and behaviours among Malaysian lower secondary students, providing an empirical foundation for subsequent large-scale validation and application.

Literature Review

Conceptualising Water Literacy

Water literacy has increasingly been recognised as a critical construct for addressing global water sustainability challenges. Contemporary scholarship conceptualises water literacy as a holistic competence that integrates understanding of water systems with values, attitudes, and responsible engagement, rather than limiting it to technical or scientific knowledge alone (McCarroll & Hamann, 2020; Otaki et al., 2015). This shift reflects recognition of the interconnected relationships between environmental processes, human behaviour, and social decision-making in water management (Mostacedo-Marasovic et al., 2021). Accordingly, several authors position water literacy as a socio-hydrological construct that links natural water systems to human actions and responsibilities (Sadler et al., 2017; Tian et al., 2022). However, definitions remain fragmented across disciplines and contexts, contributing to conceptual ambiguity and inconsistent operationalisation (McCarroll & Hamann, 2020). Such variability complicates efforts to develop standardised and comparable measurement instruments.

In this study, water literacy is conceptualised as a multidimensional competence that integrates: (i) cognitive understanding of water systems and water-related issues, (ii) affective orientations such as values and attitudes toward water conservation and sustainability, and (iii) behavioural practices reflecting responsible water use. This operational framing aligns with established perspectives that treat literacy as extending beyond factual knowledge to include evaluative dispositions and action-oriented competencies (McCarroll & Hamann, 2020; Sadler et al., 2017). Accordingly, the instrument in this study operationalises water literacy through three aligned domains, namely water knowledge, water attitudes, and water-related behaviours, to provide a more holistic profile of students' water literacy.

Multidimensional Dimensions of Water Literacy

Building upon its conceptual foundations, the literature consistently frames water literacy as encompassing cognitive, affective, and behavioural dimensions. The cognitive dimension refers to knowledge of water resources, water cycles, pollution processes, and human-water interactions (McCarroll & Hamann, 2020; Mostacedo-Marasovic et al., 2021). The affective dimension encompasses attitudes, values, and ethical orientations that shape concern for water conservation and sustainability (Saad & Mahmud, 2023; Gibson et al., 2024). In contrast, the

behavioural dimension reflects the extent to which knowledge and values are translated into responsible water-use practices and conservation actions (Tian et al., 2022; Sánchez et al., 2023). Although these dimensions are theoretically well established, empirical research operationalises them inconsistently. Many studies prioritise cognitive outcomes while treating affective and behavioural dimensions as secondary or peripheral (Mostacedo-Marasovic et al., 2021). As a result, the multidimensional nature of water literacy is often underrepresented in assessment practices, limiting comprehensive evaluation of learners' water literacy profiles.

Knowledge-Centric Orientation in Water Literacy Research

A dominant trend in water literacy research is a strong emphasis on knowledge-based assessment. Numerous studies measure factual, procedural, or systems knowledge using structured questionnaires and concept inventories (Ojeda et al., 2023; Tian & Chen, 2023). This orientation is reinforced by formal curricula, which commonly embed water-related learning through scientific content aligned with environmental and chemistry learning outcomes (Mills & Tomas, 2024; Demir & Öteleş, 2023). While such approaches build foundational awareness, evidence consistently shows that knowledge alone is insufficient to promote sustainable water-related behaviours (Fremerey & Bogner, 2014; Sánchez et al., 2023). Without corresponding affective engagement and behavioural intention, knowledge gains may not translate into responsible water use. Hence, overreliance on knowledge-centric models can constrain the broader educational aims of water literacy.

Existing Water Literacy Measurement Instruments

In response to rising interest, various instruments have been developed across educational and community contexts, including multidimensional questionnaires, literacy indices, and domain-specific concept inventories (Fernandes et al., 2022; Kang, 2022; Ojeda et al., 2023). Several instruments report acceptable psychometric properties, particularly for cognitive knowledge using advanced analyses such as item response theory or structural equation modelling (Tian & Chen, 2023; Kang, 2022). However, affective and behavioural components are frequently underrepresented or measured with fewer items, limiting comprehensive assessment (Mostacedo-Marasovic et al., 2021). In addition, instruments are often developed for specific cultural and educational settings, reducing transferability without systematic adaptation and validation (Nelson et al., 2024). These limitations highlight the need for context-sensitive instrument development and validation.

Validity and Reliability Issues in Water Literacy Measurement

Although methodological rigour has improved, concerns about validity and reliability remain prominent. Several studies report satisfactory internal consistency and construct validity, particularly for cognitive domains (Sözcü & Türker, 2020; Erbaş et al., 2023). Nevertheless, reliance on self-reported measures increases susceptibility to response bias and social desirability effects, especially for behavioural assessments (Sánchez et al., 2023). Cross-cultural validation is also limited, raising concerns about contextual relevance and measurement equivalence across settings (Meilinda et al., 2023; Nelson et al., 2024). Scholars therefore recommend iterative instrument development involving expert review and pilot testing before large-scale validation (McCarroll & Hamann, 2020; Fernandes et al., 2023).

Educational Alignment and Curriculum Context

From an educational standpoint, research indicates uneven alignment between water literacy frameworks and formal school curricula. Curriculum analyses often show a predominance of cognitive learning outcomes, with comparatively limited emphasis on attitudinal development and action-oriented competencies (Mills & Tomas, 2024; Mostacedo-Marasovic et al., 2021). In contrast, informal and community-based programmes may better foster holistic water literacy through experiential and contextually grounded learning (Gökce, 2025). These findings suggest that formal schooling requires assessment instruments that extend beyond knowledge acquisition to capture broader literacy dimensions, thereby enabling alignment between curriculum intentions and measurable learning outcomes.

Water Literacy in the Malaysian Context

In Malaysia, water literacy research among school-aged populations remains limited and unevenly developed. Existing studies indicate that Malaysian students generally demonstrate basic water-related knowledge, yet gaps persist in attitudes and water-use behaviours (Saad & Mahmud, 2023). Moreover, many local studies rely on adapted instruments with limited evidence of systematic content validation or robust reliability testing (Maniam et al., 2021). This reliance raises concerns regarding contextual relevance and construct validity, particularly given Malaysia's distinct educational and environmental contexts. Consequently, there is a clear need to develop and initially validate a multidimensional, contextually appropriate water literacy instrument for Malaysian lower secondary students.

Methodology

Research Design

This study employed a quantitative design focused on instrument development and initial psychometric evaluation. In line with recommendations for early-stage scale development, the study prioritised expert judgement for content validity and pilot testing for internal consistency reliability, rather than full construct validation procedures such as factor analysis at this stage (Boateng et al., 2018). The validation process was guided by the multidimensional conceptualisation of water literacy, encompassing cognitive, affective, and behavioural dimensions. Accordingly, a sequential approach was adopted: (i) expert-based content validation to assess item relevance and representativeness, followed by (ii) pilot testing to examine internal consistency reliability (Lynn, 1986; Polit & Beck, 2006).

Instrument Development

The water literacy instrument was developed by adapting and contextualizing established water literacy instruments reported in prior studies (Maniam et al., 2024; Sözcü & Türker, 2020). The instrument was designed to assess water literacy as a multidimensional construct comprising three domains: water knowledge, water attitudes, and water-related behaviours.

The adaptation process followed staged refinement to ensure suitability for Malaysian lower secondary learners. First, items were reviewed to ensure curriculum relevance and alignment with the intended domains. Second, wording and content were refined to enhance linguistic clarity, reduce ambiguity, and ensure age-appropriate phrasing. Third, the revised item pool underwent expert review for relevance, representativeness, and clarity, and items were

iteratively revised based on feedback prior to pilot administration. The final instrument comprised 50 items across the three domains.

Due to intellectual property and ethical considerations, the full instrument is not reproduced in this article. Researchers who wish to use the instrument for academic and non-commercial purposes may request access from the corresponding author.

Instrument Structure and Scoring

The knowledge domain comprised 20 multiple-choice items, each with four response options and one correct answer. Responses were scored dichotomously (1 = correct, 0 = incorrect) to assess students' factual and conceptual understanding of water-related issues. The attitudes and behaviours domains each comprised 15 items measured using a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicate stronger pro-water attitudes and behaviours. This combination enables assessment of both objective knowledge and self-reported dimensions of water literacy.

Content Validity Procedure

Content validity was established through expert evaluation (Lynn, 1986; Polit & Beck, 2006). A panel of six experts was purposively selected based on professional experience and domain expertise in water-related sciences, environmental education, and secondary-level pedagogy. The professional roles and areas of expertise are summarised in Table 1.

Experts were included if they met at least one of the following criteria: (i) formal academic expertise in water-related sciences (e.g., water treatment, environmental chemistry, water infrastructure/public health), (ii) professional experience in environmental or water education, and/or (iii) extensive secondary-level teaching experience and curriculum familiarity to support pedagogical appropriateness. This multidisciplinary composition was intended to ensure evaluation of both scientific accuracy and classroom relevance.

Content validity was quantified using the Content Validity Index (CVI). Item-level CVI (I-CVI) was calculated as the proportion of experts rating an item as relevant. Scale-level CVI was computed using S-CVI/Ave and S-CVI/UA. For an expert panel of six, I-CVI values of approximately 0.83 or higher were interpreted as indicating acceptable agreement on item relevance.

Table 1: Profile of Expert Panel Involved in Content Validity Evaluation

Expert	Professional Role	Area of Expertise	Years of Experience
Expert 1	Senior Lecturer	Water Treatment, Advanced Oxidation Processes, Environmental Chemistry	>10 years
Expert 2	Lecturer	Sustainable Water Infrastructure, Clean Water Access, Public Health	>5 years
Expert 3	Expert Geography Teacher	Environmental Education, Pedagogy, Curriculum Innovation	>10 years

Expert 4	Expert Geography Teacher	Environmental Education, Language, and Instructional Design	>10 years
Expert 5	Senior Geography Teacher	Environmental Education, Teaching and Learning Innovation	>10 years
Expert 6	Geography Teacher	Environmental Education and Classroom Pedagogy	>10 years

Pilot Study and Participants

A pilot study was conducted to assess internal consistency reliability and to identify potential issues related to item clarity and administration procedures. The pilot involved 30 Malaysian lower secondary students, selected purposively because their characteristics closely matched the intended population for the main study. The sample size ($n = 30$) was selected to support preliminary reliability estimation and feasibility checking in early-stage instrument development, consistent with common guidance for pilot testing (Van Teijlingen & Hundley, 2001). Participation was voluntary, and questionnaires were administered under supervised conditions. No missing data were recorded, indicating that the instrument was comprehensible and feasible for one-time administration in the target group.

Reliability Analysis

Internal consistency reliability was assessed using indices appropriate to each domain. For the knowledge domain (dichotomous scoring), the Kuder–Richardson Formula 20 (KR-20) was used, which is functionally equivalent to Cronbach’s alpha for dichotomous items and is recommended for knowledge-based tests (Rudner & Schafer, 2002). For the attitudes and behaviours domains, Cronbach’s alpha coefficients were calculated. For early-stage validation, reliability coefficients of ≥ 0.70 were interpreted as acceptable, ≥ 0.80 as good, and ≥ 0.90 as excellent (Nunnally & Bernstein, 1995; Taber, 2018), while recognising that behavioural self-report items may yield slightly lower consistency due to contextual variability. Item-total correlations and “alpha if item deleted” statistics were examined to identify items potentially requiring refinement.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics. Descriptive statistics were generated to examine item distributions and overall scale performance. Content validity indices (I-CVI, S-CVI/Ave, and S-CVI/UA) were calculated manually following established formulas. Reliability analyses were conducted separately for each domain to support accurate interpretation of internal consistency and to inform item refinement prior to the main study.

Ethical Approval and Research Permission

Formal research approval was obtained from the Educational Planning and Research Division (EPRD), Ministry of Education Malaysia. Following this approval, the Sarawak State Education Department (JPNS) granted permission to conduct the study in selected secondary schools. Data collection was conducted only after written approvals were granted by the relevant educational authorities.

Ethical Considerations

Ethical principles were observed throughout the research. Participation in the pilot study was voluntary, and participants were informed of the study's purpose and that their responses were used solely for research. Anonymity and confidentiality were maintained by collecting no identifying information and ensuring secure handling of all data in accordance with ethical research guidelines.

Results

Content Validity of the Water Knowledge Domain

Content validity for the water knowledge domain was examined using item-level and scale-level Content Validity Index (CVI). For a six-expert panel, I-CVI values of approximately 0.83 or higher indicate acceptable agreement on item relevance. As shown in Table 2, 18 of 20 items achieved an I-CVI of 1.00, indicating unanimous agreement among experts. The remaining two items recorded I-CVI values of 0.83, which still met the minimum acceptable threshold. At the scale level, the domain demonstrated excellent content validity (S-CVI/Ave = 0.983; S-CVI/UA = 1.000) (Table 3). Overall, these findings indicate strong expert consensus and confirm that the knowledge items adequately represent the intended construct.

Table 2: Item-Level Content Validity Index (I-CVI) for Water Knowledge Domain

I-CVI Value	Item Numbers	Number of Items
1.00	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20	18
0.83	4, 14	2

Table 3: Scale-Level Content Validity Index (S-CVI) for Water Knowledge Domain

Index Type	Value
S-CVI/Ave	0.983
S-CVI/UA	1.000

Content Validity of the Water Attitudes Domain

The content validity results for the water attitudes domain are presented in Table 4. Thirteen of 15 items achieved I-CVI values ≥ 0.83 , reflecting acceptable expert agreement. Two items (Items 14 and 15) recorded I-CVI values of 0.67, indicating comparatively lower agreement among experts regarding their relevance. Despite these two items, the overall attitudes scale demonstrated high content validity (S-CVI/Ave = 0.922; S-CVI/UA = 0.867) (Table 5). To strengthen content alignment, Items 14 and 15 were retained but earmarked for revision based on expert feedback (e.g., improved wording clarity and closer alignment to the intended attitudinal indicator) and will be re-evaluated in subsequent large-scale validation.

Table 4: Item-Level Content Validity Index (I-CVI) for Water Attitudes Domain

I-CVI Value	Item Numbers	Number of Items
1.00	1, 2, 3, 4, 6, 7, 8, 9, 10, 13	10
0.83	5, 11, 12	3
0.67	14, 15	2

Table 5: Scale-Level Content Validity Index (S-CVI) for Water Attitudes Domain

Index Type	Value
S-CVI/Ave	0.922
S-CVI/UA	0.867

Content Validity of the Water-Related Behaviours Domain

For the water-related behaviours domain, all 15 items achieved I-CVI values ≥ 0.83 (Table 6), indicating acceptable to unanimous agreement on relevance. Eleven items received unanimous agreement (I-CVI = 1.00), while four items achieved acceptable agreement (I-CVI = 0.83). At the scale level, the behaviours domain demonstrated high content validity (S-CVI/Ave = 0.955; S-CVI/UA = 1.000) (Table 7). These results indicate strong expert consensus regarding the relevance and appropriateness of the behavioural items

Table 6: Item-Level Content Validity Index (I-CVI) for Water-Related Behaviours Domain

I-CVI Value	Item Numbers	Number of Items
1.00	1, 3, 4, 6, 7, 8, 9, 10, 12, 13, 14	11
0.83	2, 5, 11, 15	4

Table 7: Scale-Level Content Validity Index (S-CVI) for Water-Related Behaviours Domain

Index Type	Value
S-CVI/Ave	0.955
S-CVI/UA	1.000

Internal Consistency Reliability of the Instrument

Internal consistency reliability was assessed separately for each domain (Table 8). In early-stage validation, reliability coefficients ≥ 0.70 are commonly considered acceptable, ≥ 0.80 good, and ≥ 0.90 excellent. The water knowledge domain yielded a KR-20 coefficient of 0.864, indicating high internal consistency for the dichotomously scored items. The water attitudes domain demonstrated good reliability ($\alpha = 0.805$). The water-related behaviours domain recorded $\alpha = 0.702$, meeting the minimum acceptable threshold for pilot-stage reliability screening. Collectively, these findings suggest that the instrument demonstrates coherent measurement performance across domains, while recognising that behavioural self-report items may yield slightly lower internal consistency due to contextual variability.

Table 8: Internal Consistency Reliability of the Water Literacy Instrument

Domain	Number of Items	Reliability Index	Value	Interpretation
Water Knowledge	20	KR-20	0.864	High
Water Attitudes	15	Cronbach's α	0.805	Good
Water-Related Behaviours	15	Cronbach's α	0.702	Acceptable

Summary of Psychometric Evidence

A summary of the instrument's psychometric properties is provided in Table 9. Overall, findings indicate strong content validity across domains and acceptable-to-high internal consistency reliability. While two attitude items showed lower item-level agreement during expert review, these items were retained for revision and further evaluation in subsequent large-scale validation. Taken together, the results provide preliminary evidence supporting the instrument's suitability for continued validation and application in Malaysian lower secondary contexts.

Table 9: Summary of Psychometric Evidence for the Water Literacy Instrument

Aspect	Water Knowledge	Water Attitudes	Water-Related Behaviours
Number of Items	20	15	15
Content Validity	High	High	High
Reliability Level	High	Good	Acceptable
Item Refinement Required	-	Yes (2 items: revised for future validation)	-

Discussion

This study aimed to develop and conduct an initial validation of a multidimensional water literacy instrument for Malaysian lower secondary students by examining its content validity and internal consistency reliability. In response to concerns in prior literature regarding uneven operationalisation and limited contextual validation of water literacy instruments, the present findings provide preliminary psychometric evidence supporting the instrument's suitability for assessing water knowledge, attitudes, and behaviours within the Malaysian educational context. Overall, the instrument demonstrated high content validity across domains (S-CVI/Ave range = 0.922–0.983) and acceptable to high internal consistency reliability (KR-20 = 0.864; α range = 0.702–0.805), consistent with contemporary conceptualisations of water literacy as an integrated cognitive, affective, and behavioural construct.

Content Validity of the Water Literacy Instrument

The instrument demonstrated strong content validity across the three domains. Most items achieved high I-CVI values, indicating strong expert agreement on item relevance and representativeness. At the scale level, S-CVI/Ave values exceeded commonly used thresholds for acceptable content validity, suggesting that the instrument adequately captures the intended domains of water literacy. These findings align with methodological recommendations that

emphasise expert-based content validation as a critical step in early-stage instrument development, particularly for multidimensional constructs (Lynn, 1986; Polit & Beck, 2006).

Notably, two attitude items recorded comparatively lower I-CVI values (0.67), reflecting lower expert agreement. This pattern is consistent with the inherent complexity of measuring affective constructs, which are often shaped by contextual, cultural, and experiential factors, leading to greater variability in expert interpretation compared with cognitive domains (Mostacedo-Marasovic et al., 2022; Saad & Mahmud, 2023). Importantly, rather than discarding these items prematurely, they were retained for revision based on expert feedback (e.g., improved clarity of wording and closer alignment with the intended attitudinal indicator) and will be re-evaluated in subsequent large-scale validation. This approach supports content refinement while preserving theoretical coverage of the attitude's domain.

Reliability of the Instrument

Internal consistency reliability analysis indicated acceptable to high reliability across domains. The water knowledge domain showed high reliability ($KR-20 = 0.864$), suggesting consistent item performance within the cognitive construct. This is consistent with prior research showing that knowledge-based items often yield stronger internal consistency due to their objective format and structured scoring (Taber, 2018; Tian & Chen, 2023).

The attitude and behaviour domains demonstrated acceptable reliability ($\alpha = 0.805$ and $\alpha = 0.702$, respectively), supporting their use for exploratory and early-stage validation. Slightly lower reliability for behavioural items is expected, given that self-reported behaviours may be influenced by situational constraints and social desirability (Sánchez et al., 2023). Similar patterns have been reported in water literacy and environmental behaviour instruments, in which behavioural components commonly yield moderate internal consistency relative to cognitive scales (Erbaş et al., 2023; Meilinda et al., 2023). Collectively, these findings suggest coherent measurement performance while reflecting the inherent variability of affective and behavioural constructs.

Implications for Water Literacy Measurement

The findings contribute to ongoing calls for context-sensitive, multidimensional water literacy instruments. Unlike many tools developed in other settings, this instrument underwent expert review that incorporated Malaysian educational and environmental perspectives, thereby strengthening contextual relevance and addressing concerns raised in local studies that relied on adapted instruments without systematic validation (Maniam et al., 2021). Furthermore, operationalising water literacy through knowledge, attitudes, and behaviours aligns with contemporary theoretical perspectives that conceptualise water literacy as an integrated construct rather than a purely cognitive attribute (McCarroll & Hamann, 2020; Mostacedo-Marasovic et al., 2022). As an initial validation step, these results support the instrument's potential for use in curriculum-aligned assessment and for informing targeted water education interventions for lower secondary learners.

Limitations and Future Research Directions

This study provides preliminary psychometric evidence based on expert content validation and internal consistency estimates. Several limitations should be noted. First, the pilot sample size was small and intended for initial reliability screening rather than definitive generalisation.

Second, the attitude and behaviour domains relied on self-reported responses that may be influenced by response bias and social desirability. Third, construct validity was not assessed in this initial stage. Future studies should employ larger and more diverse samples and extend validation through exploratory and confirmatory factor analysis, test–retest reliability, and measurement invariance testing (e.g., across gender or sociocultural groups) to strengthen validity evidence and support broader generalisability. Where feasible, future work may also triangulate behavioural indicators with observational or contextual measures to reduce reliance on self-report alone.

Conclusion

This study developed and reported initial validation of a water literacy instrument for Malaysian lower secondary students, focusing on content validity and internal consistency. Overall, the findings indicate that the instrument represents the multidimensional construct of water literacy across knowledge, attitudes, and behaviours. Expert evaluation demonstrated strong content validity, supporting the relevance and clarity of the items within the Malaysian educational context. Reliability analysis further showed acceptable to high internal consistency across domains, indicating coherent measurement performance at the pilot stage.

This study contributes by providing a context-sensitive, multidimensional instrument that addresses the limited availability of locally validated measures for assessing water literacy among Malaysian lower secondary learners. The evidence reported here provides a foundation for more rigorous, curriculum-aligned assessment practices in water education research and school-based evaluation. Future studies should extend validation using larger and more diverse samples and apply additional psychometric analyses, such as exploratory and confirmatory factor analysis, test–retest reliability, and measurement invariance testing, to strengthen validity evidence and support broader generalisability and application.

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Malaysia (Kementerian Pendidikan Malaysia), Research and Planning Division, under approval number KPM.600-3/2/3-eras (21336). Informed consent was obtained from all participants prior to data collection. Participation was voluntary, and participants were informed of their right to withdraw at any stage without penalty. Confidentiality and anonymity of all respondents were strictly maintained, and no personally identifiable information was collected. All data obtained in this study were used solely for academic and research purposes.

Author Contribution Statement: All authors contributed significantly to the development of this manuscript. Aaron Ismanto Anggang was responsible for the study's conceptualization, methodology, and overall supervision. Adi bin Jafar handled data collection, analysis, and interpretation of results. Soon Singh Bikar Singh contributed to the literature review, drafting, and critical revision of the manuscript. All authors read and approved the final version of the manuscript prior to submission.

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