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Exploring The Potential of the Physical Characteristics of Coastal Well Water in Majene Regency as a Context for High School Physics Learning: A Preliminary Study and Needs Analysis

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Abstract:

Physics is often perceived by students as abstract and detached from everyday experience, a recurring concern in physics education literature. Place-based learning and ethnoscience approaches, using local phenomena to connect science with students' lived experience, have been recommended to address this issue. This preliminary needs-analysis study identifies the potential of coastal well water phenomena in Majene Regency as an authentic context for fluid mechanics, while mapping misconceptions, interest, and teacher needs for contextual materials. A mixed-methods approach followed the first two stages of the Model of Educational Reconstruction (MER): content analysis and investigation of student and teacher perspectives. Data were collected from 42 Grade 11 students at SMAN 3 Majene using a Three-Tier Diagnostic Test and an interest questionnaire, and from 5 physics teachers via a needs-analysis questionnaire, with ethical approval and informed consent. Instruments were expert-validated (Aiken's V = 0.73; KR-20 = 0.78; Cronbach's alpha = 0.82). Results show coastal well water phenomena relate directly to four core concepts density, hydrostatic pressure, Archimedes' principle, and discharge-continuity and students hold significant misconceptions, particularly on Archimedes' principle (69.05%). General interest in physics was low, but interest in locally contextualized learning was high, and all teachers reported urgent need for contextual materials. This study fills a gap in place-based physics education literature in coastal West Sulawesi and yields a preliminary concept map as a foundation for contextual teaching materials, applicable locally and transferable elsewhere.

1. Introduction

Physics is often perceived by students as an abstract and difficult subject, particularly when concepts are taught in isolation from everyday experience. This condition contributes to low learning motivation and a high prevalence of conceptual misconceptions, including in fluid mechanics topics (Alfad, 2020; Kamilah et al., 2025). This is not merely a local issue: systematic reviews of student attitudes and motivation toward physics across educational levels show similar patterns (Tanti et al., 2025), while studies on misconceptions in static fluids and other mechanics topics continue to be reported across contexts (Harizah et al., 2019; Kaniawati et al., 2019). In other words, the starting point of this study is a physics education problem how to bridge abstract concepts with student experience rather than a coastal well water quality issue.

One widely recommended approach to this problem is contextual learning, encompassing Place-Based Education (PBE) and ethnoscience. A systematic review of PBE literature shows that this approach consistently connects academic concepts to student's lived environment through psychological, socio-cultural, and political-economic dimensions of place (Yemini et al., 2023). A synthesis of context-based and Science-Technology-Society (STS) approaches similarly shows that learning connected to meaningful situations consistently improves student engagement and conceptual understanding (Bennett et al., 2007). Within Indonesian physics education specifically, a systematic review of ethnoscience integration in physics learning confirms that leveraging local phenomena and wisdom from traditional games to everyday community practices contributes to conceptual understanding, motivation, science literacy, and critical thinking (Hikmawati et al., 2021; Kasim et al., 2025).

However, most ethnoscience and place-based physics research remains focused on cultural objects or traditional games (Kasim et al., 2025), while coastal geo-environmental phenomena particularly those related to water resources remain underexplored as a context for fluid mechanics learning. Meanwhile, research on coastal well water quality has so far been dominated by hydrological, geochemical, and public health perspectives: seawater intrusion into coastal aquifers has been studied extensively from the perspective of physical processes and management (Werner et al., 2013), including large-scale observations of hundreds of thousands of coastal wells revealing groundwater-level shifts due to intrusion (Jasechko et al., 2020), and links between intrusion characteristics and coastal slope geomorphology (Zahra et al., 2022). In Majene Regency specifically, prior research has documented increased salinity, total dissolved solids (TDS), and electrical conductivity in shallow groundwater due to seawater intrusion (Sunarwan & Firmansyah, 2016; Yusman et al., 2019). This is the literature gap underlying this study: no prior research has explicitly positioned Majene's coastal well water phenomenon as an authentic context for physics learning, nor assessed student and teacher readiness to use it as such.

Majene's coastal environment offers several advantages as a physics learning context. First, changes in the physical characteristics of well water due to seawater intrusion are directly observable and experienced by students in daily life, aligning with PBE's principle that the most meaningful learning occurs when students connect personal experience with academic concepts (Yemini et al., 2023). Second, this phenomenon is conceptually rich, spanning more than one core fluid mechanics concept at once density, hydrostatic pressure, buoyant force, and discharge-continuity making it usable as an integrated learning context rather than a single-concept illustration. Third, this issue carries high social relevance for coastal communities dependent on dug wells, so learning based on this phenomenon can present authentic urgency and meaning, consistent with the emphasis of Indonesia's Merdeka Curriculum on contextual learning (Ministry of Education, Culture, Research, and Technology, 2022).

Based on this gap, this study aims to: (1) identify the conceptual link between the physical characteristics of Majene's coastal well water and fluid mechanics concepts taught at the senior high school level; (2) map student misconceptions regarding these concepts; (3) assess student interest in physics learning based on local context; and (4) analyze physics teachers' needs regarding the development of contextual teaching materials. As a preliminary study and needs analysis, this research is intended to produce a conceptual and empirical basis for developing place-based physics teaching materials in subsequent research.

2. Theoretical Framework

2. 1. Place-Based Education and Ethnoscience in Physics Learning

Place-Based Education (PBE) is a teaching approach that uses the local environment as a learning context, enabling students to connect academic concepts with real-world experience around them. A systematic review of PBE literature identifies three dimensions of student-place connection psychological (personal experience and identity), socio-cultural (community norms and practices), and political-economic (issues of social justice and resource management) all of which are relevant to Majene's coastal communities, who depend on dug wells for their water needs (Yemini et al., 2023). Consistently, a synthesis of context-based and STS learning evidence shows increased relevance, engagement, and conceptual understanding when concepts are learned through situations meaningful to students (Bennett et al., 2007).

The ethnoscience approach using local knowledge and community practices as an entry point for science learning is an operational derivative of PBE widely applied in Indonesian physics education. A systematic review of 30 ethnoscience-in-physics research articles identifies that commonly used ethnoscience objects include traditional games, regional food and beverages, dances, musical instruments, crafts, and local history and customs, contributing to learning outcomes, critical thinking, conceptual understanding, motivation, interest, science literacy, and student character (Kasim et al., 2025). Local-wisdom-based ethnoscience studies have also proven relevant to specific geographical contexts, such as ethnoscience potential in Lombok Island for learning model development (Hikmawati et al., 2021). Nevertheless, most ethnoscience physics studies remain focused on cultural-ceremonial objects, while everyday geo-environmental phenomena such as coastal groundwater characteristics remain relatively unexplored — a gap this study addresses by positioning coastal well water as an environmental-ethnoscience "text," rather than merely a cultural object.

2. 2. *Student Misconceptions in Fluid Mechanics*

A misconception is an understanding that is inconsistent with the accepted scientific concept and is often resistant to conventional instruction. In fluid mechanics, the most commonly reported misconceptions relate to density, hydrostatic pressure, and Archimedes' principle (Alfad, 2020). Classic research on student understanding of Archimedes' principle found that students tend to believe buoyant force is determined by the mass or weight of the submerged object rather than the volume of displaced fluid (Loverude et al., 2003) — a pattern also widely found in Newton's laws misconceptions via tiered testing instruments (Kaniawati et al., 2019) and in general static-fluid conceptual mastery among senior high school students (Harizah et al., 2019). A review of Indonesian senior high school students' physics misconceptions confirms that fluids remain a topic with consistently high misconception rates across grade levels and regions, and recommends remediation strategies that provide cognitive confrontation through contextual experience (Kamilah et al., 2025). This framework underlies the use of the Three-Tier Diagnostic Test in this study, and supports the argument that remediating fluid mechanics misconceptions requires concrete, experience-near contexts — one of which is the coastal well water phenomenon.

2. 3. Physical Characteristics of Coastal Well Water and Their Link to Fluid Mechanics Concepts

Coastal well water is prone to changes in physical characteristics due to seawater intrusion into coastal aquifers, a process extensively studied from a hydrogeological perspective (Werner et al., 2013) and confirmed at the regional Indonesian scale (Jasechko et al., 2020). In Majene Regency specifically, shallow groundwater in coastal areas has experienced increased salinity, total dissolved solids (TDS), and electrical conductivity (Sunarwan & Firmansyah, 2016; Yusman et al., 2019), while intrusion characteristics are related to coastal slope conditions (Zahra et al., 2022). This phenomenon is not merely an environmental issue but is directly and quantitatively linked to four core fluid mechanics concepts taught at the senior high school level, as detailed below.

a. Fluid Density (ρ). Increased dissolved-solute concentration (salinity and TDS) in brackish well water increases its density relative to fresh water, per $\rho = m/V$ (mass over volume). Brackish, intruded well water has a higher ρ because the mass of dissolved solutes per unit volume increases, even though the water may still appear visually clear a source of the common misconception that "clear water must be fresh."

b. Hydrostatic Pressure (P). Well water column depth varies by season and location, while water density varies by intrusion level. Both jointly determine pressure at the well bottom, per $P = P_0 + \rho gh$, where P_0 is atmospheric pressure, g is gravitational acceleration, and h is water column depth. This allows students to compute and compare hydrostatic pressure across wells with different salinity levels.

c. Archimedes' Principle (Buoyant Force, F_a). Density differences between fresh, brackish, and seawater affect an object's buoyancy, per $F_a = \rho(\text{fluid})\cdot g\cdot V(\text{submerged})$. The commonly observed phenomenon that "objects float more easily in brackish/salty water" is a direct manifestation of this equation, and can be used to confront the misconception that buoyant force is determined by object mass rather than displaced fluid volume (Loverude et al., 2003).

d. Discharge and Continuity (Q). Well water extraction using pumps or buckets involves discharge and flow continuity principles, per $Q = A_1v_1 = A_2v_2$, where A is cross-sectional area and v is flow velocity. Variation in household distribution pipe diameter in coastal Majene households provides a concrete context for explaining the inverse relationship between cross-sectional area and flow velocity at constant discharge.

These four concepts show that the Majene coastal well water phenomenon is not a single illustration but an integrated context spanning a coherent set of core Fase F fluid mechanics concepts Fase F being the Merdeka Curriculum's designation for the senior high school phase (Grades 11–12) a characteristic that strengthens the argument that this phenomenon merits development as a complete place-based learning unit rather than a supplementary example.

3. Method

3.1 Research Design

This study employed a descriptive, mixed-methods design, conceived as the preliminary stage (a preliminary study and needs analysis) of a broader instructional-material development research program. The design follows the first two stages of the Model of Educational Reconstruction (MER): (1) clarification of science content, i.e., unpacking the scientific structure of the coastal well water phenomenon and linking it to senior high school fluid mechanics concepts; and (2) investigation of learners' and teachers' perspectives, i.e., empirical data collection on misconceptions, interest, and needs (Duit et al., 2012). The third MER stage (design of the learning environment) is beyond the scope of this study and is planned as follow-up research.

3.2 Science Content Analysis (Literature Review)

The science content analysis was conducted through a targeted narrative literature review of publications on (a) the physical characteristics and seawater intrusion processes of coastal aquifers, with an emphasis on Majene and West Sulawesi, and (b) contextual, place-based, and ethnoscience approaches in physics education. Searches were conducted on Google Scholar, DOAJ, and Crossref using combinations of "coastal groundwater," "seawater intrusion," "place-based learning," and "ethnoscience physics," restricted to reputable (DOI-indexed), openly accessible publications. Table 1 summarizes the main literature sources used in the content analysis.

Table 1. *Summary of Reviewed Literature Sources*

No.	Source (Author, Year)	Focus	Contribution to This Study
1	Werner et al. (2013)	Seawater intrusion processes, investigation, and management worldwide	Conceptual basis for the seawater intrusion process in coastal aquifers
2	Jasechko et al. (2020)	Observations of 250,000 US coastal wells regarding intrusion risk	Large-scale evidence that coastal groundwater-level change is a broad, measurable phenomenon
3	Sunarwan & Firmansyah (2016)	Groundwater chemistry in Majene Regency	Physico-chemical data of Majene's coastal well water (salinity, TDS, conductivity)
4	Yusman et al. (2019)	Mapping of coastal groundwater quality in Majene	Spatial mapping of well water quality underlying Table 3
5	Zahra et al. (2022)	Seawater intrusion characteristics and slope steepness	Link between coastal geomorphology and intrusion level
6	Yemini et al. (2023)	Systematic review of Place-Based Education	Theoretical framework of PBE and student-place connection dimensions
7	Bennett et al. (2007)	Synthesis of context-based and STS learning evidence	Basis for the argument linking context to student engagement
8	Kasim et al. (2025)	Systematic review of ethnoscience in physics learning	Positioning of this study within the Indonesian ethnoscience physics literature
9	Hikmawati et al. (2021)	Local wisdom and ethnoscience in Lombok Island	Precedent for geography/environment-based ethnoscience
10	Loverude et al. (2003); Kaniawati et al. (2019); Harizah et al. (2019); Kamilah et al. (2025)	Student misconceptions in fluid mechanics and other physics topics	Theoretical basis for the Three-Tier Diagnostic Test instrument

3.3 Participants and Data Collection Procedure

This study received ethical approval prior to data collection, in accordance with the institutional guidelines of the STKIP DDI Pinrang and was classified as a minimal-risk educational study. Permission to conduct the study was obtained from the relevant school authorities through an official research permission letter. Primary data were collected from 42 Grade 11 (Fase F) students at SMAN 3 Majene who had completed the fluid mechanics unit, selected through purposive sampling. Teacher participants comprised 5 physics teachers from two senior high schools in Majene, selected through total sampling given the limited number of active physics teachers in the area.

Prior to data collection, all participants 42 students and 5 teachers were informed of the study's purpose, procedures, and their right to withdraw at any time without consequence, and informed consent was obtained from each participant before instruments were administered. No sensitive personal data were collected, and all responses were anonymized at the point of collection. Data collection proceeded in two parallel strands: students completed the Three-Tier Diagnostic Test followed by the learning interest questionnaire in a single classroom session under teacher supervision, while teachers completed the needs-analysis questionnaire independently within the same data-collection window.

3.4 Research Instruments

The study used three main instruments, with indicators and validation results summarized in Table 2. The complete diagnostic-test instrument is presented in Appendix A, and the expert-validation results are presented in Appendix B.

Table 2. *Research Instruments, Indicators, and Validation Results*

Instrument	Purpose	Indicators Measured	Validation Results
Three-Tier Diagnostic Test (16 items)	Identify students' understanding profile and misconception forms	(1) Fluid density; (2) Hydrostatic pressure; (3) Archimedes' principle; (4) Discharge and continuity each measured via answer choice, confidence level, and reasoning (three-tier)	Content validity Aiken's V = 0.73 (3 experts); KR-20 reliability = 0.78

Learning Interest Questionnaire (4-point Likert scale)	Measure student interest in general physics and locally-contextualized physics	(1) Attention to physics learning; (2) Interest in theoretical physics; (3) Perceived relevance of physics to daily life; (4) Interest in local coastal-context learning	Cronbach's alpha reliability = 0.82
Teacher Needs Questionnaire	Capture teacher needs for contextual teaching materials	(1) Need for context-based material for the Merdeka Curriculum; (2) Difficulty designing materials independently; (3) Textbook fit with local context; (4) Feasibility of the coastal well water topic	Reviewed by 3 experts (expert judgment); open-ended items triangulated with the literature review

Expert validation was conducted by three validators (physics education lecturers and experienced physics teachers) using a content, construction, and language appropriateness rating instrument. An Aiken's V of 0.73 for the Three-Tier Diagnostic Test indicates adequate content validity ($0.60 \leq V < 0.80$ is categorized as valid), while a KR-20 reliability of 0.78 and Cronbach's alpha of 0.82 indicate adequate internal consistency for a preliminary-study-level instrument.

3.5 Data Analysis

Literature data were analyzed using content analysis to identify links between the physical characteristics of coastal well water and senior high school fluid mechanics concepts. Misconception data were analyzed using the three-tier categorization scheme (Scientific Understanding/SU, Misconception/M, Partial Understanding/PU, No Understanding/NU) based on combinations of answer and confidence-level responses, then presented as percentages per sub-concept together with the dominant misconception forms underlying each sub-concept's M percentage. Interest and needs data were analyzed descriptively using means, standard deviations, and percentages.

4. Results

4.1. Physical Characteristics of Coastal Well Water and Their Link to Fluid Mechanics Concepts

The literature review shows that Majene's coastal region is vulnerable to seawater intrusion, marked by increased salinity, TDS, and electrical conductivity in shallow groundwater (Sunarwan & Firmansyah, 2016; Yusman et al., 2019). Table 3 explicitly maps how each physical parameter quantitatively relates to a fluid mechanics concept. This table is drawn from the literature review described in Section 3.2 and is therefore conceptual rather than an empirical measurement of student understanding; the columns "SU," "M," "PU," and "NU" used later in Table 4 do not apply here and are reported separately from the empirical diagnostic-test results.

Table 3. *Physical Characteristics of Majene Coastal Well Water and Their Link to Fluid Mechanics Concepts*

Physical Parameter	Observed Change in Majene	Related Physics Concept	Quantitative Relationship
Salinity	Increases near the coastline due to intrusion (Sunarwan & Firmansyah, 2016)	Density (ϱ)	Salinity ↑ → solute concentration ↑ → $\varrho = m/V$ increases
TDS	Increases as distance to the coastline decreases (Yusman et al., 2019)	Density and hydrostatic pressure	TDS ↑ → ϱ ↑ → $P = P_0 + \varrho gh$ increases at the same h
Electrical conductivity	Increases proportionally with TDS/salinity (Sunarwan & Firmansyah, 2016)	Indirect indicator of ϱ	Used as a field proxy for ϱ without a hydrometer
Buoyancy of test objects	Objects float more easily in higher-salinity wells (field observation, synthesized from Werner et al., 2013)	Archimedes' principle (F_a)	ϱ(fluid) ↑ → $F_a = \varrho \cdot g \cdot V$(submerged) increases at constant V
Water extraction discharge	Varies with pipe/bucket diameter used by households	Discharge and continuity (Q)	$Q = A_1 v_1 = A_2 v_2$ — cross-sectional area inversely related to velocity

Table 3 shows that all four physical parameters converge on two underlying quantities fluid density and depth through which the four fluid mechanics concepts are derived. Salinity and TDS are direct empirical measures of solute concentration and therefore of ϱ, while electrical conductivity is listed separately not as a fifth physics concept but as a field-measurable proxy for the same quantity a practical substitute for salinity or TDS testing when a hydrometer or laboratory equipment is unavailable, which then feeds forward into hydrostatic pressure and buoyant force in the same way. Discharge-continuity is the one concept that depends on cross-sectional geometry rather than ϱ. This convergence indicates that the four concepts are not four independent illustrations but a connected causal chain density change drives both pressure and buoyancy change which is what qualifies the coastal well water phenomenon as an integrated rather than a piecemeal learning context, and is the empirical basis on which the diagnostic test in Section 4.2 was constructed around these same four sub-concepts.

4.2. Students' Understanding Profile and Misconceptions

Results of the Three-Tier Diagnostic Test administered to 42 students show the highest misconception rate on Archimedes' principle (69.05%), followed by hydrostatic pressure (54.76%), fluid density (47.62%), and discharge-continuity (38.10%). Table 4 presents the overall understanding profile (SU/M/PU/NU) for each sub-concept together with the dominant misconception form(s) underlying its M percentage, replacing separate reporting of the aggregate rates and specific misconception statements with a single consolidated view.

Table 4. *Students' Understanding Profile and Dominant Misconception Forms per Sub-Concept (N = 42)*

No.	Sub-Concept	SU (%)	M (%)	PU (%)	NU (%)	Dominant Misconception Form (% of cases)
1	Fluid Density	28.57	47.62	14.29	9.52	Brackish water assumed to have the same density as fresh water because both appear clear (42.86%)
2	Hydrostatic Pressure	21.43	54.76	16.67	7.14	Pressure at the well bottom assumed to depend on well shape or cross-sectional area (52.38%)
3	Archimedes' Principle	14.29	69.05	11.90	4.76	(a) Buoyant force assumed determined by mass/weight of the submerged object rather than displaced fluid volume (64.28%); (b) buoyancy assumed to increase linearly with depth once an object is fully submerged (59.52%)
4	Discharge and Continuity	35.71	38.10	19.05	7.14	Flow velocity in a narrow-diameter pipe assumed to be slower than in a wide-diameter pipe at constant discharge (38.10%)

Note: SU = Scientific Understanding; M = Misconception; PU = Partial Understanding; NU = No Understanding. The dominant-misconception percentage reflects the proportion of the 42 students exhibiting that specific reasoning pattern; it is not additive with the M column because M aggregates all misconception forms identified for that sub-concept, and Archimedes' principle shows two co-occurring dominant forms rather than a single one.

The highest misconception rate, on Archimedes' principle, is best explained by conditions specific to Majene's coastal schools rather than by comparison to distant literature. Laboratory equipment for directly measuring density or buoyant force hydrometers, spring scales, graduated cylinders is limited or absent in these schools, and the textbooks in circulation present Archimedes' principle mainly as a formula to be memorized and applied to abstract, idealized objects rather than as something students measure themselves. Without that hands-on confrontation, the intuitive belief that "heavier objects sink" is never directly challenged in class. This gap is compounded by community habit: most students' daily experience of floating and sinking comes from informal encounters with wells and the sea for example, noticing that a heavier bucket or fishing tool "feels harder to lift" underwater which reinforces a mass-based folk explanation of buoyancy rather than correcting it, since everyday well and sea use rarely makes displaced volume an explicit, nameable quantity. The misconception is therefore not simply a matter of insufficient formula practice, but the product of two reinforcing local conditions: restricted access to measurement tools in the classroom, and a community habit of talking about floating and sinking in terms of an object's felt weight rather than the water it displaces.

A comparable, locally grounded explanation applies to hydrostatic pressure, where over half of students attributed pressure at the well bottom to well shape or width rather than depth and density. This likely reflects a visual-spatial reasoning habit common in everyday well use a narrower well "looks" as though it should hold water under more pressure compounded by the fact that available textbooks illustrate $P = P_0 + \varrho gh$ using idealized uniform containers rather than the irregular hand-dug wells students actually draw water from, leaving the shape-independence property abstract rather than something students can verify against their own well. For fluid density, the misconception that clear brackish water has the same density as fresh water tracks a genuine sensory and technological limit: salinity in Majene's brackish wells is not always visually or texturally obvious at low-to-moderate intrusion levels, and without an instrument such as a hydrometer or refractometer tools rarely available in these schools or households there is nothing in students' everyday observation to contradict the assumption that clear water is fresh water. By contrast, the lowest misconception rate, on discharge-continuity, aligns with a community practice most students already have direct access to: households routinely use pumps and hoses of visibly different diameters, giving them a working qualitative intuition consistent with $Q = A_1 v_1 = A_2 v_2$ even without formal instruction or any special equipment. Read together, the four sub-concepts show a consistent pattern: misconception rates are lowest where daily household practice already supplies a correct intuition, and highest where correcting the intuition would require a measurement tool or instructional example that is not locally available a pattern that points directly to what a place-based remediation unit for Majene needs to supply: simple, low-cost measurement activities (a homemade hydrometer, a spring scale, water samples of varying salinity) that let students test their own community's intuitions against the water they use every day.

4.3. Student Learning Interest

Table 5. *Student Learning Interest Profile (N = 42)*

No.	Interest Aspect	Mean (M)	SD	Category
1	Attention to physics learning	2.33	0.45	Low
2	Interest in theoretical physics	2.46	0.51	Low
3	Perceived relevance of physics to daily life	1.65	0.38	Very low
4	Interest in local coastal-context learning	3.54	0.32	Very high
	Cumulative Mean Score	**2.49**	**0.41**	**Low**

Note: 1–4 scale (Strongly Disagree – Strongly Agree); categories: 1.00–1.75 = Very Low; 1.76–2.50 = Low; 2.51–3.25 = High; 3.26–4.00 = Very High.

The sharp gap between perceived relevance of physics in general (M = 1.65; very low) and interest in local coastal-context learning (M = 3.54; very high) is best read against Majene students' daily reality rather than against general motivation theory. Drawing and managing well water is a routine household chore for most students in coastal Majene they regularly notice, without being taught to, that some wells taste different from others, that water is heavier to carry after the dry season, or that certain wells are avoided for drinking during the dry months. This existing, culturally embedded familiarity with well water gives the coastal-context questionnaire items immediate personal meaning that abstract textbook problems (inclined planes, ideal pulleys, frictionless surfaces) cannot supply, because those objects are not part of any household routine students already perform. The very-low relevance score for physics in general is therefore better read as a mismatch between the objects used in current instruction and the objects already present in students' daily and cultural life rather than as evidence that Majene students are, by disposition, uninterested in science. This interpretation also fits a further practical detail: the same textbook-availability and equipment constraints noted for Table 4 mean that current physics instruction in these schools relies almost entirely on printed, generic worked examples rather than materials drawn from the coastal environment, which may itself help explain why physics as currently taught scores so far below physics taught through a locally recognizable phenomenon.

4.4. *Teacher Needs Analysis*

Table 6. *Teacher Needs Analysis Results (N = 5)*

No.	Indicator	Agree (%)
1	New context-based physics teaching materials are needed to support Merdeka Curriculum implementation	100
2	Teachers experience difficulty independently designing contextual materials based on local phenomena	80
3	Current textbooks do not adequately reflect Majene's local context	100
4	The coastal well water physical-characteristics topic is feasible to integrate into senior high school physics	100

All teachers (100%) reported needing contextual teaching materials and considered the coastal well water topic feasible for curriculum integration, yet 80% reported difficulty designing such materials independently. Because the teacher sample is small (N = 5), each percentage point in Table 6 corresponds to a coarse fraction of respondents 100% represents all 5 teachers, and 80% represents 4 of the 5 so these figures should be read as a consistent directional signal from the full population of active physics teachers available in the study area rather than as a statistically stable estimate generalizable beyond it. Open-ended responses point to two connected local barriers rather than a lack of pedagogical awareness. The first is limited access to technology and reference materials: teachers reported no access to validated local water-quality data (salinity, TDS readings for specific village wells) they could cite directly in a lesson, no textbook or teacher's guide that includes coastal-groundwater examples, and no bank of ready-made place-based worksheets or modules for West Sulawesi they could adapt rather than build entirely from scratch. The second is a practical constraint of time: designing an original contextual unit sourcing local data, writing indicators, building assessment items competes directly with regular teaching load, which most teachers described as already full. Neither barrier reflects doubt about the value of using students' own community's well water as a teaching context; rather, both point to a resourcing gap between what teachers recognize as pedagogically valuable and what their schools currently equip them to produce on their own. This “high need, limited independent development capacity” pattern accordingly locates the practical next step outside the individual classroom: in physics education researchers and the local teacher working group (MGMP) jointly producing and sharing ready-to-use, locally sourced materials the concept map in Table 7 and Section 4.5 is offered as a first step toward that resource.

4.5. *Preliminary Concept Map*

Table 7 synthesizes the findings of Sections 4.1–4.4 into a single instructional reference, linking each observable coastal well water phenomenon to its underlying physical parameter, the fluid mechanics concept it operationalizes, and a concrete recommended classroom activity. This map is the primary output carried forward into the Discussion and forms the conceptual and empirical foundation referenced in the Conclusion.

Table 7. *Preliminary Concept Map: Fluid Mechanics Based on the Majene Coastal Well Water Phenomenon*

Coastal Well Water Phenomenon	Physical Parameter/Indicator	Fluid Mechanics Concept	Recommended Learning Activity
Well water becomes brackish due to seawater intrusion	Salinity and fluid density (ρ)	Density ($\rho = m/V$)	Measure and compare the density of fresh, brackish, and sea water using a simple student-made hydrometer

Well water column height varies seasonally	Depth (h) and fluid density	Hydrostatic Pressure ($P = P_0 + \rho gh$)	Calculate hydrostatic pressure at the well bottom across different depths and salinities
Objects float more easily in brackish/salty water	Buoyant force (F_a) and submerged volume (V)	Archimedes' Principle ($F_a = \rho gV$)	Test floating-suspending-sinking conditions with manipulated water salinity samples
Well water extraction via pump/bucket	Flow velocity (v) and pipe cross-sectional area (A)	Discharge and Continuity ($Q = Av$)	Calculate well pump discharge based on the variation in pipe diameter used by households

5. Discussion

5.1. Interpretation of Findings

Overall, the findings point to three mutually reinforcing conclusions. Conceptually, the Majene coastal well water phenomenon proved to have a quantitative not merely qualitative-analogical link to four core fluid mechanics concepts, qualifying it as a “conceptually rich context” in place-based learning terms. These four concepts together span the full core content of the senior high school fluid mechanics unit rather than a single isolated topic, indicating that the phenomenon is conceptually complete enough to anchor an entire teaching unit rather than serve as a supplementary illustration for one lesson a scope broadly comparable to other context-based physics units reported in the literature that similarly span multiple related concepts rather than one (Bennett et al., 2007). A precise mapping of this scope onto the number of class meetings allocated under the Merdeka Curriculum's capaian pembelajaran (learning outcomes) for Fase F was beyond the scope of the present study and is noted as a task for the subsequent module-development stage.

Cognitively, the diagnostic results show students still carry an intuitive, mass-based rather than volume-based understanding of buoyancy, and a shape-based rather than depth-based understanding of hydrostatic pressure, most acutely for Archimedes' principle. For buoyant force specifically the sub-concept with the highest misconception rate (69.05%) this mass-based reasoning mirrors the same difficulty documented in classic research on student understanding of Archimedes' principle (Loverude et al., 2003), indicating the pattern found in Majene is not an artifact of this instrument but a well-recognized difficulty in teaching this concept generally. The shape-based reasoning found for hydrostatic pressure is likewise consistent with reports of persistently weak static-fluid conceptual mastery among Indonesian senior high school students (Harizah et al., 2019), while the “clear water is fresh water” density misconception matches the broader finding that fluid misconceptions in Indonesian classrooms often stem from surface, appearance-based cues rather than quantitative reasoning (Alfad, 2020). Discharge-continuity, the sub-concept with the lowest misconception rate, is the one exception to this pattern; its relatively stronger performance is consistent with a general review noting that misconception severity in Indonesian physics classrooms varies with how much everyday, hands-on exposure students already have to a concept before formal instruction (Kamilah et al., 2025). Across all four sub-concepts, then, the qualitative pattern reasoning from visible object or container attributes rather than the physical-quantity relationships those attributes obscure is not unique to this study's sample but a genuine, generalizable feature of how each concept is typically misunderstood.

Affectively, the sharp gap between students' low interest in general physics and their high interest in local-context learning indicates that Majene's physics motivation problem is more pedagogical how material is presented than dispositional students' basic attitude toward science a distinction consistent with context-based learning theory (Bennett et al., 2007). Together, these findings support the argument that coastal well water is not only "theoretically suitable" as a learning context but also "practically needed" by students and teachers in the field.

This study also offers a distinct contribution to the literature. It is, to our knowledge, the first study to explicitly position seawater intrusion in coastal wells as an integrated fluid mechanics learning context spanning four core concepts at once, differing from prior ethnoscience physics research that typically focuses on cultural-ceremonial objects such as traditional games or regional food (Kasim et al., 2025). It also bridges two previously separate research traditions hydrogeological/geochemical research on Majene's coastal water quality (Sunarwan & Firmansyah, 2016; Yusman et al., 2019) and context-based physics education research (Yemini et al., 2023) through an explicit quantitative concept map, and grounds that map directly in end-user empirical evidence (student misconceptions, interest, and teacher needs) rather than literature-content analysis alone.

5.2. Implications

For classroom practice in Majene, these findings suggest that teachers begin using brackish well water samples as simple laboratory media to provide cognitive-confrontation experiences directly targeting the misconception patterns identified in Section 4.2 — for instance, measuring buoyant force across samples of different salinity to correct the assumption that buoyancy is determined by object mass. For physics education researchers, the concept map in Table 7 can directly inform subsequent development (R&D) research, such as electronic modules, guided-inquiry worksheets, or simple laboratory kits based on PBE.

Beyond this local application, the findings speak to physics education more generally in three ways. First, the misconception patterns identified mass-based reasoning about buoyancy and shape-based reasoning about hydrostatic pressure are not artifacts of the coastal well water context itself but recognizable, well-documented misconceptions in fluid mechanics teaching everywhere; what this study adds is evidence that a concrete, locally available phenomenon can be used as the confrontation tool for remediating them, offering physics educators anywhere a template for selecting a local context by matching it against the specific misconceptions it can concretely address rather than by cultural relevance alone. Second, the consistent gap between low general interest and high local-context interest found here adds to a growing body of context-based learning evidence (Bennett et al., 2007) that motivation problems in physics are frequently pedagogical rather than dispositional, an implication relevant to any setting where physics is taught in the abstract, not just coastal regions. Third, the approach demonstrated here explicitly deriving a quantitative concept map from an environmental phenomenon before assessing student and teacher readiness offers a transferable methodological template (grounded in the first two MER stages) that other physics education researchers can apply to different local phenomena, whether coastal, agricultural, or industrial, when selecting and validating a context for physics instruction.

More specifically for coastal settings, seawater intrusion into coastal aquifers is not unique to Majene but affects hundreds of thousands of coastal communities worldwide, as shown by large-scale observations of US coastal wells (Jasechko et al., 2020) and global reviews of intrusion processes (Werner et al., 2013). The conceptual framework developed here linking coastal groundwater physical parameters to density, hydrostatic pressure, buoyant force, and discharge-continuity is therefore potentially transferable to other coastal regions facing similar seawater intrusion issues, both within Indonesia and internationally, as a place-based learning model connecting climate-linked coastal environmental change with contextual science education. For Majene's physics teacher working group (MGMP) specifically, the teacher-needs findings point to the value of a regular forum for documenting other coastal natural phenomena across West Sulawesi as a shared regional "context bank" for physics learning.

5.3. Limitation

This study has several limitations. First, the primary sample size (42 students from one school and 5 teachers from two schools) is small and drawn from a geographically limited area, so findings cannot be generalized to the entire student and teacher population in Majene Regency, let alone other coastal regions. Second, physical well-water characteristic data in this study derive from secondary literature rather than direct field measurement at the specific wells relevant to participating students, so the link between literature data and students' specific experience remains inferential. Third, as a preliminary study, this research has not tested the effectiveness of coastal-well-water-context learning on students' conceptual change experimentally; the resulting concept map (Table 7) remains a conceptual design rather than a piloted intervention outcome. Additionally, results at the C1-analogous lower and highest cognitive levels should be interpreted cautiously given the limited number of items per sub-concept.

Future research is recommended to: (1) conduct direct physical measurements (salinity, TDS, conductivity) at wells relevant to participating students' experience to strengthen the link between literature data and empirical context; (2) expand sampling to multiple schools and other coastal regions in West Sulawesi to test the transferability of findings; and (3) proceed to the third MER stage by developing and piloting teaching materials (modules, worksheets, or experiment kits) based on the concept map through a quasi-experimental design to measure their impact on misconception remediation and learning interest.

6. Conclusion

This study set out to address four objectives, each of which is answered as follows. First, regarding the conceptual link between Majene's coastal well water and fluid mechanics: the phenomenon, shaped by seawater intrusion, was found to be quantitatively not merely analogically linked to four core Fase F concepts (density, hydrostatic pressure, Archimedes' principle, and discharge-continuity), converging on fluid density and depth as the two underlying physical quantities that connect them. Second, regarding student misconceptions: significant misconceptions persist across all four sub-concepts, most severely for Archimedes' principle (69.05%) and hydrostatic pressure (54.76%), with a shared reasoning pattern of relying on visible object or container attributes rather than the underlying physical-quantity relationships. Third, regarding student interest: interest in physics as generally taught is low, but interest in learning based on local coastal phenomena is very high, indicating that the motivation problem is pedagogical rather than dispositional. Fourth, regarding teacher needs: all participating teachers reported an urgent need for contextual teaching materials and considered the coastal well water topic feasible for integration, while also reporting limited independent capacity to develop such materials, chiefly due to time, data, and reference-example constraints.

Taken together, these results are synthesized into a preliminary fluid mechanics concept map based on coastal well water (Table 7), the main contribution of this study. This map provides a conceptual and empirical foundation for developing physics teaching materials, modules, and learning tools in future research, both for the Majene context and as a potentially transferable framework for other coastal regions facing similar seawater intrusion challenges.

Author Contributions

Sulfianty Sulfianty: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision. **Juniar Rasyid:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Nurul Amalia Aris:** Methodology, Writing – review & editing, Supervision. **Mawardi Jalil Masri:** Methodology, Writing – review & editing, Supervision. **Nurvadillah Angraini. A:** Methodology, Writing – review & editing, Supervision. **Nurhandayani Nurhandayani:** Methodology, Writing – review & editing, Supervision. All authors have reviewed and approved the content of the manuscript.

Ethical Statement

This study was conducted in the regular classroom setting at SMAN 3 Majene and two high schools in Majene Regency, and was classified as a minimal-risk educational study based on the institutional guidelines of the STKIP DDI Pinrang. Ethical approval for the study procedures was obtained prior to data collection under these institutional guidelines. Permission to conduct the study and collect data was obtained from the relevant school authorities via an official research permission letter. Participation was voluntary, and informed consent was obtained from all participants 42 eleventh-grade students and 5 physics teachers prior to the administration of any instrument. No sensitive personal data was collected. All responses were anonymized and used solely for educational research purposes, specifically to identify students' misconceptions, measure their interest in learning, and analyze teachers' needs regarding the development of teaching materials based on the local environment of Majene Regency.

Declaration of AI Use

The authors used ChatGPT (OpenAI) to improve sentence clarity and readability in the original Indonesian-language draft, particularly in the introduction, theoretical framework, discussion, and conclusion sections. QuillBot was used to translate the revised text into English, including the abstract and keywords. Finally, DeepL was used to refine the English grammar, spelling, punctuation, and writing style in the final version of the manuscript. All AI-assisted results have been substantially reviewed, edited, and verified by the authors, who remain fully responsible for the accuracy, originality, scientific integrity, and the entire content of the final manuscript.

Conflict of Interest

The authors declare that there are no conflicts of interest, whether financial or non-financial, that could directly or indirectly influence the results of this study.

Supplementary Materials and Data Availability

The research instruments and validation data supporting the findings of this study are included within the article's Appendices.

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Appendix A. Research Instruments

The 8 presents the complete three-tier item for each of the 16 questions in a single location: Tier 1 (answer choice), Tier 2 (confidence scale), and Tier 3 (reasoning choice). Tier 2 uses the same 4-point confidence scale for every item (1 = guessing, 2 = unsure, 3 = sure, 4 = very sure) and is therefore stated once in the Tier 2 column of each row rather than repeated as separate response text. Tier 3 reasoning options are shared across the four items within the same sub-concept, following standard three-tier diagnostic test design.

Table 8. *Complete Three-Tier Diagnostic Test Instrument*

No.	Sub-Concept / Indicator	Tier 1: Question and Answer Options	Tier 2: Confidence Scale	Tier 3: Reasoning Options	Key
1	Density Indicator: Compare the density of two well water sources of different salinity despite similar visual clarity	Residents in Village X, Majene, have two dug wells: Well A, whose water tastes fresh, and Well B, whose water tastes slightly brackish, even though both appear equally clear. Which statement is correct regarding the density of the water in the two wells? a. The density of Well A and Well B water is the same, because both appear clear b. The density of Well B water is greater than Well A, because it contains more dissolved solutes c. The density of Well A water is greater, because its water feels lighter d. The density of the two wells cannot be compared without knowing the water temperature	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. The density of two water sources is the same as long as both look clear (surface-appearance reasoning). b. The density of brackish/saltier water is greater than fresh water because it contains more dissolved solute mass per unit volume ($\rho = m/V$; scientifically correct). c. The water that feels or tastes lighter has the greater density. d. Density cannot be compared without knowing the water's temperature.	B
2	Density Indicator: Relate solute concentration to water mass at equal volume	A small stone is placed into two glasses of water from Well A (fresh) and Well B (brackish) of equal volume. How do the masses of water in the two glasses compare? a. The mass of water in both glasses must be equal, because the volumes are equal b. The mass of Well B water is greater, because it contains more dissolved solutes per unit volume c. The mass of Well A water is greater, because fresh water is naturally heavier d. Cannot be determined without knowing the water temperature	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. The density of two water sources is the same as long as both look clear (surface-appearance reasoning). b. The density of brackish/saltier water is greater than fresh water because it contains more dissolved solute mass per unit volume ($\rho = m/V$; scientifically correct). c. The water that feels or tastes lighter has the greater density. d. Density cannot be compared without knowing the water's temperature.	B
3	Density Indicator: Rank the density of water sources with differing salinity from smallest to largest	A student measures the density of water from three sources — rainwater, Majene brackish well water, and seawater — using a simple hydrometer. The correct order of density from SMALLEST to LARGEST is... a. Seawater < brackish well water < rainwater b. Rainwater < brackish well water < seawater c. Brackish well water < rainwater < seawater	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. The density of two water sources is the same as long as both look clear (surface-appearance reasoning). b. The density of brackish/saltier water is greater than fresh water because it contains more dissolved solute mass per unit volume ($\rho = m/V$; scientifically correct). c. The water that feels or tastes lighter has the greater density. d. Density cannot be compared without knowing the water's temperature.	B

No.	Sub-Concept / Indicator	Tier 1: Question and Answer Options	Tier 2: Confidence Scale	Tier 3: Reasoning Options	Key
		d. All three have the same density			
4	Density Indicator: Determine the effect of evaporation-induced concentration on fluid density	If brackish well water is heated until part of it evaporates and the remaining salt water becomes more concentrated, what happens to the density of the remaining water? a. Density stays the same, because only water evaporates b. Density increases, because the concentration of dissolved solutes per volume increases c. Density decreases, because there is less water d. Density becomes zero because the water evaporates	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. The density of two water sources is the same as long as both look clear (surface-appearance reasoning). b. The density of brackish/saltier water is greater than fresh water because it contains more dissolved solute mass per unit volume (ϱ = m/V; scientifically correct). c. The water that feels or tastes lighter has the greater density. d. Density cannot be compared without knowing the water's temperature.	B
5	Hydrostatic Pressure Indicator: Determine that hydrostatic pressure at a well bottom is independent of well cross-sectional shape	Two dug wells in Majene have the same water depth (3 meters), but Well C is a narrow cylinder and Well D is a wide cylinder. Which statement is correct regarding the hydrostatic pressure at the bottom of the two wells? a. Pressure at the bottom of Well D is greater, because its cross-section is wider b. Pressure at the bottom of both wells is the same, because the depth and water density are the same c. Pressure at the bottom of Well C is greater, because the water is more concentrated in the narrow cross-section d. Pressure depends on well shape, not depth	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Pressure at the bottom of a well depends on the well's cross-sectional shape or width. b. Pressure at the bottom of a well depends only on fluid density (ϱ), gravitational acceleration (g), and depth (h), following $P = P_0 + \varrho gh$, and is independent of container shape. c. Pressure is greater on the side where the water "feels" more concentrated or crowded. d. Pressure does not change with depth as long as the fluid is the same.	B
6	Hydrostatic Pressure Indicator: Compare hydrostatic pressure between wells of different water density at equal depth	A resident measures water pressure at a depth of 2 meters in Well A (fresh water, lower ϱ) and Well B (brackish water, higher ϱ). Which well has greater pressure at the same depth? a. Well A, because fresh water is lighter so its pressure is greater b. Well B, because the density of brackish water is greater, so $P = \varrho gh$ increases c. Equal, because the depths are the same d. Cannot be compared without knowing the well diameter	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Pressure at the bottom of a well depends on the well's cross-sectional shape or width. b. Pressure at the bottom of a well depends only on fluid density (ϱ), gravitational acceleration (g), and depth (h), following $P = P_0 + \varrho gh$, and is independent of container shape. c. Pressure is greater on the side where the water "feels" more concentrated or crowded. d. Pressure does not change with depth as long as the fluid is the same.	B
7	Hydrostatic Pressure	If the water depth in a well doubles due to the rainy season (water density assumed constant),	1 = guessing	a. Pressure at the bottom of a well depends on the well's cross-sectional shape or width.	A

No.	Sub-Concept / Indicator	Tier 1: Question and Answer Options	Tier 2: Confidence Scale	Tier 3: Reasoning Options	Key
	Indicator: Apply the direct proportionality between hydrostatic pressure and water column depth	how does the hydrostatic pressure at the well bottom change? a. Pressure becomes twice as large b. Pressure becomes four times as large c. Pressure stays the same, because density did not change d. Pressure becomes half	2 = unsure 3 = sure 4 = very sure	b. Pressure at the bottom of a well depends only on fluid density (ϱ), gravitational acceleration (g), and depth (h), following $P = P_0 + \varrho gh$, and is independent of container shape. c. Pressure is greater on the side where the water "feels" more concentrated or crowded. d. Pressure does not change with depth as long as the fluid is the same.	
8	Hydrostatic Pressure Indicator: Confirm that hydrostatic pressure does not depend on container shape	A student argues that hydrostatic pressure at the bottom of a round well will differ from that at the bottom of a square well, even though the depth and type of water are the same. Is this argument correct? a. Correct, because shape affects pressure distribution b. Incorrect, because hydrostatic pressure depends only on ϱ, g, and h, not container shape c. Correct only if the well is very deep d. Cannot be determined without direct measurement	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Pressure at the bottom of a well depends on the well's cross-sectional shape or width. b. Pressure at the bottom of a well depends only on fluid density (ϱ), gravitational acceleration (g), and depth (h), following $P = P_0 + \varrho gh$, and is independent of container shape. c. Pressure is greater on the side where the water "feels" more concentrated or crowded. d. Pressure does not change with depth as long as the fluid is the same.	B
9	Archimedes' Principle Indicator: Determine the effect of fluid density on the buoyant force experienced by a submerged object	An empty bucket is lowered into a brackish well (high ϱ) and a fresh well (low ϱ). An identical empty bucket is placed in each well. In which well will the bucket float more easily? a. The brackish well, because the higher fluid density increases the buoyant force $F_a = \varrho gV$ b. The fresh well, because fresh water is lighter so the bucket rises more easily c. The same in both wells, because the bucket has the same weight d. It depends on the bucket's weight, not the type of water	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Buoyant force depends mainly on the mass or weight of the submerged object. b. Buoyant force depends on the fluid's density and the submerged volume, following $F_a = \varrho \cdot g \cdot V(\text{submerged})$, and increases when fluid density increases at constant submerged volume. c. Buoyant force keeps increasing the deeper an object is submerged, even after it is fully submerged. d. An object floats because the fluid pushes with an extra force not described by $F_a = \varrho gV$.	A
10	Archimedes' Principle Indicator: Determine that buoyant force remains constant with depth once an object is fully submerged	An object tied to a rope is slowly lowered deeper into a well filled with brackish water. How does the buoyant force (F_a) on the object change as it goes deeper, assuming the object is already fully submerged? a. Buoyant force keeps increasing linearly with depth	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Buoyant force depends mainly on the mass or weight of the submerged object. b. Buoyant force depends on the fluid's density and the submerged volume, following $F_a = \varrho \cdot g \cdot V(\text{submerged})$, and increases when fluid density increases at constant submerged volume.	B

No.	Sub-Concept / Indicator	Tier 1: Question and Answer Options	Tier 2: Confidence Scale	Tier 3: Reasoning Options	Key
		b. Buoyant force stays constant as long as the submerged volume and fluid density do not change c. Buoyant force decreases with depth d. Buoyant force becomes zero at a certain depth		c. Buoyant force keeps increasing the deeper an object is submerged, even after it is fully submerged. d. An object floats because the fluid pushes with an extra force not described by $F_a = \varrho gV$.	
11	Archimedes' Principle Indicator: Compare buoyant force on two objects of equal volume but different mass	Objects X and Y have the same volume, but the mass of X is twice the mass of Y. Both are fully submerged in the same well water. How do the buoyant forces on X and Y compare? a. The buoyant force on X is twice that on Y, because its mass is greater b. The buoyant force on X and Y is equal, because the displaced fluid volume is the same c. The buoyant force on Y is greater, because it is lighter d. Cannot be determined without knowing the objects' shape	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Buoyant force depends mainly on the mass or weight of the submerged object. b. Buoyant force depends on the fluid's density and the submerged volume, following $F_a = \varrho \cdot g \cdot V$(submerged), and increases when fluid density increases at constant submerged volume. c. Buoyant force keeps increasing the deeper an object is submerged, even after it is fully submerged. d. An object floats because the fluid pushes with an extra force not described by $F_a = \varrho gV$.	B
12	Archimedes' Principle Indicator: Explain floating/sinking behavior based on the relative density of fluid and object	An egg sinks in fresh well water but floats in a very brackish well. The correct scientific explanation for this phenomenon is... a. The egg becomes lighter when placed in brackish water b. The density of brackish water is greater than the density of the egg, so the resulting F_a can balance the egg's weight c. Brackish water provides an additional pushing force not present in fresh water d. The egg absorbs salt and becomes lighter	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Buoyant force depends mainly on the mass or weight of the submerged object. b. Buoyant force depends on the fluid's density and the submerged volume, following $F_a = \varrho \cdot g \cdot V$(submerged), and increases when fluid density increases at constant submerged volume. c. Buoyant force keeps increasing the deeper an object is submerged, even after it is fully submerged. d. An object floats because the fluid pushes with an extra force not described by $F_a = \varrho gV$.	B
13	Discharge & Continuity Indicator: Apply the inverse relationship between pipe cross-sectional area and flow velocity at constant discharge	Water from a well is pumped through a pipe that narrows toward its end before flowing into a holding tank. If the discharge (Q) is constant, how does the flow velocity (v) in the narrow section compare with the wide section? a. Velocity in the narrow section is smaller, because the space is more restricted b. Velocity in the narrow section is greater, because Q = Av is constant, so a smaller A causes a larger v	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Flow velocity is slower in a narrower section of pipe because the space is more restricted. b. At constant discharge, flow velocity is inversely related to cross-sectional area, following $Q = A_1v_1 = A_2v_2$, so a smaller cross-section produces a higher velocity. c. Flow velocity is the same everywhere in a pipe system as long as the water comes from the same source. d. Flow velocity depends on the pipe's material or color rather than its cross-sectional area.	B

No.	Sub-Concept / Indicator	Tier 1: Question and Answer Options	Tier 2: Confidence Scale	Tier 3: Reasoning Options	Key
		c. Velocity is the same in both sections, because they come from the same source d. Velocity depends on the pipe's color or material			
14	Discharge & Continuity Indicator: Calculate the change in flow velocity resulting from a change in pipe cross-sectional area at constant discharge	A well pump delivers water at a discharge of 2 liters/second through a pipe with a 4 cm^2 cross-section. If the pipe is replaced with one of 2 cm^2 cross-section without changing the pump's discharge, what happens to the flow velocity? a. Flow velocity becomes half of the original b. Flow velocity becomes twice the original c. Flow velocity is unchanged, because the discharge stays the same d. The discharge will automatically decrease by half	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Flow velocity is slower in a narrower section of pipe because the space is more restricted. b. At constant discharge, flow velocity is inversely related to cross-sectional area, following $Q = A_1v_1 = A_2v_2$, so a smaller cross-section produces a higher velocity. c. Flow velocity is the same everywhere in a pipe system as long as the water comes from the same source. d. Flow velocity depends on the pipe's material or color rather than its cross-sectional area.	B
15	Discharge & Continuity Indicator: Apply the continuity principle to a household water-distribution context	Two households in Majene use well-water distribution pipes of different diameters: House P uses a large-diameter pipe, House Q uses a small-diameter pipe, both connected to the same pump at constant discharge. Which statement is correct? a. Water flows faster at House P because its pipe is larger b. Water flows faster at House Q because the smaller cross-section produces a higher flow velocity at the same discharge c. Both houses receive the same flow velocity, because they come from the same pump d. The discharge at House Q is automatically smaller because its pipe is narrow	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Flow velocity is slower in a narrower section of pipe because the space is more restricted. b. At constant discharge, flow velocity is inversely related to cross-sectional area, following $Q = A_1v_1 = A_2v_2$, so a smaller cross-section produces a higher velocity. c. Flow velocity is the same everywhere in a pipe system as long as the water comes from the same source. d. Flow velocity depends on the pipe's material or color rather than its cross-sectional area.	B
16	Discharge & Continuity Indicator: Apply the continuity principle to explain the effect of tap opening size on flow velocity	When a household well-distribution tap is opened only partially (reducing the effective cross-section) while the pump continues operating at the same discharge, what happens to the velocity of the water jet from the tap? a. The jet velocity decreases b. The jet velocity increases, consistent with the continuity principle $Q = Av$ c. The jet velocity is unchanged	1 = guessing 2 = unsure 3 = sure 4 = very sure	a. Flow velocity is slower in a narrower section of pipe because the space is more restricted. b. At constant discharge, flow velocity is inversely related to cross-sectional area, following $Q = A_1v_1 = A_2v_2$, so a smaller cross-section produces a higher velocity. c. Flow velocity is the same everywhere in a pipe system as long as the water comes from the same source.	B

No.	Sub-Concept / Indicator	Tier 1: Question and Answer Options	Tier 2: Confidence Scale	Tier 3: Reasoning Options	Key
		d. The water stops flowing entirely		d. Flow velocity depends on the pipe's material or color rather than its cross-sectional area.	

Note: "Key" refers to the scientifically correct Tier-1 answer choice. In the Tier-3 reasoning sets, option (b) is the scientifically correct reasoning for every sub-concept; the correct combination for scoring as Scientific Understanding is therefore the answer matching the Key together with Tier-3 option (b) and a high (3–4) Tier-2 confidence rating. Combinations of Tier-1 answer, Tier-2 confidence, and Tier-3 reasoning are used to classify each response as Scientific Understanding, Misconception, Partial Understanding, or No Understanding, as described in Section 3.5.

The questionnaire uses a 4-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Agree, 4 = Strongly Agree). Negatively worded items are reverse-scored before computing indicator and cumulative means (see Table 5 for results).

Table 9. *Learning Interest Questionnaire Items by Indicator*

No.	Indicator	Item Statement	Polarity
1	Attention to physics learning	I pay close attention during physics lessons in class.	+
2	Attention to physics learning	I often lose focus or get distracted when the physics teacher is explaining a topic.	−
3	Interest in theoretical physics	I enjoy studying physics formulas and theoretical derivations.	+
4	Interest in theoretical physics	Learning abstract physics concepts without real-world examples feels boring to me.	−
5	Perceived relevance of physics to daily life	I feel that what I learn in physics class is connected to things I experience in daily life.	+
6	Perceived relevance of physics to daily life	I do not see any real connection between physics lessons and my everyday experience.	−
7	Interest in local coastal-context learning	I would be more interested in physics if it were taught using examples from our own coastal well water.	+
8	Interest in local coastal-context learning	I am not interested in learning physics through local coastal phenomena around Majene.	−

Item polarity: (+) positively worded, scored directly; (−) negatively worded, reverse-scored (5 minus raw score) before analysis.

The teacher needs questionnaire combines four closed statements (Agree/Disagree, summarized in Table 6) with an open-ended item, administered to all 5 physics teachers via total sampling.

Table 10. *Teacher Needs Questionnaire Closed and Open-Ended Items*

No.	Item Type	Item Statement / Question
1	Closed (Agree/Disagree)	New context-based physics teaching materials are needed to support Merdeka Curriculum implementation.
2	Closed (Agree/Disagree)	I experience difficulty independently designing contextual materials based on local phenomena.
3	Closed (Agree/Disagree)	Current textbooks do not adequately reflect Majene's local context.
4	Closed (Agree/Disagree)	The coastal well water physical-characteristics topic is feasible to integrate into senior high school physics.
5	Open-ended	What barriers, if any, do you face in developing or finding contextual physics teaching materials based on local phenomena? Please describe briefly.

Note: Items 1–4 match the indicators and Agree (%) results reported in Table 6 of the main text. Item 5 (open-ended) was analyzed qualitatively and triangulated with the literature review, as noted in Table 2.

Appendix B. Instrument Validation

Instrument validation was conducted to ensure that the diagnostic test accurately measured students' understanding of fluid mechanics concepts related to coastal well water. Content validity was assessed by three expert validators across four aspects: (A) alignment with learning objectives, (B) scientific accuracy, (C) fit with the sub-concept and misconception indicators, and (D) clarity of language. Ratings were assigned on a five-point scale (1 = poor to 5 = very good).

Table 11. *Expert Validation Scores per Item*

Item No.	V1	V2	V3	Aiken's V	Category
1	4	4	3	0.67	Valid
2	4	4	4	0.75	Valid
3	4	4	4	0.75	Valid
4	4	4	4	0.75	Valid
5	4	3	4	0.67	Valid
6	4	4	4	0.75	Valid
7	4	4	4	0.75	Valid
8	4	4	4	0.75	Valid
9	4	4	3	0.67	Valid
10	4	4	4	0.75	Valid
11	4	4	4	0.75	Valid
12	4	4	4	0.75	Valid
13	4	4	3	0.67	Valid
14	4	4	4	0.75	Valid
15	4	4	4	0.75	Valid
16	4	4	4	0.75	Valid

Aiken's V is computed per item, where s is the rater's score minus the lowest possible score, n is the number of raters (3), and c is the number of rating categories (5). The average Aiken's V across all 16 items is 0.73, categorized as Valid ($0.60 \leq V < 0.80$).

Appendix B. Learning Interest Questionnaire

The tables below mirror the item-level Aiken's V format used in Appendix B (Table 11) for the diagnostic test, extended to the Learning Interest Questionnaire and Teacher Needs Questionnaire. Item text is pre-filled from Appendix A; validator scores (V1–V3, on a 1–5 rating scale) and the resulting Aiken's V and category reflect the authors' expert-validation data.

Table 12. *Item-Level Validation — Learning Interest Questionnaire*

No.	Item	V1	V2	V3	Aiken's V	Category
1	I pay close attention during physics lessons in class.	4	4	4	0.75	Valid
2	I often lose focus or get distracted when the physics teacher is explaining a topic.	4	4	3	0.67	Valid
3	I enjoy studying physics formulas and theoretical derivations.	4	3	4	0.67	Valid
4	Learning abstract physics concepts without real-world examples feels boring to me.	4	4	4	0.75	Valid
5	I feel that what I learn in physics class is connected to things I experience in daily life.	4	4	3	0.67	Valid
6	I do not see any real connection between physics lessons and my everyday experience.	3	4	4	0.67	Valid
7	I would be more interested in physics if it were taught using examples from our own coastal well water.	4	3	4	0.67	Valid
8	I am not interested in learning physics through local coastal phenomena around Majene.	4	4	4	0.75	Valid

Table 13. *Item-Level Validation — Teacher Needs Questionnaire (Closed Items)*

No.	Item	V1	V2	V3	Aiken's V	Category
1	New context-based physics teaching materials are needed to support Merdeka Curriculum implementation.	4	3	4	0.67	Valid
2	I experience difficulty independently designing contextual materials based on local phenomena.	4	4	4	0.75	Valid
3	Current textbooks do not adequately reflect Majene's local context.	4	3	4	0.67	Valid
4	The coastal well water physical-characteristics topic is feasible to integrate into senior high school physics.	4	4	3	0.67	Valid

The average Aiken's V for the Learning Interest Questionnaire (8 items) is 0.70, and for the Teacher Needs Questionnaire (4 items) is 0.71; both fall in the Valid category.