Profiling Problem-Solving Skills in Physics Among Pre-Service Science Teachers: A Baseline Assessment

Crisostomo C. Canencia, Ph.D

***Abstract* - This study assessed pre-service science teachers' baseline problem-solving skills in fluid mechanics before implementing the PSISLI model. Thirty-six participants completed a diagnostic test on Archimedes', Pascal's, and Bernoulli's principles. Most items were difficult ($p \leq 0.40$), with the weakest performance in logical progression and consistently low scores in concept identification and equation formulation. Moderate mathematical skills did not offset deeper conceptual gaps. Overall, results show low to moderate readiness, underscoring the need for structured, scaffolded instruction such as PSISLI.**

***Keywords* - Fluid Mechanics, Pre-Service Science Teachers, Problem-Solving Skills, Conceptual Understanding, Diagnostic Assessment, Difficulty Index, Foundational Knowledge and Skills**

I. Introduction And Literature Review

Physics is one of the most conceptually demanding areas of science education, requiring the integration of mathematical reasoning, conceptual understanding, and analytical thinking (Hestenes, 2015; McDermott, 2001). For preservice teachers, strong problem-solving competence is essential for explaining complex ideas, anticipating misconceptions, and designing inquiry-based instruction (Singh, 2008). Yet most research has focused on conceptual understanding or pedagogical knowledge (McDermott & Redish, 1999; Shulman, 1986), leaving limited evidence on preservice teachers' performance across multiple cognitive domains (Reif, 2008).

Profiling offers a systematic way to examine competencies such as conceptual understanding, procedural fluency, analytical reasoning, critical thinking, and transfer of learning (Halpern, 2014; Bransford et al., 2000), but it has rarely been applied to physics problem solving—especially among preservice educators. This study addresses this gap by profiling their problem-solving skills in Fluid Mechanics, specifically Archimedes', Pascal's, and Bernoulli's principles, using non-routine, context-rich problems to inform curriculum refinement and targeted interventions in STEM teacher preparation.

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Literature Review. The key constructs underlying physics problem-solving among future science educators—conceptual understanding, procedural fluency, analytical reasoning, critical thinking, and transfer of learning. Research consistently shows that preservice teachers hold persistent misconceptions (Kaltakci Gurel et al., 2017; Madsen et al., 2017; Henderson et al., 2017) and require targeted conceptual-change approaches to build coherent understanding (Susanti & Suhandi, 2020). Studies on procedural fluency reveal heavy reliance on algorithmic manipulation with limited conceptual grounding (Caballero et al., 2015; Kim & Pak, 2002; Tuminaro & Redish, 2007), underscoring the need for flexible, principle-based skills. Analytical reasoning is strongly linked to success in physics tasks (Ding & Mollohan, 2019) and can be strengthened through modeling, representation, and argument-driven inquiry (Sikorski & Hammer, 2017; Suwono et al., 2021; Kurnaz & Çepni, 2021). Critical thinking likewise improves through explicit instruction and physics-based argumentation (Tiruneh et al., 2016; Bezanilla et al., 2019; Snyder & Snyder, 2020). Finally, transfer of learning requires adaptive expertise and representation fluency (Barnett & Ceci, 2002; Bransford & Schwartz, 1999; Lobato, 2006; Rebello et al., 2007). Together, these studies highlight the need for intentional, research-aligned approaches to develop the full spectrum of problem-solving competencies in preservice physics teachers.

II. Main Objectives Of The Study

The study aims to determine pre-service science teachers' foundational knowledge and conceptual understanding in physics problem solving, focusing on how well they grasp core principles and representations needed for effective reasoning. It also assesses their procedural and mathematical skills, including equation use, identification of known and unknown quantities, and execution of logical solution steps.

Finally, the study profiles their overall problem-solving performance by examining difficulty indices, error patterns, and areas of strength and weakness across physics principles, providing diagnostic insights into misconceptions and competencies that require targeted instructional support.

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III. Methodology

The baseline assessment was conducted to determine the foundational knowledge and skills in physics problem solving among pre-service science teachers prior to the implementation of the intervention. A one-group pretest design was used, with a researcher-developed performance-based task evaluated through an analytic rubric.

Participants: Thirty-six ((N = 36)) pre-service science teachers enrolled in a physics-related course. They completed the baseline task individually under standard classroom conditions.

A. Instrument and Scoring Procedure

The baseline assessment consisted of structured physics problem-solving tasks measuring both conceptual and procedural skills, evaluated through an analytic rubric covering useful description, physics approach, specific application, equation use, foundational mathematical skills, and logical progression. Each indicator was scored on a three-point scale (High, Moderate, Low), and mean scores for all 36 participants were converted into index ratings classified as Very Good, Good, Fair, or Poor.

B. Data collection procedure

The pretest was administered at the beginning of the term, before any exposure to the PSISLI instructional model or other targeted problem-solving interventions. Clear instructions and sample items were provided to ensure that students understood the format and expectations. All answer sheets were collected immediately after the allotted time and tallied anonymously for scoring.

C. Data Analysis

Descriptive statistics were used to analyze the baseline data by computing mean scores for each criterion, generating index ratings to standardize performance, and assigning interpretive labels (High, Moderate, Low, with tags such as M/F, L/F, M/VG) based on predefined cut-off values.

Results

IV. Data Presentation, Results And Discussion

The table below shows the pre-test frequency and statistical measures of instructional material evaluation

TABLE I: PRE-TEST FREQUENCY AND STATISTICAL MEASURES OF INSTRUCTIONAL MATERIAL EVALUATION

Criteria	Mean	Index	Interpretation
1. Useful description	1.75	0.58	M/G
2. Physics approach	1.25	0.42	MF
3. Specific application of Physics	1.28	0.43	M/F
4. Physics equation	1.08	0.36	M/F
Foundational Knowledge and mathematical skills processes			
· Given identification	1.72	0.49	M/F
· Transposition	1.00	0.33	M/F
· Derivation formula	0.97	0.33	L/F
· Unit identification	1.06	0.34	M/F
· Unit cancellation and extraction	0.97	0.33	L/F
· Concept relation	0.36	0.34	L/F
· Equation translation into words	2.72	0.75	M/VG
· Sign rule	1.53	0.44	M/F
· Unit conversion	1.03	0.34	M/F
· Scientific Notation	1.00	0.34	M/F
· Simple Mathematical operation	1.25	0.41	M/F
6. Logical progression	0.91	0.34	F/M
Overall	1.03	0.49	F/M

Students show **developing but insufficient proficiency**, with strengths in descriptive and verbal tasks but notable weaknesses in equation formulation, mathematical fluency, and logical reasoning—highlighting the need for targeted instructional support.

TABLE II: PRE TEST DIFFICULTY ITEM ANALYSIS TABLE AMONG PRE SERVICE SCIENCE TEACHERS

Item	Description	Difficulty Index	
		$\sum x_i$	Interp.
1	Archimedes problem sketch formulation	0.28	D
2	Archimedes concepts and principles involve in the problem	0.19	D
3	Archimedes principle resolving the problem with the known and unknown identification	0.17	D
4	Archimedes formulation of Physics Equation	0.36	M
5	Archimedes correct translation of equation into words	0.75	E
6	Archimedes mathematical procedure using the equation	0.28	D
7	Archimedes mathematical procedure using the equation	0.67	M
8	Archimedes mathematical procedure using the equation	0.25	D
9	Archimedes mathematical procedure using the equation	0.19	D
10	Archimedes logical progression	0.03	D
11	Pascal principle problem sketch formulation	0.14	D
12	Pascal's concepts and principles involve in the problem	0.08	D
13	Pascal's principle resolving the problem with the known and unknown identification	0.14	D
14	Pascal's formulation of Physics Equation	0.00	D
15	Pascal's principle correct translation of equation into words	0.36	M
16	Pascal's mathematical procedure using the equation	0.44	M
17	Pascal's mathematical procedure using the equation	0.06	D
18	Pascal's mathematical procedure using the equation	0.58	M
19	Pascal's mathematical procedure using the equation	0.58	M
20	Pascal's logical progression	0.06	D
21	Bernoulli's principle problem sketch formulation	0.31	M
22	Bernoulli's concepts and principles involve in the problem	0.06	D
23	Bernoulli's principle resolving the problem with the known and unknown identification	0.19	D
24	Bernoulli's principle in formulation of Physics Equation	0.42	M
25	Bernoulli's principle correct translation of equation into words	0.33	M
26	Bernoulli's mathematical procedure using the equation	0.36	M
27	Bernoulli's mathematical procedure using the equation	0.25	D
28	Bernoulli's mathematical procedure using the equation	0.25	D
29	Bernoulli's mathematical procedure using the equation	0.06	D
30	Bernoulli's principle logical progression	0.06	D

Table 2 tabulates pre-posttest item analysis Table 2 shows that pre-service teachers exhibit low to moderate mastery of foundational physics problem-solving skills. The overall mean of 0.38 (Index 0.41, Low/Fair) indicates substantial difficulty applying concepts, equations, and mathematical procedures.

Students performed best in Useful Description (Moderate/Good), showing some ability to visualize and describe problem situations. However, Physics Approach, Specific Application, and Physics Equation skills remained Moderate/Fair, reflecting challenges in selecting principles and formulating equations.

Most foundational mathematical skills were also Moderate/Fair, though several—such as formula derivation and unit cancellation—fell into Low/Fair, indicating weak symbolic manipulation. Only Equation Translation into Words showed stronger performance (Moderate/Very Good).

The lowest scores occurred in Logical Progression, revealing gaps in reasoning, justification, and evaluating solutions. Overall, the results indicate developing but insufficient proficiency, with strengths in description and verbal explanation but significant weaknesses in conceptual application, mathematical fluency, and logical reasoning.

TABLE III: PRE-TEST FREQUENCY AND STATISTICAL MEASURES OF INSTRUCTIONAL MATERIAL EVALUATION

Score Range	(f)	(%)	(μ)	(□)
25 -30 (Excellent)	0	0		
19 - 24 (Very Good)	0	0		
13 – 18 (Good)	3	8%		
7 - 12 (Fair)	22	61%	7.89	2.78
0- 6(Needs Improvement)	11	31%		
Total /Overall	36	100		

Table 3 shows that most respondents scored in the Fair range, indicating limited mastery of the assessed competencies. No student reached the Excellent or Very Good categories, while only 8% performed at the Good level. A substantial 31% fell under Needs Improvement, reflecting significant difficulty with the tasks. The overall mean score of 7.89 (SD = 2.78) places the group firmly in the Fair category, with wide score variation. Overall, the results indicate generally low to moderate proficiency and highlight the need for strengthened instruction and targeted support.

V. Discussion

The low difficulty indices across Archimedes', Pascal's, and Bernoulli's principles reflect well-documented challenges in fluid mechanics learning. Persistent misconceptions—such as misunderstanding buoyant force (Trowbridge & McDermott, 1980) and difficulty applying Archimedes' principle (Loverude et al., 2003)—align with low concept-identification scores. Similar patterns in Pascal's principle, including confusion between pressure and force (Barbosa et al., 2004) and weak understanding of hydraulic relationships (Kautz et al., 2005), match the near-zero indices for equation formulation. Misconceptions in Bernoulli's principle (Singh, 2005; Sozbilir, 2004) parallel students' difficulty identifying variables and interpreting flow conditions.

Weak equation formulation, especially in Pascal's principle, is consistent with findings that students memorize formulas without understanding their physical meaning (Redish, 2005) and lack symbolic-mapping skills (Sherin, 2001). Low scores in sketches and known–unknown identification reflect novice difficulties in problem representation (Larkin et al., 1980; Heller & Reif, 1984). Moderate procedural fluency alongside poor conceptual performance mirrors earlier evidence that students can compute without understanding (Reif & Heller, 1982; Kim & Pak, 2002). The lowest indices in logical progression echo research showing fragmented reasoning and surface-feature categorization (Chi et al., 1981) and the need for structured problem-solving frameworks (Heller et al., 1992).

Overall, the results align with extensive literature showing that preservice teachers struggle with conceptual reasoning, symbolic formulation, and coherent problem-solving strategies in fluid mechanics.

VI. CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

A. Conclusion

The baseline assessment revealed that pre-service science teachers possess limited foundational knowledge and weak problem-solving skills in fluid mechanics, particularly in conceptual understanding, equation formulation, known–unknown identification, and logical progression. Difficulty indices across the 30 items showed that most concepts—especially Pascal's and Bernoulli's principles—were classified as very difficult, indicating pervasive misconceptions and fragmented reasoning. While some procedural skills were moderately demonstrated, these were insufficient to compensate for deeper conceptual gaps. Overall, the results confirm that learners enter instruction with low to moderate readiness for physics problem solving, underscoring the need for structured, scaffolded, and conceptually oriented teaching approaches such as the PSISLI instructional model.

B. Implications

The findings underscore the need for instructional designs that deliberately build conceptual understanding, representation skills, and stepwise reasoning, making models like PSISLI—grounded in structured inquiry and logical sequencing—highly relevant. Strengthening teacher preparation is equally critical, as pre-service teachers require deeper physics content knowledge and explicit problem-solving frameworks to enhance their pedagogical content knowledge. The prevalence of misconceptions also highlights the need to improve assessment practices by incorporating diagnostic tools such as four-tier tests to monitor conceptual change. Finally, curriculum development in fluid mechanics should emphasize conceptual coherence, multiple representations, and real-world applications to reduce cognitive load and address persistent misconceptions.

C. Recommendations

Future research should examine how preservice teachers' conceptual understanding develops over time, compare PSISLI with other research-based strategies such as Modeling Instruction, Peer Instruction, and Tutorials in Introductory Physics, and use qualitative methods like interviews or think-alouds to uncover reasoning patterns behind errors. Expanding diagnostic assessments to other physics domains and exploring technology-enhanced interventions such as simulations or virtual labs may further strengthen learning. These directions align with long-standing recommendations to scaffold conceptual understanding (McDermott, 1991), emphasize representation and reasoning (Van Heuvelen, 1991), integrate metacognitive monitoring (Schoenfeld, 1985), and promote structured problem-solving strategies (Heller & Heller, 1995). Collectively, they reinforce PSISLI's relevance and validate the difficulty-index findings, which mirror decades of evidence on persistent conceptual, representational, and reasoning challenges in fluid mechanics.

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