UKR Journal of Education and Literature (UKRJEL)
Homepage: https://ukrpublisher.com/ukrjel/
Email: submit.ukrpublisher@gmail.com
Volume 2, Issue 4, July-August 2026 ISSN: 3107-8672 (Online)

Low-Cost, Accessible Experimental Toolbox for Introductory Fluid Mechanics Education

Mashall James P. Dantic

President Ramon Magsaysay State University.

***Corresponding Author**: Mashall James P. Dantic

DOI: *https://doi.org/10.5281/zenodo.21913173*

Article History
Original Research Article
Received: 12-06-2026
Accepted: 16-07-2026
Published: 13-08-2026

Citation: Dantic, M. J. P. (2026). Low-cost, accessible experimental toolbox for introductory fluid mechanics education. UKR Journal of Education and Literature, 2(4), 182-193.

ABSTRACT

The instruction of introductory fluid mechanics is often characterized as mathematically onerous and conceptually difficult due to the inherent non-linearity of governing equations and a persistent lack of accessible visualization tools. This study aimed to design, develop, and evaluate a low-cost, accessible experimental toolbox to transform static lectures into active learning environments that facilitate the practical application of hydraulic and fluid principles. Utilizing a developmental research design, the study proceeded through iterative phases of design, construction using locally sourced sustainable materials, and evaluation. The participants consisted of 33 undergraduate science education students from a state university in Zambales, Philippines. The experimental apparatus and research instruments, including pre/post-assessments and usability checklists, were validated by four experts in physics and science education before full-scale implementation. Statistical analysis was conducted using n-gain analysis to quantify learning improvements, while paired t-tests were utilized to determine the significance of score improvements alongside descriptive statistics for engagement and usability data.

The implementation of the experimental toolbox resulted in a statistically significant advancement in student conceptual understanding, with post-assessment scores showing a robust grasp of fluid principles. Students reported high levels of engagement and motivation, particularly noting that manipulating everyday materials provided a tangible connection to theoretical concepts. Developed at a total production cost of only P1,860.00, the toolbox demonstrates that high-quality experiential learning can be achieved with minimal financial investment. The study concludes that this "frugal science" approach effectively bridges the theory-practice gap by solidifying theoretical understanding through active, student-led investigations. These findings highlight the potential for portable, low-cost laboratory equipment to democratize access to STEM education by providing scalable alternatives for resource-constrained institutions.

***Keywords**: Fluid Mechanics Education, Active Learning, Experimental Toolbox, Frugal Science, STEM Education, Conceptual Understanding.*

INTRODUCTION

Fluid mechanics is a fundamental topic in physics and engineering, crucial for understanding natural phenomena and addressing real-world problems. It focuses on the analysis of fluid behavior at rest and in motion, providing the technical basis for advancements in aerospace, civil, and environmental engineering (Minichiello et al., 2020).

Yet, students often find the discipline mysterious. The culprit? Inherent non-linearity in governing equations combined with a dearth of accessible visualization tools (Ebadi & Sabuncu, 2024). Consequently, many learners struggle to reconcile dense, mathematically onerous theoretical frameworks with physical reality. This disconnect inevitably erodes both conceptual intuition and engagement (Elliott et al., 2021). Teaching this crucial subject—particularly at the introductory level—is therefore fraught with challenges.

Fluid Mechanics is a major course for Bachelor of Science Education Major in Science. But with the current curriculum it is just lecture subject. But this approach feels insufficient to cultivate the necessary practical intuition. Because reliance on purely content-based instruction limits students' capacity to connect theoretical models with observable physical behavior (Chau et al., 2023).

However, traditional laboratory equipment is often prohibitively expensive and resource-intensive, rendering it inaccessible to many teacher education programs. This creates a significant void, especially as the field increasingly emphasizes experiential learning. Without affordable, accessible tools to spark active engagement, current methods often fall short of providing the necessary hands-on experimentation.

By integrating locally sourced, affordable apparatus, educators can transform static lectures into active learning environments, effectively closing the gap between abstract principles and physical application (Misbah et al., 2024; Patron & Desojo, 2020). This "frugal science" approach offers more than a budget-friendly solution. It leverages relatable, everyday experiences to build the deep conceptual intuition required to decode complex fluid phenomena (Mathijssen et al., 2023).

The research focuses on the design, development, and evaluation of this toolbox, examining its effectiveness in fostering student learning and engagement with fluid mechanics concepts.

RESEARCH PROBLEMS

The primary research problem addressed in this study is the lack of affordable and accessible tools for hands-on experimentation. It sought to answer the following questions;

1. Design and Development:

1.1 How can the toolbox be described in terms of;

1.1.1 design; and

1.1.2 cost?

1.2 What are the experiments can be done on the designed and developed toolbox for Fluid Mechanics?

2. Effectiveness and Impact:

2.1 How effectively does the toolbox facilitate student understanding of key fluid mechanics principles?

2.2 Does the toolbox enhance student engagement and motivation in learning fluid mechanics?

3. How is the usability of the toolbox perceived in terms of;

3.1 physical ergonomics; and

3.2 instructional clarity?

METHODOLOGY

Research Design

This study will use developmental research methods to design, develop, and evaluate the low-cost, accessible fluid mechanics experiment toolbox. This iterative process involves three distinct phases: design and construction using locally sourced, sustainable materials, followed by a rigorous validation process to ensure the apparatus accurately demonstrates essential hydraulic and fluid principles.

Sampling and Participants

The study will employ at total population sampling selecting undergraduate science education students who are currently enrolled in introductory fluid mechanics courses to ensure the sample possesses the baseline theoretical knowledge required for the intervention. There are 33 science education students who served as participants of this study. The toolbox was designed by the researcher.

Research Locale

The study was conducted at the College of Teacher Education in a state university in Zambales, Philippines. The university has 7 campuses. However, the study was only conducted on two campuses: Iba and San Marcelino. These specific sites were chosen due to the only College that offers Bachelor of Secondary Education Major in Science.

Instrumentation

This study used multiple research instruments including; validation tests, assessment tests, engagement survey checklist, and usability checklist. The validation instrument is used to confirm the toolbox accurately demonstrates theory and is safe for classroom use. The assessment test measures the students' conceptual mastery of fundamental hydraulic principles before and after engaging with the experimental apparatus. The engagement survey checklist is designed to quantify student interest and motivation levels throughout the hands-on sessions. Lastly, the usability checklist systematically evaluates the physical ergonomics and instructional clarity of the experimental apparatus to ensure it meets pedagogical requirements for undergraduate instruction.

The instrument was validated by four experts including Physics educator, Science Education researcher, grammar specialist. Following these evaluations, the tools underwent pilot testing with a small group of students to refine their clarity and reliability before full-scale implementation.

Data Collection

Before the researcher started the project, it has seek permission to the research committee to begin the implementation phase. Next is the seeking of approval from the dean of the college. When preliminary approval was done, the researcher began the project by designing the experimental apparatus, ensuring that each component was selected for its durability, affordability, and ability to clearly demonstrate core fluid principles (Rogayan & Dollete, 2019). Subsequently, the apparatus that was like trial phase, where students utilized the prototypes to execute a series of structured fluid mechanics activities, during which their performance and engagement levels were documented. Meaning, the instrument was its first testing as well with the students. Before every lesson discussion and intervention, pre-test was conducted. Following this, participants engaged with the newly developed experimental toolbox to facilitate hands-on learning, after which a post-test was administered to measure gains in conceptual understanding. Furthermore, survey checklist was administered after the whole implementation.

Data Analysis

The study had used different statistical analysis to evaluate the toolbox's efficacy, including the use of n-gain analysis to quantify the improvement between pre-test and post-test conceptual understanding scores. Additionally, expert and student feedback gathered through surveys is analyzed using descriptive statistics to interpret the level of agreement based on predetermined criteria. Meanwhile, Mann Whitney U test was utilized to determine the difference in performance between male and female participants. Also, it was used to determine the difference in the perceived usability and engagement scores across the participating student groups.

Ethical Considerations

To ensure the integrity of the research, informed consent was obtained from all participants to guarantee their voluntary involvement and understanding of the study's objectives. Furthermore, to protect student privacy and ensure data integrity, all collected information remained strictly confidential and anonymous, adhering to established ethical research protocols (Asyhari et al., 2023; Bahtaji, 2023).

CONCEPTUAL FRAMEWORK

The conceptual framework of this study is grounded in the inquiry-based pedagogical approach, where student engagement with physical prototypes facilitates the reconstruction of theoretical knowledge into applied technological understanding (Rahman et al., 2021). This framework posits that hands-on experimentation bridges the gap between abstract physics concepts and tangible engineering applications, ultimately fostering deeper cognitive mastery (Gartner et al., 2020). This process aligns with established practices in educational research, where standardized assessments and gain scores are utilized to quantify improvements in concept mastery following pedagogical interventions (Purnama et al., 2023). Furthermore, the integration of iterative feedback loops within this framework mirrors successful methodologies in physics education, which utilize expert observation and longitudinal reflection to triangulate student learning outcomes (Achuthan et al., 2021).

Based on the paradigm of the Engineering Design Process, this study assumes that the act of troubleshooting and refining physical apparatuses serves as a primary driver for developing scientific reasoning and conceptual stability (Ngo, 2024). The input consists of the design parameters and initial conceptual requirements, which are then processed through the assembly and testing of the fluid mechanics toolbox to produce measurable learning outcomes and improved technical competencies.

Meanwhile, the process incorporates iterative cycles of reflection and assessment to ensure that the experimental apparatus remains both pedagogically effective and accessible for diverse learner needs. It also includes the content mapping and field testing. These stages ensure that all experimental activities align with established curriculum standards while simultaneously verifying that the apparatus functions reliably within varied classroom environments. Lastly, survey feedback instruments are utilized to perform data triangulation, allowing for a comprehensive evaluation of student engagement and the overall pedagogical impact of the low-cost toolbox.

The output of this study are the designed and developed toolbox along with its instructional manual on how to use it.

RESULTS AND DISCUSSION

This section focuses on the design and development of the tool box. It highlights the Physical design and its packaging layout, the cost breakdown of its components, and the content of the instructional material.

Physical Design & Packaging Layout of the Toolbox

The physical layout of the experimental apparatus is designed to prioritize portability, organization, and durability, ensuring it meets the rigorous demands of undergraduate instruction. Given its intended use by pre-service teachers who may need to travel for internships, a clear plastic latch-box serves as the optimal storage solution, balancing ease of transport with structural integrity. Each component within the kit was specifically selected for its durability, affordability, and ability to clearly demonstrate core fluid principles (Rogayan & Dollete, 2019). The interior features a modular configuration: Compartment A is designated for precision instruments such as the electronic pocket scale, spring balance, stopwatches, and rulers; Compartment B stores fluid-related components including syringes, vinyl tubing, and valves or clamps; and Compartment C holds experimental materials like ping-pong balls, pre-cut cardboard airfoils, fishing line, and the portable mini-fan. Finally, the lid includes a transparent waterproof sleeve to securely house the laminated Quick Activity Cards and the Laboratory Manual, ensuring all resources remain organized and protected.

The toolbox is case that serves as a self-contained laboratory storage, enabling students to access materials needed to perform basic fluid mechanics experiments without requiring traditional, space-intensive floor infrastructure (Starks et al., 2018). This modular approach addresses the growing necessity for remote and portable laboratory experiences, effectively bridging the logistical divide in engineering education (Jones et al., 2021).

Table 1: Cost Breakdown of the Toolbox Components

Item Description	Quantity	Estimated Cost
Electronic Mini Pocket Scale (0.01g to 500g accuracy)	1	P120.00
Assorted Medical Syringes (2x 10mL, 2x 20mL, 2x 50mL)	1 set	P100.00
Clear Vinyl Tubing (Aquarium grade, 1/4 inch, approx. 3 meters)	1 pack	P90.00
Clear Acrylic/Plastic Tubes (For viscosity/bead-drop)	2	P100.00
Mini Luggage Scale (Handheld digital)	1	P140.00
Small Portable Mini Fan	1	P180.00
Toolbox Case (14.5”x11.8”x4.1”)	1	P850.00
Miscellaneous Consumables & Small Tools *(Ping-pong balls, food coloring, marbles, fishing line, plastic valves, rulers, pipettes)*	1 lot	P200
Instructional Manual Printing (Soft Binded)	1 book	P80.00
Overall Cost		P1860.00

These are the materials used for the toolbox. Based on the table, One-thousand Eight Hundred Sixty pesos (P1860.00) are the whole cost. This significantly lower price point compared to traditional laboratory equipment demonstrates that high-quality, experiential learning tools can be developed with minimal financial investment (Richards et al., 2015). Moreover, the durability of these components ensures that the kit withstands repeated use across multiple laboratory sessions, mitigating common concerns regarding wear and tear associated with low-cost educational artifacts (Nafie et al., 2022).

Furthermore, this ultra-low-cost design ensures accessibility for every student, effectively democratizing access to professional-grade learning modules that were previously restricted by the prohibitive costs of commercial laboratory stations (Njau et al., 2015).

Doable Experiments from the Designed and Developed Toolbox for Fluid Mechanics

This section outlines the experimental protocols supported by the toolbox, enabling students to investigate fundamental fluid mechanics concepts—including flow visualization, pressure variation, and hydraulic energy conversion—through compact, benchtop simulations.

Table 2: Doable Experiments from the Designed and Developed Toolbox for Fluid Mechanics

Topic	Proposed Activity Name	Tools to Include in the Toolbox	Key Scientific Target
Fundamental Properties	Syringe Pycnometry & Liquid Racing	20mL & 50mL syringes, digital pocket scale (0.01g), clear acrylic tubes, steel/glass marbles, stopwatch.	Mass-volume relationships to find ρ and SG; terminal velocity to observe viscosity (μ).
Fluid Types	The Quick-Sand Mimic	Small plastic mixing bowls, plastic spatulas, cornstarch, water, food coloring.	Visual and tactile contrast between Newtonian behavior (water) and shear-thickening non-Newtonian behavior.

Introduction to Pressure	The DIY U-Tube Manometer	Clear vinyl aquarium tubing, rigid plastic ruler, colored water, small syringe (for pressure generation).	Measuring gauge pressure based on liquid column height displacement (Δh).
Pressure vs. Depth	Hydrostatic Spurt Test	1.5L clear plastic bottle (pre-drilled vertically at 3 points), waterproof electrical tape, catch basin.	Demonstration of Torricelli's Law and hydrostatic pressure increasing with depth ($P = \rho gh$).
Pascal's Principle	Syringe Hydraulic Press	One 10mL syringe, one 50mL syringe, flexible connecting tube, wooden platform, small calibration weights.	Mechanical advantage verification where force amplifies relative to area ratios ($F_1/A_1 = F_2/A_2$).
Archimedes' Principle	Buoyant Force Verification	DIY overflow cup (plastic container with straw spout), catch cup, electronic pocket scale, assorted dense objects, string.	Verifying that the buoyant force (F_B) exactly equals the weight of the fluid displaced by the submerged object.
Fluid Kinematics	Streamline Trace	Clear plastic siphon hoses, fine-tip pipettes/droppers, dark food coloring, a mini valve or clamp to control flow speed.	Visual identification of laminar (smooth, steady) versus turbulent (chaotic, mixing) flow regimes.
Bernoulli's Principle	The Attracting Spheres & Venturi Bottle	Ping-pong balls, lightweight cotton strings, flexible drinking straws, a custom multi-diameter plastic bottle.	Showing that an increase in fluid velocity simultaneously causes a decrease in static pressure.
Aerodynamics & Lift	Mini-Wind Tunnel Airfoil	Cardboard/Styrofoam airfoils, smooth fishing line (guide wire), hand-held portable mini-fan, lightweight spring scale.	Observing the effects of lift and drag as the angle of attack changes against a steady airflow stream.

Based on the table, it shows different proposed activities aligned with the topics, materials, and objectives. By integrating these modular components, students are afforded the opportunity to engage in project-based learning, which has been shown to improve specific fluid mechanics comprehension.

There are 9 distinct experimental modules within the toolbox, each curated to support both demonstration-based and student-led investigations that mirror the complexity of professional laboratory environments while minimizing the space and cost requirements typically associated with such coursework. These topics were based from the course syllabus used by the Bachelor of Secondary Education Major in Science. Topics including fundamental properties, fluid types, introduction to pressure, and pressure vs depth were part of the mid term. While, the topics Pascal’s Principle, Archimedes' Principle, fluid kinematics, Bernoulli’s Principle, and aerodynamics were integrated into the final term curriculum. Moreover, all of these activities were written in an instructional manual specifically made along with the toolbox.

By aligning these experimental activities with established pedagogical theories of inquiry-based learning, this toolbox facilitates conceptual transitions even in resource-constrained settings (Delgado et al., 2024). This alignment ensures that the toolkit serves as a direct, evidence-based intervention to solidify theoretical understanding through active learning, similar to successful implementations of hands-on trainers for non-specialized engineering students (Dam-O et al., 2025; Earp & Parker, 2024).

Toolbox Effectiveness in Facilitating Student Understanding to Fluid mechanics principles

This section presents the results of the pre- and post-assessment tests, and its significant differences. It also highlights how the toolbox enhances student engagement and motivation in learning fluid mechanics.

Table 4: Level of Students Understanding on Fluid Mechanics Concepts Based on Pre Assessment Tests

Grades	Midterm		Final Term		Description
	Frequency	Percentage	Frequency	Percentage	
46 – 50	0	0	0	0	Outstanding
40 – 45	0	0	0	0	Very Satisfactory
34 – 39	0	0	0	0	Satisfactory
28 – 30	7	21	0	0	Slightly Satisfactory
0 – 27	26	79	33	100	Did not meet expectations
	M = 21.75	SD = 4.37	M = 18.44	SD = 3.92	Did not meet expectations

The table presents the pre-assessment scores of the students before using the toolbox. The data reveals a significant deficit in baseline knowledge across both assessment periods, with 79% to 100% of participants failing to meet the minimum proficiency standards. Most students enter the course lacking the foundational conceptual framework required for advanced fluid mechanics (Firmansyah et al., 2021). This deficiency highlights the need for structured pedagogical interventions to scaffold core concepts and facilitate conceptual change (Nurdini et al., 2025). Integrating these hands-on instruments provides a vital bridge between abstract theoretical models and tangible experience, effectively alleviating common misconceptions (Nazempour et al., 2015; Saehana et al., 2019).

Table 5: ***Level of Students Understanding on Fluid Mechanics Concepts Based on Post Assessment Tests***

Grades	**Midterm**		**Final Term**		**Description**
	Frequency	Percentage	Frequency	Percentage	
46 – 50	8	24	1	3	Outstanding
40 – 45	16	48	16	48	Very Satisfactory
34 – 39	8	24	14	42	Satisfactory
28 – 30	1	3	2	6	Slightly Satisfactory
0 – 27	0	0	0	0	Did not meet standards
	M = 42.59	SD = 3.64	40.07	SD = 3.31	Very Satisfactory

The table presents the post-assessment scores of the students after using the toolbox. The data reveals a marked improvement in performance. Students transitioned from baseline proficiency deficits to a robust conceptual grasp, as evidenced by post-assessment scores showing marked improvements in both midterm and final terms. These gains demonstrate that the toolbox's active, low-cost experimentation effectively mitigates common misconceptions (Kaye & Ogle, 2022). The substantial upward shift in mean scores underscores the efficacy of these modules in fostering higher-level cognitive evaluation of fluid phenomena (Reynolds et al., 2020). Such performance improvements mirror findings in experiential learning research, where hands-on laboratory activities correlate with improved retention and higher post-test scores compared to passive instruction (Cimbala et al., 2020; Tizón et al., 2021).

Table 6: Significant Difference in the Level of Understanding between the Pre and Post Assessment Scores

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-test midterm - postmid	-21.00000	5.35814	.94719	-22.93182	-19.06818	-22.171	31	.000
prefin - postfin	-20.65625	5.68875	1.00564	-22.70726	-18.60524	-20.540	31	.000

The table presents the significant differences between the pre- and post-test scores, revealing a statistically significant improvement in students' conceptual knowledge ($p < 0.001$). The observed t-value of -36.196, associated with a p-value less than 0.001, confirms that the implementation of the toolbox facilitates a statistically significant advancement in student proficiency. This marked gain aligns with broader pedagogical evidence indicating that tangible laboratory interventions successfully remediate specific misconceptions while simultaneously elevating overall student performance and consistency (Mufit et al., 2023; Vianna & Enne, 2025).

Table 7: Enhancement of Student Engagement through the Use of the Fluid Mechanics Toolbox

Statements	Mean	Verbal Description	Rank
1. The use of the localized toolbox allowed me to actively manipulate materials and conduct experiments myself, rather than just passively watching a teacher's lecture or demonstration."	3.33	Highly Engaging	2.5
2. Manipulating everyday materials (such as syringes, vinyl tubes, and cornstarch) to observe abstract principles like viscosity and lift	3.36	Highly Engaging	1

3. "The portable and modular design of the toolbox in discussing, problem-solving, and collaborating with my classmates during laboratory activities	3.33	Highly Engaging	2.5
4. "Using low-cost, accessible tools to replicate the exact fluid mechanics experiments	3.24	Engaging	4
5. "Having physical, tactile tools to test principles like Bernoulli's or Pascal's helps focus throughout the lesson and retain principles	3.09	Engaging	5
Overall	3.27	Highly Engaging	a

The table presents the perceived student engagement levels when learning Fluid Mechanics. Based on the data, it revealed that manipulating everyday materials makes them highly engaging evident from the highest mean of 3.36. It provides a more tangible connection to theoretical concepts, thereby fostering active participation and a more positive attitude toward the subject matter (Albers & Bottomley, 2020). Moreover, the use of localized tools to conduct experiment themselves (m=3.33), and the modularity of the design facilitates collaborative problem-solving (m=3.33) makes them highly engaging, significantly enhancing peer-to-peer interaction and knowledge construction (Rizki et al., 2024). In overall, the use of this low-cost pedagogical intervention effectively elevates student interest and engagement evident from the overall mean of 3.27, mirroring the positive impacts on academic performance observed in similar active learning applications (Awwad, 2025).

Table 8: Enhancement of Student Motivation through the Use of the Fluid Mechanics Toolbox

Statements	Mean	Verbal Description	Rank
1. "Working with the low-cost toolbox made me genuinely curious to explore how changes in variables (such as changing the depth in the hydrostatic bottle) affect fluid behavior."	3.39	Strongly Agree	1
2. "Successfully completing the experiments using simple, everyday tools made me feel more capable of mastering complex fluid mechanics topics that I previously found intimidating."	3.30	Strongly Agree	3.5
3. "Seeing how high-level principles like Pascal's or Bernoulli's apply to accessible objects (like syringes and ping-pong balls) motivated me to look for physics concepts in our daily environment."	3.30	Strongly Agree	3.5
4. The immediate visual feedback from using the toolbox motivated me to stay deeply engaged in the physics lessons, making me eager to discover the outcomes of each module	3.36	Strongly Agree	2
5. "The hands-on nature of the tools motivated me to actively troubleshoot errors and spend more time trying to fully understand why an experiment worked, rather than just memorizing formulas for an exam."	3.18	Agree	5
Overall	3.31	Strongly Agree	a

The table presents the impact of the toolbox on student motivation when learning Fluid Mechanics. Based on the data, it revealed that the participants strongly agreed working with the toolbox makes them curious to explore evident from the highest mean of 3.39. It suggests that These hands-on experiments bridge the gap between theory and practice, sustaining student interest in fluid phenomena (Maryati et al., 2022). Moreover, they also strongly agreed that the immediate visual feedback provided by the apparatus significantly sustained their curiosity (m=3.36), and mastering complex concepts (m=3.30). However, they only agreed that the hands-on nature of the tools motivated them to actively troubleshoot errors and spend more time trying to fully understand why an experiment worked, rather than just memorizing formulas for an exam evident from the lowest mean of 3.18. This shows a move away from just listening to lectures and toward hands-on learning, where the ability to test and improve their work directly helps increase student motivation (Tan & Subramaniam, 2024).

Perceived Usability of the Toolbox

This section assesses the usability and design of the Fluid Mechanics Toolbox, highlighting how its intuitive setup helps students bridge the gap between theory and hands-on practice.

Table 9: Perceived Usability of the Toolbox in terms of Physical Ergonomic

Statements	Mean	Verbal Description	Rank
1. "The toolbox is compact, lightweight, and easy to transport, making it highly practical to bring to different classrooms or school locations."	3.11	Agree	4
2. The internal layout and compartments of the organizer box allow me to easily identify, retrieve, and return specific components without clutter."	2.90	Agree	5
3. "The physical parts (such as connecting the vinyl tubing to the syringes or adjusting the mini-fan) can be handled, attached, and manipulated comfortably without physical strain."	3.16	Agree	3
4. "The materials included in the toolbox have smooth edges, are non-toxic, and are secure to operate, ensuring a physically safe experimental environment."	3.51	Strongly Agree	1
5. "The physical components and containers are sturdy enough to withstand regular handling, repeated assembly, and occasional minor water spills during activities."	3.31	Strongly Agree	2
Overall	3.19	Agree	

The table presents the perceived usability of the material in terms of physical ergonomics. The table revealed that the tool box is assured to be safe when use in experimental environment evident from the highest mean of 3.51. However, they only agreed that it can be attached and manipulated comfortably (m=3.16) highly practical in bringing to everywhere (m=3.11) , and the organization of components within the storage container could be improved to enhance retrieval efficiency, as indicated by the lower mean score of 2.90. This indicates that improving the layout could simplify setup and reduce mental effort for students (Shaikh et al., 2017). Additionally, better hardware design is key to helping students focus on the physics concepts instead of just managing the equipment (Ibáñez et al., 2013).

Table 10: Perceived Usability of the Toolbox in terms of Instructional Clarity

Statements	Mean	Verbal Description	Rank
1. The step-by-step procedures on the instructional cards are written in clear, simple language that is easy to interpret.	3.32	Strongly Agree	1
2. The diagrams, labels, or illustrations provided in the guide accurately match the physical setup of the tools.	2.99	Agree	4
3. The time suggested for each activity in the guide is realistic, allowing us to complete the setup and cleanup in a class period.	3.12	Agree	3
4. The instructions provide clear tips or warnings on what to avoid (e.g., preventing air bubbles or managing fluid overflow).	2.83	Agree	5
5. The guide cards clearly state the target fluid mechanics concept being tested, making the purpose immediately obvious.	3.26	Strongly Agree	2
Overall	3.10	Agree	a

The table presents the perceived usability of the toolbox in terms of instructional clarity. The table revealed that the step-by-step procedures are easy to interpret, and clearly stating the concepts being tested evident from the highest mean of 3.32 and 3.26. Conversely, the guide allowing students to complete setup (m=3.12), labels and illustrations matches the setup (m=2.99), and the inclusion of safety warnings regarding experimental pitfalls(m=2.83) yielded lower ratings, suggesting that students need clearer guidance to avoid mistakes when working on their own (Matos & Zannin, 2021). To solve these issues, adding video guides could provide better support, allowing students to see exactly how to assemble the equipment and fix problems before they start using it (Yaacob & Velte, 2021).

CONCLUSIONS

With a total production cost of 1,860 pesos, this toolbox demonstrates that high-quality, experiential learning tools can be developed with minimal financial investment. Its compact, self-contained design addresses the need for remote and portable laboratory experiences, effectively bridging logistical gaps in engineering education. The toolbox integrates nine distinct experimental modules aligned with the Bachelor of Secondary Education Major in Science syllabus, providing a professional-grade environment for student-led investigations. Accompanied by a comprehensive instructional manual, these activities facilitate the study of essential fluid mechanics concepts, ranging from fundamental properties to advanced aerodynamics.

The pre-assessment revealed that most students lacked the foundational knowledge needed for advanced fluid mechanics. After using the toolbox, students demonstrated marked improvements in their post-assessment scores, showing a robust conceptual grasp. These gains indicate that the active, low-cost experimentation effectively helps students overcome common misconceptions. Statistical analysis further confirms that the implementation of the toolbox leads to a significant advancement in student proficiency.

Students reported high engagement and motivation while using the toolbox, as the hands-on approach effectively bridged the gap between theory and fluid phenomena. Regarding physical ergonomics, the toolbox is considered safe, though component organization requires improvement to reduce mental effort, and better hardware design is necessary to help students focus on physics concepts. While instructional procedures were found to be clear, lower ratings for safety warnings indicate a need for enhanced support. Integrating video guides and with interactive explanation would address these gaps by providing clearer assistance for equipment assembly and troubleshooting.

IMPLICATIONS OF THE STUDY

The outcome of this study demonstrates the potential for low-cost, portable laboratory equipment to democratize access to high-quality STEM education, offering a scalable alternative to resource-intensive traditional setups. Moreover, it can be leveraged to promote self-directed, open-ended laboratory experiences that encourage students to explore fluid dynamics.

ACKNOWLEDGEMENT

The researcher would like to express profound gratitude to the institution, President Ramon Magsaysay State University, for providing the essential resources and environment necessary to conduct this research. Further, thanks to the college and science department for their invaluable support and guidance, which were instrumental in the development of these experimental tools and the successful realization of this research project. Lastly, to the students that participated in this study, whose curiosity and feedback proved essential in refining these modules into a more effective and engaging learning tool.

REFERENCES

1. Achuthan, K., Raghavan, D., Shankar, B., Francis, S. P., & Kolil, V. K. (2021). Impact of remote experimentation, interactivity and platform effectiveness on laboratory learning outcomes. *International Journal of Educational Technology in Higher Education*, *18*(1), 38–38. https://doi.org/10.1186/s41239-021-00272-z
2. Albers, L., & Bottomley, L. (2020). *Six Hands-on Activities Designed to Improve Student Achievement in and Attitude Towards Learning Fluid Mechanics*. https://doi.org/10.18260/1-2--21916
3. Asyhari, A., Irawan, W. D., Sunyono, S., Rosidin, Undang, Sowiyah, S., & Hariri, H. (2023). FLM-based AFL improves physics engagement and conceptual understanding. *Journal of Education and Learning (EduLearn)*, *18*(1), 154–164. https://doi.org/10.11591/edulearn.v18i1.20925
4. Awwad, F. (2025). Enhancing Electronics Courses Education: Active Learning Strategies for Undergraduate Engineering Students. *International Journal of Engineering Pedagogy (iJEP)*, *15*(2), 42–73. https://doi.org/10.3991/ijep.v15i2.51739
5. Bahtaji, M. A. A. (2023). EXAMINING THE PHYSICS CONCEPTIONS, SCIENCE ENGAGEMENT AND MISCONCEPTIONS OF UNDERGRADUATE STUDENTS IN STEM. *Journal of Baltic Science Education*, *22*(1), 10–19. https://doi.org/10.33225/jbse/23.22.10
6. Chau, T., Nguyen, H. T., Lý, H. A., Ghazali, I., Nguyen, D. C., & Nguyen, T. D. (2023). A Low-cost Pitot Tube-based Experimental Model for Active Teaching-learning of Applied Fluid Mechanics: A Demonstration from NTTU. *Engineering Science Letter*, *2*(3), 84–91. https://doi.org/10.56741/esl.v2i03.432
7. Cimbala, J. M., Pauley, L. L., Zappe, S., & Hsieh, M.-F. (2020). *Experiential Learning In A Fluid Flow Class Via Take Home Experiments*. https://doi.org/10.18260/1-2--792
8. Dam-O, P., Eadkhong, T., & Sirisathitkul, C. (2025). Integrating problem-based learning into the first-year physics laboratory course: A post-COVID-19 scenario at Walailak University, Thailand. *Eurasia Journal of Mathematics Science and Technology Education*, *21*(1). https://doi.org/10.29333/ejmste/15801
9. Delgado, P., Luna, C. A., Dissanayaka, A., Oshinowo, O., Waggoner, J. J., Schley, S., Fernandez, T., & Myers, D. R. (2024). An economical in-class sticker microfluidic activity

develops student expertise in microscale physics and device manufacturing. *Lab on a Chip*, *24*(8), 2176–2192. https://doi.org/10.1039/d3lc00912b

10. Earp, B., & Parker, K. (2024). *Hands-On Fluid Flow Trainer to Support Experimental Learning*. https://doi.org/10.18260/1-2--43337

11. Ebadi, A., & Sabuncu, A. C. (2024). *Lab on Cart: Developing a Low-Cost Fluid Visualization Setup for Experiential Learning, Class Demonstration, and Outreach*. https://doi.org/10.18260/1-2--47712

12. Elliott, J., Minichiello, A., & Caldwell, L. (2021, August 20). "Implementation of a Low Cost, Mobile Instructional Particle Image Velocimetry (mI-PIV) Learning Tool for Increasing Undergraduate and Secondary Learners' Fluid Mechanics Intuition and Interest." *2021 ASEE Virtual Annual Conference Content Access Proceedings*. https://doi.org/10.18260/1-2--36528

13. Firmansyah, J., Suhandi, A., Setiawan, A., & Permanasari, A. (2021). Level Pemahaman Konsep Fluida Mahasiswa Calon Guru Fisika dalam Project Based Laboratory (PJB-Lab). *JIPFRI (Jurnal Inovasi Pendidikan Fisika Dan Riset Ilmiah)*, *5*(2), 102–109. https://doi.org/10.30599/jipfri.v5i2.1061

14. Gartner, J., Finkel, D., Wie, B. V., Adesope, O., Brown, S., & Atkinson, J. (2020). *New Hands-on Fluid Mechanics Cartridges and Pedagogical Assessment*. https://doi.org/10.18260/1-2--22312

15. Ibáñez, M. B., Serio, Á. D., Villarán, D., & Kloos, C. D. (2013). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & Education*, *71*, 1–13. https://doi.org/10.1016/j.compedu.2013.09.004

16. Jones, N., Niemi, S. R., & Traum, M. J. (2021, August 20). A Hands-on Learning Module Pipe-flow Velocity Profile Interrogator Laboratory Kit for Remote Online Fluid Mechanics Instruction. *2021 ASEE Virtual Annual Conference Content Access Proceedings*. https://doi.org/10.18260/1-2--36585

17. Kaye, N. B., & Ogle, J. (2022). Overcoming misconceptions and enhancing student's physical understanding of civil and environmental engineering fluid mechanics. *Physics of Fluids*, *34*(4). https://doi.org/10.1063/5.0083993

18. Maryati, R. E., Permanasari, A., & Ardianto, D. (2022). Fluid Learning with Arduino-Based on Engineering Design Process (EDP) to Improve Student's Problem Solving Ability. *Scientiae Educatia*, *11*(2). https://doi.org/10.24235/sc.educatia.v11i2.11760

19. Mathijssen, A. J. T. M., Lisicki, M., Prakash, V. N., & Mossige, E. J. L. (2023). Culinary fluid mechanics and other currents in food science. *Reviews of Modern Physics*, *95*(2). https://doi.org/10.1103/revmodphys.95.025004

20. Matos, M. T., & Zannin, M. (2021). Educational Robotics: Building and Applying an App-controlled Car to Study Newton's Laws. *Open Education Studies*, *3*(1), 49–55. https://doi.org/10.1515/edu-2020-0139

21. Minichiello, A., Armijo, D., Mukherjee, S., Caldwell, L., Kulyukin, V., Truscott, T., Elliott, J., & Bhouraskar, A. (2020). Developing a mobile application-based particle image velocimetry tool for enhanced teaching and learning in fluid mechanics: A design-based research approach. *Computer Applications in Engineering Education*, *29*(3), 517–537. https://doi.org/10.1002/cae.22290

22. Misbah, M., Hamidah, I., Sriyati, S., & Samsudin, A. (2024). A scoping review with bibliometric analysis of topic fluid in science education: State of the art and future directions. *Momentum Physics Education Journal*, *8*(1), 144–153. https://doi.org/10.21067/mpej.v8i1.9334

23. Mufit, F., Festiyed, F., Fauzan, A., & Lufri, L. (2023). The Effect of Cognitive Conflict-Based Learning (CCBL) Model on Remediation of Misconceptions. *Journal of Turkish Science Education*. https://doi.org/10.36681/tused.2023.003

24. Nafie, G., Rosi, G., Mai, A., & Johnston, K. A. (2022, November 1). Building Engineering Fundamentals in an Active Learning Environment. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.vi.15944

25. Nazempour, A., Golter, P., Richards, C. D., Richards, R. F., & Wie, B. V. (2015). *Assessments of Ultra-Low-Cost Venturi Nozzle in Undergraduate Engineering Classes*. https://doi.org/10.18260/p.23605

26. Ngo, V. T. (2024). Applying the engineering design process to teach the physics course for engineering students using the flipped classroom combined with an instructional design model. *Journal of Research in Innovative Teaching & Learning*. https://doi.org/10.1108/jrit-07-2023-0095

27. Njau, S., Wie, B. V., Burgher, J., Golter, P., Richards, R. F., Richards, C. D., Meng, F., Adesope, O., Hunsu, N., Beheshtipour, N., Dutta, P., Thiessen, D. B., Graviet, A., & Nazempour, A. (2015). *Miniature Low-Cost Desktop Learning Modules for Multi-Disciplinary Engineering Process Applications*. https://doi.org/10.18260/p.24492

28. Nurdini, N., Suhandi, A., Fratiwi, N. J., Samsudin, A., Ramalis, T. R., & Feranie, S. (2025). E-CDCCText Development: An Instructional Material for Facilitating Conceptual Change in Fluid Concepts. *Journal of Natural Science and Integration*, *8*(1), 93–93. https://doi.org/10.24014/jnsi.v8i1.32928

29. Patron, B., & Desojo, A. G. B. (2020). Inexpensive Demonstrations and Experiments in Understanding Basic Concepts of Fluid Mechanics. *Journal of Higher Education Research Disciplines*, *5*(1). https://doi.org/10.65023/jherd.v5i1.168

30. Purnama, A. N. H., Winarno, N., Prima, E. C., & Ahmad, N. J. (2023). FOSTERING STUDENTS' CONCEPT MASTERY THROUGH STEM-ENGINEERING DESIGN PROCESS IN THERMAL ENERGY AND HEAT TRANSFER TOPIC. *INSECTA Integrative Science Education and Teaching Activity Journal*, *4*(2), 209–230. https://doi.org/10.21154/insecta.v4i2.7240

31. Rahman, N. F. A., Roslan, A. N., Azaha, A. N., Ismail, N. H., & Murshed, M. B. (2021). Informal Science Pedagogical Innovation to Promote Understanding of Technology Application in Fluids Mechanics. *International Journal of Emerging Technologies in Learning (iJET)*, *16*(18), 242–242. https://doi.org/10.3991/ijet.v16i18.25083

32. Reynolds, O., Kaiphanliam, K., Khan, A. I., Pour, N. B., Dahlke, K., Thiessen, D. B., Gartner, J., Adesope, O., Dutta, P., & Wie, B. V. (2020). *Board 131: Nationwide Dissemination and Critical Assessment of Low-cost Desktop Learning Modules for Engineering: A Systematic, Supported Approach*. https://doi.org/10.18260/1-2--32236

33. Richards, C. D., Meng, F., Wie, B. V., Golter, P., & Richards, R. F. (2015). *Implementation of Very Low-cost Fluids Experiments to Facilitate Transformation in Undergraduate Engineering Classes*. https://doi.org/10.18260/p.24246

34. Richards, R. F., Meng, F., Wie, B. V., Spadoni, F., & Ivory, A. (2015). *MAKER: Very Low-cost Experiments via 3-D Printing and Vacuum Forming*. https://doi.org/10.18260/p.24458

35. Rizki, I. A., Khoir, E. F., Nikmah, F., Prahanı, B. K., & Hariyono, E. (2024). Effect of Physics Inquiry Learning with Low-cost Experiment Tool on Students' Problem-solving Skills and Self-efficacy. *Physics Education Research Journal*, *6*(1), 1–10. https://doi.org/10.21580/perj.2024.6.1.19001

36. Rogayan, D. V., & Dollete, L. F. (2019). Development and Validation of Physical Science Workbook for Senior High School. *Science Education International*, *30*(4), 84–290. https://doi.org/10.33828/sei.v30.i4.5

37. Saehana, S., Ali, M., & Supriyatman, S. (2019). Thermal Expansion and Hydrostatic Pressure Experiment Using Common Materials for Supporting Science Education in a Rural Area at Central Sulawesi, Indonesia. *Jurnal Pendidikan IPA Indonesia*, *8*(2). https://doi.org/10.15294/jpii.v8i2.18403

38. Shaikh, U., Magana, A. J., Neri, L., Escobar-Castillejos, D., Noguez, J., & Beneš, B. (2017). Undergraduate students' conceptual interpretation and perceptions of haptic-enabled learning experiences. *International Journal of Educational Technology in Higher Education*, *14*(1). https://doi.org/10.1186/s41239-017-0053-2

39. Starks, J., Hendrickson, F., Hadi, F., & Traum, M. J. (2018). *Miniaturized Inexpensive Hands-On Fluid Mechanics Laboratory Kits for Remote Online Learning*. https://doi.org/10.18260/1-2--28671

40. Tan, Y. L. K., & Subramaniam, R. (2024). Promoting integrated STEM education among students via fabrication of interactive exhibit. *Frontiers in Education*, *9*. https://doi.org/10.3389/feduc.2024.1423158

41. Tizón, J. M., Sierra, P., León, L. S. de, Navarro, E., Vilá, J., & Moral, J. F. Q. del. (2021). Developing a New Tool to Implement Computer-Supported Active Learning\n Strategies in the Engineering Classroom. In *arXiv (Cornell*

University). Cornell University. https://doi.org/10.48550/arxiv.2104.10118

42. Torick, D. (2009). Product Development Meets Instructional Design- A Case Study in the Redesign of a Fundamentals of Fluids Course. *D-Scholarship@Pitt (University of Pittsburgh)*.

43. Vianna, A. dos S., & Enne, B. W. (2025). Approach with Active-cooperative, Flipped and Hands-on Learning: A Case Study in Transport Phenomena. *International Journal of Higher Education*, *14*(5), 18–18. https://doi.org/10.5430/ijhe.v14n5p18

44. Yaacob, M. R., & Velte, C. M. (2021). Students Perception Towards the Implementation of Asynchronous Video Lectures and Video-based Instructions in Experimental Fluid Mechanics Course. *Evergreen*, *8*(2), 374–378. https://doi.org/10.5109/4480719