CHECKLIST PEMENUHAN PERSYARATAN
KENAIKAN JABATAN AKADEMIK DOSEN
ASISTEN AHLI → LEKTOR
PEMENUHAN SYARAT WAJIB ARTIKEL ILMIAH FIRST AUTHOR

Nama Dosen	: Larasati Rizky Putri
NIDN/NUPTK	: 0320029201/8552770671230172
Program Studi	: Teknik mesin - FTI
Perguruan Tinggi	: Universitas Trisakti
Jabatan Akademik Saat Ini	: Asisten Ahli
Jabatan Akademik yang Diusulkan	: **Lektor**
Periode Pengusulan	: **2026**

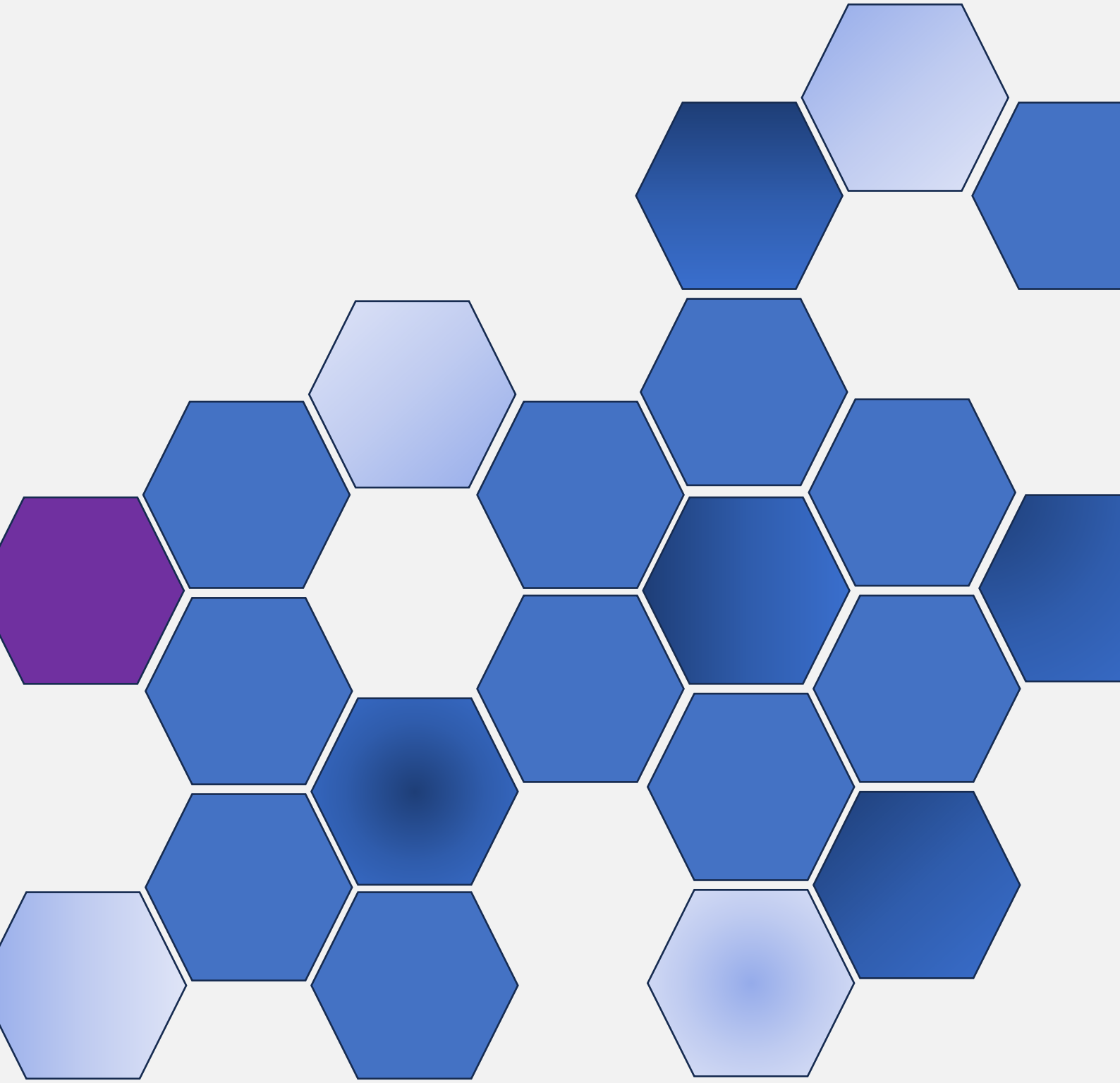
Daftar Checklist:

1. Cover & Identitas Jurnal
2. Artikel Full Paper
3. Similarity Check + Exclude Sources
4. Bukti SINTA/DOAJ
5. Submission/LoA
6. Bukti Korespondensi

Volume 08
Issue 01
June 2026

IJASST

International Journal of
Applied Sciences and Smart Technologies



Faculty of Science and Technology
Universitas Sanata Dharma

IJASST
International Journal of
Applied Sciences and Smart Technologies
p-ISSN 2655-8564, e-ISSN 2685-943, 2026

Volume 08
Issue 01

CONTENTS

CONTENTS i

EDITORIAL BOARD iii

PREFACE iv

A Simulation-Based Approach To Spiral Pump Design 1–8
Hengky Luntungan, Stenly Tangkuman, Benny L. Maluegha

The Influence of Printing Parameter Variations on the Dimensional Accuracy of 3D Nylon Carbon FDM Prints Using the Grey-Taguchi Method 9-28
Gilang Argya Dyaksa, Felix Krisna Aji Nugraha, Heryoga Winarbawa, Kristian Ismartaya, Robertus Bellarmino Radya Ananda, Hadrianus Felin Saputra

Technical and Cost Barriers in Accessing Smart Educational Technologies in Rural Areas 29-42
Nusrat Jahan

Handling Highly Imbalanced Flood Data Using K-Means Clustering in Skyline Query Dominance Testing 43-56
Vega Purwayoga, Zakwan Gusnadi , Winda Ayu Anggraini

Modelling and Analysis of Ziegler-Nichols PID Tuning on Water Tank Control System 57-80
Regina Chelinia Erianda Putri, Bernadeta Wuri Harini

Using the Six Sigma DMAIC Approach to Improve Maintenance Practices of Ground-Service Mechanical Equipment within a Sub-Saharan African Airport 81-118
Samson Olanrewaju Omisakin, Sunday Ayoola Oke, Oluwarotimi Toluwalope Shitta-bey, John Rajan, Swaminathan Jose

IoT Based Nozzle Actuation System Design for Automated Fish Feed Distribution 119-152
Sentot Novianto, Larasati Rizky Putri, Amrullah Gilang Ibrahim, Tono Sukarnoto, Faisal Adinegoro, Supriyadi, Nanang Ruhyat

Tourism News Classification Using Convolution Long Short-Term Memory (C-LSTM) 153-168
Yoga Dwitya Pramudita, Husni, Mohammad Syarief, Eka Mala Sari Rochman, Arif Muntasa, Zahra Arwananing Tyas, Ika Oktavia Suzanti

IJASST
International Journal of
Applied Sciences and Smart Technologies
p-ISSN 2655-8564, e-ISSN 2685-943, 2025

Volume 08
Issue 01

Psychrometric Performance of the Air Dehumidifier Base Clothes Dryer 169-182
Wibowo Kusbandono, Prasetyadi, Nico Ndaru Pratama, Doddy Purwadianto, Rines, Y.B Lukiyanto, I.G.K Puja, Michael Seen, Budi Setyahandana

Principal Component Analysis-Driven Feature Reduction for Predicting Coffee Quality Using a Machine Learning Approach 183-202
Siti Yuliyanti, Heni Sulastri, Sakifah

A Sub-Saharan African Airport Mechanical Equipment Failure Assessment Using Joint FMECA-GRA Method Based on Technical Process Efficiency 203-238
Olanrewaju Samson Omisakin, Sunday Ayoola Oke, Adeyinka Oluwo, John Rajan, Swaminathan Jose

Development of an Arduino-Based Water Rocket Launcher in Physics Experiments 239-260
Larasati Rizky Putri, Fakhrizal Arsi, Kiar Vansa Febrianti, Sentot Novianto, Ika Wahyu Utami, Muhammad Najih, Sofia Debi Puspa, Muhammad Gilang Ramadhan,Harry Munandar

Analysis of Key Features in PCOS Diagnosis Using Random Forest and XGBoost with SMOTE and SHAP 261-278
Aulia Firdatunnisa, Eka Wahyu Hidayat, Siti Yuliyanti

Durability of Silica Sand-Based Self-Compacting Mortar: A Study on Sorptivity and Chemical Attack 279-292
Toluwalope Dominion Zubair, Mutiu Abiodun Kareem, Abibat Oyindamola Usman, Divine Favour Adejumo, Glory Olajide Ponnle, David Adeyemi Adeyeye, Ojo Adeleye Akinbade

Grouping Weekly Weather Based on Weather Elements in Pagaralam by Using K-Means Clustering Analysis 293-320
Sri Indra Maiyanti, Irmeilyana, Putri Nilam Cayo, Dinny Indah Angelia, Angelina

Thermal Investigation of Changes in The Mass Flow Rate of The Lithium-Ion Battery Coolant 321-330
Stefan Mardikus, Petrus Setyo Prabowo, Bernadeta Wuri Harini, Budi Sugiharto, F.A. Rusdi Sambada, Achilleus Hermawan Astyanto, I.M.W Ekaputra

AUTHOR GUIDELINES 331-332

IJASST
International Journal of
Applied Sciences and Smart Technologies
p-ISSN 2655-8564, e-ISSN 2685-943

EDITORIAL BOARD

Editor in Chief
Dr. I Made Wicaksana Ekaputra *(Sanata Dharma University, Yogyakarta, Indonesia)*
Email: made@usd.ac.id

Associate Editor
Dr. Pham Nhu Viet Ha *(Vietnam Atomic Energy Institute, Hanoi, Vietnam)*
Dr. Hendra Gunawan Harno *(Gyeongsang National University, Jinju, The Republic of Korea)*
Dr. Mukesh Jewariya *(National Physical Laboratory, New Delhi, India)*
Dr. Mongkolsery Lin *(Institute of Technology of Cambodia, Phnom Penh, Cambodia)*
Dr. Yohanes Baptista Lukiyanto *(Sanata Dharma University, Yogyakarta, Indonesia)*
Dr. Apichate Maneewong *(Thailand Institute of Nuclear Technology, Bangkok, Thailand)*
Prof. Dr. Sudi Mungkasi *(Sanata Dharma University, Yogyakarta, Indonesia)*
Dr. Pranowo *(Universitas Atma Jaya Yogyakarta, Yogyakarta, Indonesia)*
Dr. Monica Cahyaning Ratri *(Sanata Dharma University, Yogyakarta, Indonesia)*
Dr. Mahardhika Pratama *(Nanyang Technological University, Singapore)*
Prof. Dr. Leo Hari Wiryanto *(Bandung Institute of Technology, Bandung, Indonesia)*
Dr. Ranggo Tungga Dewa *(Universitas Pertahanan, Bogor, Indonesia)*

Editorial Assistant
Rosalia Arum Kumalasanti, M.T. *(Sanata Dharma University, Yogyakarta, Indonesia)*
Vittalis Ayu, M.Cs. *(Sanata Dharma University, Yogyakarta, Indonesia)*

Contact us
International Journal of Applied Sciences and Smart Technologies
Faculty of Science and Technology
Universitas Sanata Dharma
Kampus III Paingan, Maguwoharjo, Depok, Sleman
Yogyakarta, 55282
Phone : +62 274883037 ext. 523110, 52320
Fax : +62 272886529
Email : editorial.ijasst@usd.ac.id
Website : http://e-journal.usd.ac.id/index.php/IJASST

IJASST is an open-access peer-reviewed journal that mediates the dissemination of research and studies conducted by academicians, researchers, and practitioners in science, engineering, and technology.

IJASST
International Journal of
Applied Sciences and Smart Technologies
p-ISSN 2655-8564, e-ISSN 2685-943

PREFACE

Dear readers, we are delighted to serve you Volume 08, Issue 01 of *International Journal of Applied Sciences and Smart Technologies* (IJASST), which is managed and published by the Faculty of Science and Technology, Universitas Sanata Dharma. IJASST is an open-access peer-reviewed journal that mediates the dissemination of research and studies conducted by academicians, researchers, and practitioners in science, engineering, and technology. Its scope also includes basic sciences which relate to technology, such as applied mathematics, physics, and chemistry.

In this edition, we have sixteen papers authored by researchers from Indonesia, Bangladesh, India, Malaysia, and Africa. Submitted papers are reviewed fairly using the open journal system (OJS) of IJASST. After the review process, accepted papers of the journal are publicly available for free at the website of IJASST. For future issues, we are looking forward to your contributions to IJASST.

Dr. I Made Wicaksana Ekaputra
Editor in Chief
IJASST

IJASST
International Journal of
Applied Sciences and Smart Technologies
p-ISSN 2655-8564, e-ISSN 2685-943, pp. 239-260, 2025

Volume 08
Issue 01

Development of an Arduino-Based Water Rocket Launcher in Physics Experiments

Larasati Rizky Putri[1*], Fakhrizal Arsi[2], Kiar Vansa Febrianti[3],
Sentot Novianto[1], Ika Wahyu Utami[1], Muhammad Najih[1]
Sofia Debi Puspa[1], Amrullah Gilang Ibrahim[1],
Harry Munandar[1]

[1]*Faculty of Industrial Technology, Universitas Trisakti,*
Grogol West Jakarta, 11440, Indonesia
[2]*Physics of High School, State Senior High School 8 Jakarta,*
Tebet South Jakarta, 12840, Indonesia
[3]*Physics of Middle School and High School, Cita Buana School,*
Jagakarsa South Jakarta, 12620, Indonesia
[*]*Corresponding Author: larasati.rizki@trisakti.ac.id*

(Received 18-09-2025; Revised 02-12-2025; Accepted 09-04-2026)

Abstract
The effective science education requires practical methods that allow students to explore complex physics concepts. One promising approach is the use of physics experiment as an interactive media. This research focuses on the development of water rocket launcher using an Arduino as an innovative physics experiment. Arduino in water rocket launcher is used for making the precise control and relevant measurement of variables, such as angle of projection, speed of launch, maximum altitude of launch, and air pressure. The research process followed the ADDIE instructional design model and involved hardware, software prototyping, work testing, and user instruction. The launcher's performance was tested with 33 engineering students and assessed by 5 experts. Expert evaluations rated the relevance, design, and usability of the kit highly (3.4–4.0 on a 4-point Likert scale). User responses from 33 students indicated strong agreement on ease of use and engagement (mean scores 3.79–3.91), with a high reliability (Cronbach's alpha = .964). Experimental launches, using three and four finned rockets, showed maximum height percentage differences between theoretical and observed values ranging from 0.0%–52.6% (three fins) and 1.2%–51.8% (four fins); range errors were 3.4%–36.8% (three fins) and 2.1%–42.7% (four fins). The findings confirm that the Arduino-based water rocket launcher provides effective, interactive learning, though further refinement in data accuracy and instructional materials is recommended to maximize its classroom impact and is needed for improved accuracy.

Keywords: Arduino, Experiment, Launcher, Water Rocket.

1 Introduction

Science, Technology, Engineering, and Mathematics (STEM) education is widely recognized as a key driver for developing problem-solving ability, creativity, and 21st-

This work is licensed under a Creative Commons Attribution 4.0 International License

century skills among students [1], [2], [3]. Project-based and hands-on learning, especially in physics, has been found to increase student engagement, conceptual understanding, and scientific interest [3], [4]. However, in many educational settings, barriers such as limited resources and teacher readiness can restrict the adoption of innovative practical activities [5].

Integrating microcontroller platforms, such as Arduino, into physics classrooms enables students to automate experiments, collect real-time data, and connect abstract concepts with tangible projects [6]. Reviews and systematic studies confirm that Arduino-based activities help bridge theory with practice, enhance computational thinking, and support the development of engineering skills [1], [6]. Water rocket experiments, in particular, are effective for teaching core topics like Newton's laws, the action-reaction principle, air pressure [7], momentum, and projectile motion, all while enhancing motivation and inquiry-based learning [3], [4].

Despite these benefits, implementing Arduino-enhanced practical physics projects on a broad scale requires consideration of curriculum integration, teacher training, and equitable access to technology [5]. To answer that problem, the research needs to consider the technical aspects of developing a water rocket launcher, including optimal hardware and software design. In addition, the research should also determine whether the water rocket launcher is properly made by comparing the launch data with theoretical data. Thus, this study aims to design, build, and evaluate an Arduino-based water rocket launcher as an engaging physics teaching tool, assessing its impact on student understanding and motivation in physics learning.

1.1 Principles of STEM and Project-Based Learning

STEM education is grounded in the integration of science, technology, engineering, and mathematics, aiming to equip students with skills for problem-solving, inquiry, and innovation [1], [2]. Project-based learning (PBL), a cornerstone of effective STEM teaching, encourages students to engage deeply with content by designing, constructing, and evaluating tangible products or solutions [4]. Research shows that PBL promotes higher-order thinking and increases students' motivation for learning science concepts [3].

The successful implementation of technological tools like Arduino within STEM education demands not only adequate resources but also teacher readiness and effective curriculum integration [5]. Professional development and support help educators design learning experiences where technology is not an add-on but an essential part of the investigation and discovery process.

1.2 Physics of Water Rocket

Water rocket experiments are an accessible means to teach principles of mechanics, specifically Newton's laws of motion, conservation of momentum, and projectile motion. When the rocket is launched, expelling water downwards due to the pressurized air creates an upward thrust as described by Newton's third law. The motion of the rocket after launch demonstrates projectile motion, where the range and maximum height can be mathematically described using classical equations:

$$R = \frac{v_0^2 \sin 2\theta}{g} \tag{1}$$

where R is the range, v_0 is the initial velocity, θ is the launch angle, and g is the acceleration due to gravity [4].

1.3 Water Rocket Launcher

Project-based physics learning allows students to research, plan, design and reflect on the creation of their technology projects. This type of learning not only stimulates student creativity but also requires different assessments. Projects will provide information about students' understanding and knowledge of the learning process, their ability to apply knowledge, and their ability to communicate information. Recent research in this field has shown that the use of Arduino-based water rocket launchers can improve students' understanding of physics concepts. In addition, the use of this technology also stimulates students' interest in science and technology. This is particularly relevant in the face of modern educational challenges where students often struggle to understand abstract physics concepts [22].

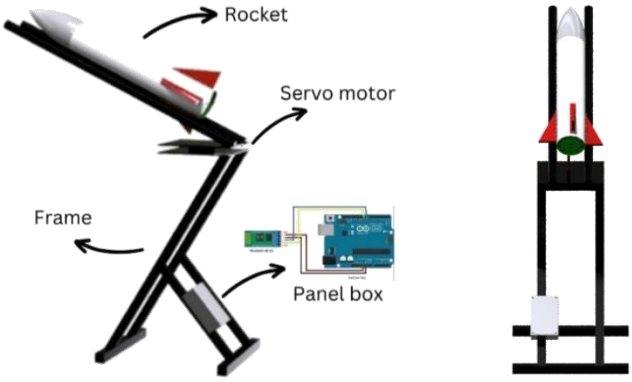


Figure 1. Development of water rocket launcher: (a) Parts of Arduino-based water rocket launcher and (b) Back view of the launcher.

The components of the launcher are shown in Fig. 1. The main raw material of the kit is hollow aluminum pipe and 3 mm iron plates. Hollow pipe was cut into several pieces, then iron plates were cut into 20 × 20 cm size. Researcher also welded the hollow pipes into L-shape. After that researcher drills some hole for motor servo installation later, then welded iron plates to the hollow pipes and installed ball bearings between the plates. After the frame is fixed, researcher installed servo motors and the Arduino. The installation documentation is shown in Fig. 2.

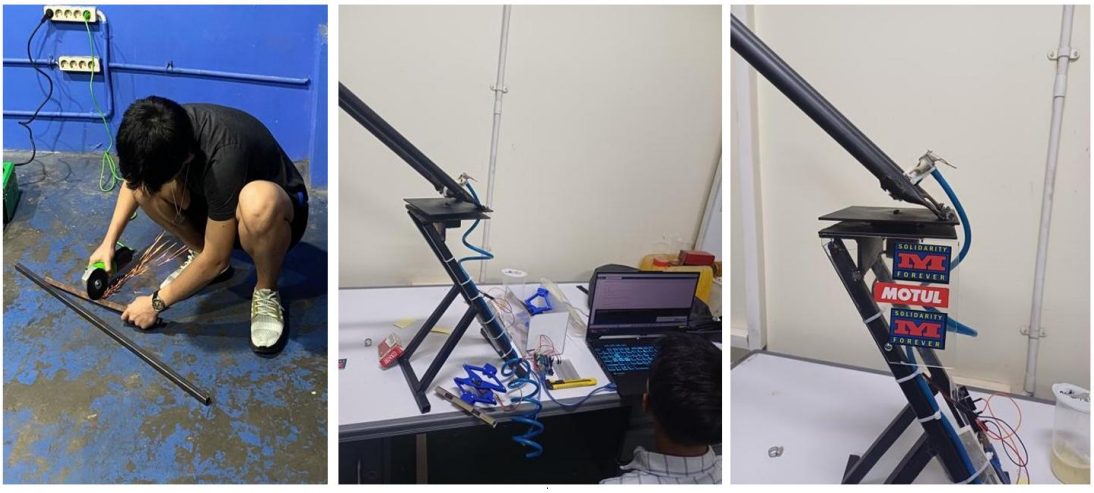


Figure 2. Frame assembly and installation

1.4 Arduino Installation and Coding

Arduino is an open-source microcontroller platform, widely adopted for introducing automation, programming, and sensor data acquisition in classroom environments. Systematic reviews of classroom Arduino use show that it fosters the development of computational thinking, problem-solving, and scientific inquiry [6]. In STEM projects, Arduino provides a bridge between theoretical physics and practical application by allowing real-time measurement, control of system variables (such as launch angle or timing), and digital data logging [6].

As technology advances, the use of Arduino in the development of water rocket launchers has become increasingly popular. Arduino is an affordable and programmable hardware platform that can be used to control a wide variety of experimental tools, including water rocket launchers. With Arduino, teachers can program the device to measure physics parameters during the rocket launch, such as angular projection, velocity, altitude, and air pressure, so that students can see and analyze the experimental results directly [8].

The servo motor is controlled via Arduino Uno and Bluetooth module HC-05 (Fig. 3). Researcher used Bluetooth HC-05 module, male to male cable, Arduino Uno, and a breadboard. The pins of HC-05 module are connected to the Arduino with the following configuration.

- VCC : 5V
- GND : GND
- TXD : RXD
- RXD : TX

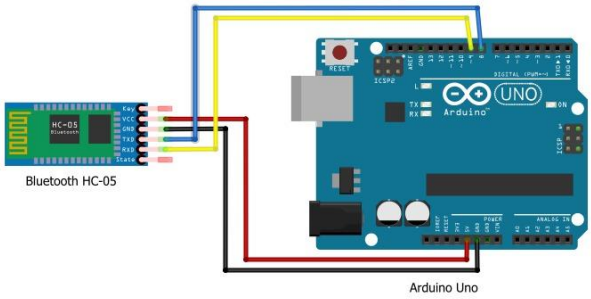


Figure 3. Arduino schemes

Then, researcher installed Arduino IDE from https://www.arduino.cc/en/software, connected Arduino cable to a laptop, and run the software. The following code is written to control the servo motor (Fig. 4).

After the code is installed, researcher connected their phones to HC-05 module via Bluetooth, and control the Arduino using Arduino Controller apps. The rocket launcher then tested with two types of rockets, 3-fins rocket and 4-fins rocket as shown in Fig.5.

```
#include <Servo.h>
Servo servoAxis1;  // Create servo object for first axis
Servo servoAxis2;  // Create servo object for second axis
int posAxis1 = 90;  // Initial value for first axis (90°)
int posAxis2 = 90;  // Initial value for second axis (90°)
char receivedChar;  // Variabel to receive data from Bluetooth
void setup() {
  servoAxis1.attach(9);  // Attach servo motor for first axis to pin no.
9
  servoAxis2.attach(10); // Attach servo motor for first axis to pin no.
10
  Serial.begin(9600);  // Initialize serial communication
  Serial.println("Kendalikan servo dengan tombol 'u', 'd', 'l', 'r' di
ponsel Anda melalui Bluetooth."); // Print servo motor instruction in
Indonesian
}
void loop() {
  if (Serial.available() > 0) {
    receivedChar = Serial.read();
    if (receivedChar == 'u') {
      // Up botton pressed
      posAxis1 = 120;  // Adjust position increment as needed
    } else if (receivedChar == 'd') {
      // Down botton pressed
      posAxis1 = 60;  // Adjust position decrement as needed
    } else if (receivedChar == 'l') {
      // Left button pressed
      posAxis2 = 120;  // Adjust position increment as needed
    } else if (receivedChar == 'r') {
      // Right button pressed
    // Limit servo motor range
    posAxis1 = constrain(posAxis1, 0, 180);
    posAxis2 = constrain(posAxis2, 0, 180);

    // Adjust servo motor position
    servoAxis1.write(posAxis1);
    servoAxis2.write(posAxis2);
  }
}
```

Figure 4. Arduino codes

Figure 5. Three-fins rocket and four-fins rocket

Researchers compile the launch data in Table 1.

Table 1. Experimental data

Number of fins	Launch Angle (º)	T (s)	Powered flight time (s)	Projectile flight time (s)	Total distance/ x total (m)	Air pressure (kPa)	Nozzle diameter (m)	Initial mass (kg)	Final mass (kg)	Ejected water mass (kg)	Max height (m)
3	15	0.82	0.01	0.82	7.4	250	0.012	0.52117	0.20777	0.3134	0.3
3	30	0.92	0.02	0.9	14.35	300	0.014	0.52117	0.18443	0.33674	1.33
3	45	1.24	0.04	1.2	20.86	250	0.016	0.52117	0.17131	0.34986	2.35
3	60	1.5	0.05	1.45	13.51	210	0.018	0.52117	0.16988	0.35129	5.23
3	75	1.69	0.07	1.62	10.34	200	0.02	0.52117	0.15933	0.36184	6.01
3	90	1.87	0.09	1.78	2.52	150	0.024	0.52117	0.15142	0.36975	9.41
4	15	0.68	0.01	0.67	10.15	350	0.012	1.00479	0.30036	0.70443	1.67
4	30	0.77	0.02	0.75	18.13	300	0.014	1.00479	0.34658	0.65821	2.92
4	45	1.15	0.04	1.11	23.1	250	0.016	1.00479	0.35958	0.64521	4.14
4	60	1.44	0.06	1.38	15.58	210	0.018	1.00479	0.23772	0.76707	5.84
4	75	1.66	0.08	1.58	12.96	200	0.02	1.00479	0.20513	0.79966	8.67
4	90	1.95	0.12	1.83	3.79	150	0.024	1.00479	0.18248	0.82231	10.4

2 Material and Methods

This research utilized the Research and Development (R&D) approach, adopting the ADDIE instructional design model, Analysis, Design, Development, Implementation, and Evaluation, as proposed by Dick and Carey in 1996 [9] and adapted widely in educational technology development [10], [11]. The ADDIE model provides a systematic and iterative process well-suited to producing effective educational materials and STEM kits [11].

To begin, the researchers conducted open-ended interviews with physics teachers to identify challenges and needs in conducting water rocket activities. The feedback highlighted practical difficulties in assembling launchers and the need for better alignment with learning objectives. As suggested by prior studies, gathering user input in the early stages supports relevant and effective instructional design [12]. Consequently, this research was undertaken to create an Arduino-based water rocket launcher so that teachers can focus more in the physical concepts rather than the launcher assembly itself.

During the Design stage, the water rocket launcher was designed using 3D modelling software. Particular attention was paid to selecting low-cost, locally available components, ensuring affordability and ease of replication, an important consideration in educational kit design [13]. All parts were chosen based on quality, durability, and their suitability for educational use. Then in the Develop stage, a prototype of the kit was assembled.

During the Implement stage, the prototype was pilot tested with 30 engineering students at Universitas Trisakti, Jakarta, Indonesia. Data collected for each launch angle (repeated 10 times) included air time, maximum distance, maximum height, air pressure, rocket nozzle diameter, initial rocket mass, and final rocket mass. Experiments were conducted using both three- and four-finned rockets to examine stability and performance, consistent with methodologies used in practical physics research [4].

In the final evaluation stage, experimental results were compared with theoretical calculations to assess the kit's effectiveness in demonstrating physics concepts and to identify discrepancies for further improvement. Iterative evaluation and refinement are

essential aspects of the ADDIE approach and are supported by best practices in instructional design [11], [12].

2.1 Development of Research Instrument

Two self-developed questionnaires were used as primary research instruments. The first questionnaire was designed for expert assessment, aiming to evaluate the content accuracy, clarity, and alignment of the Arduino-based water rocket launcher with educational objectives. The second questionnaire targeted end-users (students), focusing on their attitudes and satisfaction with the kit's usability and learning value. Both questionnaires employed twelve statements rated on a four-point Likert scale, ranging from "strongly disagree" to "strongly agree," allowing participants to express their level of agreement with each item [14].

2.2 Validity and Reliability

Content validity was established through expert review: two lecturers in science education and two experienced physics teachers examined the questionnaire drafts for completeness, accuracy, and item clarity. Their feedback was used to revise ambiguous or redundant items, following established guidance for instrument validation [15].

Cronbach’s alpha was utilized to assess internal consistency as a measure of reliability. The experts’ questionnaire yielded a Cronbach’s alpha of .513, indicating weak internal consistency and suggesting that items may assess somewhat different constructs or lack coherence [16]. This result should be interpreted with caution; further item refinement or expansion may be warranted. In contrast, the user attitude questionnaire demonstrated excellent reliability with a Cronbach’s alpha of .964, well above the commonly accepted threshold of .7, indicating strong internal consistency and repeatability among items. Together, these steps help ensure that the research instruments are credible for evaluating both expert perspectives and end-user experiences in the context of educational kit development.

2.3 Data Collection Procedure

2.3.1 Target Respondents

To ensure participants were appropriately qualified to address the research objectives, the expert questionnaire was distributed to university lecturers in Indonesia

who specialize in fundamental physics and mechanical engineering, particularly those involved with experimental topics such as water rocket investigations. These experts were selected from departments known to support and engage with the Arduino-based water rocket launcher, ensuring the feedback was grounded in relevant technical and pedagogical experience [17]. The user questionnaire was administered to students enrolled in fundamental physics courses within the mechanical engineering department at the same university. These students had recent hands-on experience with the Arduino-based water rocket launcher developed for this research.

2.3.2 Instrument Delivery and Collection

For the user survey, the procedure was as follows: Researchers collaborated with faculty within the engineering faculty to identify relevant departments and courses where fundamental physics experiments are taught. Course lecturers were briefed about the developed water rocket launcher and its intended educational use. The demonstration of the tool was conducted as part of a laboratory experiment. After participating in the experiment, students were invited to complete the user questionnaire. For the expert evaluation, five lecturers across different subject areas relating to tool development and mechanical engineering were individually contacted and invited to review and test the educational kit. They then completed the expert questionnaire provided by the research team.

2.3.3 Responding Rate

A total of 5 expert questionnaires and 35 user questionnaires were distributed. All 5 experts responded (100% response rate), and 33 out of 35 students completed the user questionnaire, resulting in a response rate of approximately 94%. These response rates are considered high and support the credibility of the dataset [18].

2.3.4 Respondents' Professional Background

The five expert respondents were experienced lecturers teaching subjects associated with industrial automation, materials engineering, machine construction, applied physics, and fluid mechanics. The 33 student participants were undergraduates enrolled in a fundamental physics course within the mechanical engineering department, ensuring familiarity with both the subject matter and the experimental apparatus.

2.3.5 Statistical Analysis

All responses were analyzed using IBM SPSS Statistics version 22.0. Cronbach's alpha was first calculated to assess the internal consistency of the instruments. Descriptive statistics (means and standard deviations) were then computed to summarize participant perceptions of the Arduino-based water rocket launcher and to identify strengths and areas for improvement. Where appropriate, inferential tests such as independent-samples t-tests were used to examine group differences in perception or satisfaction, following standard practice in educational evaluation research [19].

3 Results and Discussions

Expert Evaluation of Arduino-based Water Rocket Launcher

Experts provided high ratings for the launcher kit across multiple dimensions, with mean scores ranging from 3.80 to 4.00 out of 4.00 (Table 2). All respondents agreed that the kit aligns well with key physics concepts, supports project-based learning, and can be safely and effectively utilized in the classroom with minimal teacher supervision.
Each item was rated by experts on a four-point Likert scale:
4 = Strongly agree, 3 = Agree, 2 = Disagree, 1 = Strongly disagree.

Table 2. Expert evaluation of arduino-based water rocket launcher

No	Factors	Mean Score
1	The launcher kit aligns well with physics concepts (e.g., Newton's Laws, projectile motion).	4.00
2	The launcher kit content is appropriate for the intended educational level.	3.80
3	The experiment reflects real-world physics principles accurately.	3.80
4	The design and materials of the launcher are appropriate for school use.	4.00
5	The Arduino programming is relevant and effectively supports the experiment.	4.00

No	Factors	Mean Score
6	The Bluetooth control system operates reliably and enhances interactivity.	4.00
7	The launcher kit helps students understand complex concepts in a simple and engaging way.	4.00
8	The launcher kit supports student-centered, project-based learning methods.	3.80
9	The launcher kit encourages students' curiosity and scientific thinking.	4.00
10	The launcher kit is safe for classroom/laboratory use with minimal risk.	3.40
11	Instructions for assembling and operating the launcher kit are clear and easy to follow.	4.00
12	The launcher kit can be used with minimal teacher supervision.	4.00

User Evaluation on Arduino-based Water Rocket Launcher

As shown in Table 3, user ratings for the Arduino-based water rocket launcher were consistently high across all measured factors, with mean scores generally above 3.8 (on a 4-point Likert scale). Respondents agreed that the kit was easy to use, enhanced engagement through Bluetooth control, and helped clarify important physics concepts such as the relationship between launch angle, pressure, and projectile motion. Most participants indicated that the activity fostered critical thinking, made lessons feel more "real" and hands-on, and increased their interest in physics and technology.

Each item was rated by experts on a four-point Likert scale:
4 = Strongly agree, 3 = Agree, 2 = Disagree, 1 = Strongly disagree.

Table 3. User evaluation on arduino-based water rocket launcher

No.	Factors	Mean Score
1	The launcher kit is easy to set up and operate.	3.85
2	The Bluetooth control makes launching the rocket more engaging.	3.85
3	I am able to control the launcher's angle and timing easily.	3.79
4	The instructions are easy to understand.	3.85
5	The activity helps me understand physics concepts better.	3.91
6	Using the launcher kit makes the physics lesson more enjoyable.	3.91
7	I now have a better understanding of how angle and pressure affect projectile motion.	3.79
8	This activity encourages me to think critically and experiment more.	3.82
9	I enjoy learning physics using this launcher kit.	3.85
10	I would recommend this activity to others learning physics.	3.82
11	This experiment makes me more interested in physics and technology.	3.85
12	The launcher kit makes the lesson feel more real and hands-on.	3.88

3.1 Discussions

Experts Recommendations

Expert evaluations highlighted that the utilization of Arduino as the primary controller was appropriate for facilitating interactive physics experiments, as it simplifies measurement and allows for reproducible trials, an advantage well documented in literature on technology-enhanced science learning [6]. However, experts emphasized the need to further enhance data accuracy through well-defined sensor calibration procedures, particularly for the pressure and angle sensors. Incorporating calibration steps and validating measurements against standardized reference instruments, such as a certified manometer, are essential to ensuring the reliability of experimental data [20].

In addition, experts recommended explicit documentation of safety operating procedures (SOP), including the use of personal protective equipment (PPE), maintaining

a safe distance, and installing protective barriers during launches. Refining the launcher's structural stability, through a stronger support base or reinforced framework, was also suggested to improve operational safety and consistency.

Enhancements in user experience and data management were among the suggestions, specifically the development of a simple graphical user interface (GUI) using platforms such as Processing or web-based dashboards to monitor real-time parameters like pressure and angle. Automated data storage to SD cards or cloud-based systems was recommended to facilitate subsequent data analysis and reporting.

Documentation emerged as a priority; experts urged the inclusion of comprehensive Arduino schematic diagrams, complete source code, and a detailed component list in supplemental materials. Providing an accessible user manual would also allow for the tool's replication and wider adoption in other educational settings [13].

To further strengthen the instructional value, experts recommended a more rigorous theoretical framework, utilizing equations of projectile motion and fluid dynamics to model the rocket's behavior. Direct comparison of experimental outcomes with theoretical predictions would offer students deeper insight into the physical principles at play and promote higher-order analytical skills.

User Feedback

User responses were overwhelmingly positive. Students consistently reported that the Arduino-based water rocket launcher was engaging, easy to operate, and effective in clarifying physics concepts through hands-on investigation. Many respondents expressed increased motivation and interest in physics and technology and viewed the tool as highly beneficial for active learning in engineering education. Several users suggested maintaining or expanding the deployment of this tool, with some proposing commercial development for broader educational access.

Direct comments highlighted that the activity made abstract physics concepts feel more tangible and enjoyable, and that the launcher contributed positively to both their learning and classroom experience. No significant negative feedback or suggestions for major improvements were recorded, indicating a strong alignment of the tool with student expectations and educational needs.

Launch Result and Comparison with Theoretical Value

To evaluate the performance of the Arduino-based launcher and analyze its educational effectiveness, researchers compared empirical launch data with theoretical predictions. Due to the brevity of the rocket's powered flight phase, a simplified model was employed: the mass flow rate ($\dot{m}$) was first calculated using the nozzle area, the water density, and the internal bottle pressure, following Sutton & Biblarz [20]:

$$\dot{m} = C_d A\sqrt{2\rho P} \tag{2}$$

where:

$\dot{m}$ is the mass flow rate (kg/s)

C_d is the discharge coefficient (average is 0.7)

A is the cross-sectional area of the nozzle (m^2)

ρ is the density of water (approximately 1000 kg/m^3)

P is the pressure inside the bottle (Pa)

The exhaust velocity of the water leaving the rocket nozzle was approximated using Bernoulli's equation:

$$v_e = \sqrt{\frac{2(P_{in} \times P_{out})}{\rho}} \tag{3}$$

where:

P_{in} is the pressure inside the bottle

P_{out} is the pressure of air outside the bottle

ρ is the density of water.

Total thrust (T) is then calculated as:

$$T = \dot{m} v_e \tag{4}$$

where:

$\dot{m}$ is the mass flow rate.

v_e is the exhaust velocity.

The initial velocity v_0 is derived using the thrust and the duration of the powered flight.

$$v_0 = \frac{T \times t_{powered}}{m_i} \tag{5}$$

where:

T is the thrust.

$t_{powered}$ is the powered flight time

m_i is the initial mass of the rocket.

For the ballistic (unpowered) phase, standard projectile motion equations give maximum height (hmax) and range (R) [21]:

$$H_{max} = H_{powered} + \frac{v_0^2 \sin^2(\theta)}{2g} \quad (6)$$

$$R = D_{powered} + \frac{v_0^2 \sin(2\theta)}{g} \quad (7)$$

Given the short-powered flight time, the rocket's initial velocity and subsequent projectile motion can be approximated without detailed integration. According to the mentioned equations, the theoretical value compared to the experimental value of maximum height and total distance are as following.

For maximum height, the percentage difference between experimental and theoretical values for the three-finned rocket ranged from 0.0% to 52.6%, whereas for the four-finned rocket, it ranged from 1.2% to 51.8%. In terms of total distance (range), the percentage differences for the three-finned rocket ranged from 3.4% to 36.8%, and for the four-finned rocket from 2.1% to 42.7%, excluding cases where the theoretical value was zero (vertical launches at 90°, for which the theoretical range is always zero and the percentage difference is undefined).

These variations can be attributed to multiple factors, including experimental limitations, air resistance, minor inconsistencies in rocket construction, or deviations in the discharge coefficient from assumed values. Researchers use the average value 0.7 for discharge coefficient due to the limitations of apparatus, while the actual number may vary from 3-fins rocket to 4-fins rockets (Table 4). Another possible cause that causes the difference is the flaw in the rocket design itself, with flaws which make it not following projectile trajectory.

Larger discrepancies, exceeding 50% in some height comparisons, often occurred at lower or intermediate launch angles, which may reflect measurement errors, environmental influences, or instability during flight. Nonetheless, the data generally demonstrate reasonable agreement between theoretical models and empirical outcomes,

underscoring the kit's value as a practical, inquiry-based learning tool. The inclusion of quantitative error analysis not only deepens students' understanding of the underlying physics but also highlights the importance of critical thinking and iterative improvement in experimental science [4], [20].

Table 4. Comparison between experimental and theoretical data

Number of Fins	Launch Angle (°)	Experimental		Theoretical	
		Maximum Height (m)	Total Distance (m)	Maximum Height (m)	Total Distance (m)
3	15	0.30	7.40	0.30	5.63
3	30	1.33	14.35	2.70	22.39
3	45	2.35	20.86	4.96	23.39
3	60	5.23	13.51	6.65	17.19
3	75	6.01	10.34	8.58	10.08
3	90	9.41	2.52	8.30	0.00
4	15	1.67	10.15	1.10	17.71
4	30	2.92	18.13	2.46	23.01
4	45	4.14	23.10	4.46	21.42
4	60	5.84	15.56	7.72	22.08
4	75	8.67	12.96	10.25	13.24
4	90	10.40	3.79	10.53	0.00

4 Conclusions

The development and evaluation of an Arduino-based water rocket launcher demonstrated both strong feasibility and educational value. Quantitative comparisons showed that, while some measurement discrepancies exist due to real-world factors, the experimental results broadly align with theoretical predictions, providing a sound basis for experiential physics education. Expert assessments confirmed that the tool is pedagogically effective, technologically robust, and safe for classroom and laboratory

use, while user feedback underscored its positive impact on student engagement, motivation, and conceptual understanding.

In summary, the Arduino-based water rocket launcher offers a replicable, scalable, and impactful solution for introducing project-based STEM learning. Continued development should focus on enhancing data accuracy, safety, and supporting materials to maximize its educational potential. Broader implementation may contribute to improved science learning outcomes and increased student interest in physics and engineering disciplines.

Acknowledgements

We would like to express my sincere gratitude to Universitas Trisakti for providing the facilities and resources. Our appreciation goes to all participants and colleagues who contributed to this study. Finally, we are deeply grateful to my family and friends for their encouragement throughout this journey.

References

[1] L. D. English, "STEM education K-12: Perspectives on integration," *International Journal of STEM Education*, vol. 3, no. 1, pp. 1–8, March 2016. https://doi.org/10.1186/s40594-016-0036-1

[2] T. Kennedy & M. Odell, "Engaging students in STEM education". *Science Education International*, vol. 25, no. 3, pp. 246–258, Available: https://files.eric.ed.gov/fulltext/EJ1044508.pdf

[3] Z. Abidi, R. A. Annisa, A. R. Arianti, & Y. H. Anggriawan, "Integrating STEM and Environmental Education: Effects On Student Attitudes and Knowledge", *International Journal of Mathematics and Science Education*, vol. 1, no. 1, pp. 48–54. https://doi.org/10.62951/ijmse.v1i1.80

[4] R. J. Beichner, "Instructional technology research and development in a US physics education group," *European Journal of Engineering Education*, vol. 31, no. 4, pp. 383–393, August 2006, https://doi.org/10.1080/03043790600676125

[5] D. Herro & C. Quigley, "Exploring teachers' perceptions of STEAM teaching through professional development: implications for teacher educators," *Professional Development in Education*, vol. 43, no. 3, pp. 416–438, Jul. 2016, https://doi.org/10.1080/19415257.2016.1205507

[6] García-Tudela, Pedro & Marín-Marín, José-Antonio. (2023). Use of Arduino in Primary Education: A Systematic Review. Education Sciences. 13. 134. https://doi.org/10.3390/educsci13020134

[7] Box, S., Bishop, C. M., & Hunt, H. (2014). *Stochastic six-degree-of-freedom flight simulator for passively controlled high-power rockets*. Journal of Aerospace Engineering, 24(1), 31-45. https://doi.org/10.1061/(ASCE)AS.1943-5525.0000252

[8] Muslow, M. (2011). *Modelling and optimization of multi-stage water rockets* (Bachelor's thesis). Ernst-Moritz-Arndt-Universität Greifswald. Retrieved from https://physik.uni-greifswald.de/storages/uni-greifswald/fakultaet/mnf/physik/ag_schneider/Arbeiten/matthiasBA.pdf

[9] Dick, W., & Carey, L. 1996. *The systematic design of instruction 4th ed*. New York, NY: HarperCollins College Publishers.

[10] Molenda, M. (2003). *In search of the elusive ADDIE model.* Performance Improvement, 42(5), 34–36. https://doi.org/10.1002/pfi.4930420508

[11] Branch, R. M. (2009). Instructional design: The ADDIE approach. Springer. https://doi.org/10.1007/978-0-387-09506-6

[12] Gagné, R. M., Wager, W. W., Golas, K. C., & Keller, J. M. (2005). Principles of instructional design (5th ed.). Wadsworth/Thomson Learning.

[13] Mills, Julie & Treagust, David. (2003). *Engineering Education, Is Problem-Based or Project-Based Learning the Answer.* Aust J Eng Educ. 3.

[14] DeVellis, R. F. (2017). *Scale development: Theory and applications* (4th ed.). Sage Publications.

[15] Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). *Best practices for developing and validating scales for health, social, and behavioral research: A primer*. Frontiers in Public Health, 6, 149. https://doi.org/10.3389/fpubh.2018.00149

[16] Tavakol, M., & Dennick, R. (2011). *Making sense of Cronbach's alpha.* International Journal of Medical Education, 2, 53–55.

[17] Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage.

[18] Fowler, F. J. (2014). Survey research methods (5th ed.). Sage.Box, S., Bishop, C. M., & Hunt, H. (2014). Stochastic six-degree-of-freedom flight simulator for passively controlled high-power rockets. *Journal of Aerospace Engineering, 24*(1), 31-45. https://doi.org/10.1061/(ASCE)AS.1943-5525.0000252

[19] Field, A. (2013). *Discovering statistics using IBM SPSS Statistics* (4th ed.). Sage.

[20] Sutton, G. P., & Biblarz, O. (2016). *Rocket propulsion elements* (9th ed.). John Wiley & Sons.

[21] Serway, R. A., & Jewett, J. W. (2014). *Physics for scientists and engineers with modern physics* (9th ed.). Cengage Learning.

[22] Irawati, I. (2016). *Water rocket competition: Application of project-based physics learning.* Proceedings of the National Seminar on Physics (E-Journal) SNF2016, 5, 29-34. https://doi.org/10.21009/0305010207

Larasati Rizky FTI

12.Larasati+Rizky+Putri,+Fakhrizal+Arsi,+Kiar+Vansa+Febriant...

GENAP 2025-2026 (2)

Document Details

Submission ID
trn:oid:::3618:149594481

Submission Date
Aug 27, 2026, 2:25 PM GMT+7

Download Date
Aug 27, 2026, 2:43 PM GMT+7

File Name
12.Larasati+Rizky+Putri,+Fakhrizal+Arsi,+Kiar+Vansa+Febrianti,+Sentot+Novianto,+Ika+Wahyu+U....pdf

File Size
775.0 KB

22 Pages

5,334 Words

30,077 Characters

7% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography
- Quoted Text

Exclusions

- 1 Excluded Source
- 15 Excluded Matches

Match Groups

22 Not Cited or Quoted 4%
Matches with neither in-text citation nor quotation marks

16 Missing Quotations 3%
Matches that are still very similar to source material

0 Missing Citation 0%
Matches that have quotation marks, but no in-text citation

0 Cited and Quoted 0%
Matches with in-text citation present, but no quotation marks

Top Sources

5% Internet sources
3% Publications
4% Submitted works (Student Papers)

Integrity Flags

0 Integrity Flags for Review

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

Match Groups

- **22** Not Cited or Quoted 4%
  Matches with neither in-text citation nor quotation marks
- **16** Missing Quotations 3%
  Matches that are still very similar to source material
- **0** Missing Citation 0%
  Matches that have quotation marks, but no in-text citation
- **0** Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

- 5% Internet sources
- 3% Publications
- 4% Submitted works (Student Papers)

Top Sources

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Student papers	
University of Malaya on 2017-03-23		<1%
2	Internet	
futurity-philosophy.com		<1%
3	Internet	
www.frontiersin.org		<1%
4	Internet	
www.iiste.org		<1%
5	Internet	
www.sec.gov		<1%
6	Student papers	
BITS, Pilani-Dubai on 2014-12-26		<1%
7	Student papers	
British International School on 2015-01-31		<1%
8	Internet	
aaacwa.com		<1%
9	Student papers	
University of Warwick on 2026-08-26		<1%
10	Internet	
bspace.buid.ac.ae		<1%

11 Internet
core-cms.prod.aop.cambridge.org <1%

12 Internet
dspace.enset-skikda.dz <1%

13 Student papers
Faculty of Educational Sciences and Technology on 2025-07-22 <1%

14 Student papers
John Paul College on 2018-06-19 <1%

15 Publication
P. Kedarnath Reddy, Rahul Kulkarni, Sumit Sen. "A Cost-Effective Probe for Monit... <1%

16 Student papers
Scout from University of California on 2025-11-09 <1%

17 Internet
learning-gate.com <1%

18 Publication
Ahmad Faiz Shaharin, Shahrul Kadri Ayop, Anis Nazihah Mat Daud. "The Develop... <1%

19 Student papers
Laguna College of Business and Arts on 2026-04-12 <1%

20 Publication
S. Karthikeyan. "PERCEIVED EFFECTIVENESS OF CREDIT SERVICES OF DIFFERENT D... <1%

21 Internet
umu.diva-portal.org <1%

22 Internet
www.redbooklive.com <1%

23 Internet
(7-22-15) http://128.86.132.180/sites/default/files/programme_resources/lse/lse_p... <1%

24 Student papers
Faculty of Educational Sciences and Technology on 2025-07-23 <1%

25 Student papers

Politeknik Sultan Azlan Shah (PSAS) on 2026-07-14 <1%

26 Internet

esp.as-pub.com <1%

27 Internet

impa.usc.edu <1%

28 Internet

repository.usd.ac.id <1%

29 Internet

www.jrmsu.university <1%

30 Internet

yayinevi.trakya.edu.tr <1%

31 Student papers

Universiti Teknologi MARA on 2026-08-26 <1%

32 Publication

Carla C. Johnson, Margaret J. Mohr-Schroeder, Tamara J. Moore, Lyn D. English. "H... <1%

33 Internet

mdpi-res.com <1%

34 Internet

itdl.org <1%

35 Internet

ejournal.uin-suska.ac.id <1%

turnitin Page 6 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

IJASST International Journal of Applied Sciences and Smart Technologies
Volume 08
Issue 01
p-ISSN 2655-8564, e-ISSN 2685-943, pp. 239-260, 2025

Development of an Arduino-Based Water Rocket Launcher in Physics Experiments

Larasati Rizky Putri[1*], Fakhrizal Arsi[2], Kiar Vansa Febrianti[3], Sentot Novianto[1], Ika Wahyu Utami[1], Muhammad Najih[1] Sofia Debi Puspa[1], Amrullah Gilang Ibrahim[1], Harry Munandar[1]

[1]*Faculty of Industrial Technology, Universitas Trisakti, Grogol West Jakarta, 11440, Indonesia*
[2]*Physics of High School, State Senior High School 8 Jakarta, Tebet South Jakarta, 12840, Indonesia*
[3]*Physics of Middle School and High School, Cita Buana School, Jagakarsa South Jakarta, 12620, Indonesia*
[*]*Corresponding Author: larasati.rizki@trisakti.ac.id*

(Received 18-09-2025; Revised 02-12-2025; Accepted 09-04-2026)

Abstract
The effective science education requires practical methods that allow students to explore complex physics concepts. One promising approach is the use of physics experiment as an interactive media. This research focuses on the development of water rocket launcher using an Arduino as an innovative physics experiment. Arduino in water rocket launcher is used for making the precise control and relevant measurement of variables, such as angle of projection, speed of launch, maximum altitude of launch, and air pressure. The research process followed the ADDIE instructional design model and involved hardware, software prototyping, work testing, and user instruction. The launcher's performance was tested with 33 engineering students and assessed by 5 experts. Expert evaluations rated the relevance, design, and usability of the kit highly (3.4–4.0 on a 4-point Likert scale). User responses from 33 students indicated strong agreement on ease of use and engagement (mean scores 3.79–3.91), with a high reliability (Cronbach's alpha = .964). Experimental launches, using three and four finned rockets, showed maximum height percentage differences between theoretical and observed values ranging from 0.0%–52.6% (three fins) and 1.2%–51.8% (four fins); range errors were 3.4%–36.8% (three fins) and 2.1%–42.7% (four fins). The findings confirm that the Arduino-based water rocket launcher provides effective, interactive learning, though further refinement in data accuracy and instructional materials is recommended to maximize its classroom impact and is needed for improved accuracy.

Keywords: Arduino, Experiment, Launcher, Water Rocket.

1 Introduction

Science, Technology, Engineering, and Mathematics (STEM) education is widely recognized as a key driver for developing problem-solving ability, creativity, and 21st-

This work is licensed under a Creative Commons Attribution 4.0 International License
turnitin Page 6 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 7 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

century skills among students [1], [2], [3]. Project-based and hands-on learning, especially in physics, has been found to increase student engagement, conceptual understanding, and scientific interest [3], [4]. However, in many educational settings, barriers such as limited resources and teacher readiness can restrict the adoption of innovative practical activities [5].

Integrating microcontroller platforms, such as Arduino, into physics classrooms enables students to automate experiments, collect real-time data, and connect abstract concepts with tangible projects [6]. Reviews and systematic studies confirm that Arduino-based activities help bridge theory with practice, enhance computational thinking, and support the development of engineering skills [1], [6]. Water rocket experiments, in particular, are effective for teaching core topics like Newton's laws, the action-reaction principle, air pressure [7], momentum, and projectile motion, all while enhancing motivation and inquiry-based learning [3], [4].

Despite these benefits, implementing Arduino-enhanced practical physics projects on a broad scale requires consideration of curriculum integration, teacher training, and equitable access to technology [5]. To answer that problem, the research needs to consider the technical aspects of developing a water rocket launcher, including optimal hardware and software design. In addition, the research should also determine whether the water rocket launcher is properly made by comparing the launch data with theoretical data. Thus, this study aims to design, build, and evaluate an Arduino-based water rocket launcher as an engaging physics teaching tool, assessing its impact on student understanding and motivation in physics learning.

1.1 Principles of STEM and Project-Based Learning

STEM education is grounded in the integration of science, technology, engineering, and mathematics, aiming to equip students with skills for problem-solving, inquiry, and innovation [1], [2]. Project-based learning (PBL), a cornerstone of effective STEM teaching, encourages students to engage deeply with content by designing, constructing, and evaluating tangible products or solutions [4]. Research shows that PBL promotes higher-order thinking and increases students' motivation for learning science concepts [3].

turnitin Page 7 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 8 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

The successful implementation of technological tools like Arduino within STEM education demands not only adequate resources but also teacher readiness and effective curriculum integration [5]. Professional development and support help educators design learning experiences where technology is not an add-on but an essential part of the investigation and discovery process.

1.2 Physics of Water Rocket

Water rocket experiments are an accessible means to teach principles of mechanics, specifically Newton's laws of motion, conservation of momentum, and projectile motion. When the rocket is launched, expelling water downwards due to the pressurized air creates an upward thrust as described by Newton's third law. The motion of the rocket after launch demonstrates projectile motion, where the range and maximum height can be mathematically described using classical equations:

$$R = \frac{v_0^2 \sin 2\theta}{g} \quad (1)$$

where R is the range, v_0 is the initial velocity, θ is the launch angle, and g is the acceleration due to gravity [4].

1.3 Water Rocket Launcher

Project-based physics learning allows students to research, plan, design and reflect on the creation of their technology projects. This type of learning not only stimulates student creativity but also requires different assessments. Projects will provide information about students' understanding and knowledge of the learning process, their ability to apply knowledge, and their ability to communicate information. Recent research in this field has shown that the use of Arduino-based water rocket launchers can improve students' understanding of physics concepts. In addition, the use of this technology also stimulates students' interest in science and technology. This is particularly relevant in the face of modern educational challenges where students often struggle to understand abstract physics concepts [22].

turnitin Page 8 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 9 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

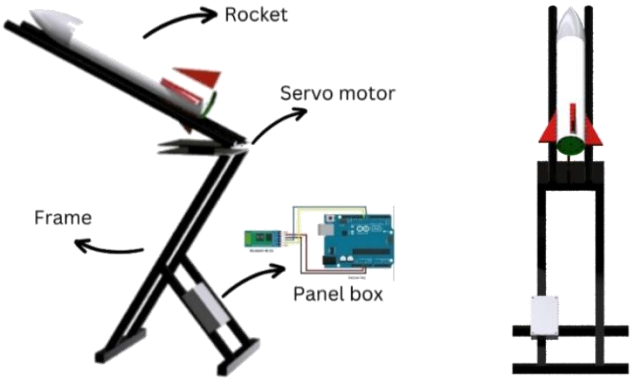


Figure 1. Development of water rocket launcher: (a) Parts of Arduino-based water rocket launcher and (b) Back view of the launcher.

The components of the launcher are shown in Fig. 1. The main raw material of the kit is hollow aluminum pipe and 3 mm iron plates. Hollow pipe was cut into several pieces, then iron plates were cut into 20 × 20 cm size. Researcher also welded the hollow pipes into L-shape. After that researcher drills some hole for motor servo installation later, then welded iron plates to the hollow pipes and installed ball bearings between the plates. After the frame is fixed, researcher installed servo motors and the Arduino. The installation documentation is shown in Fig. 2.

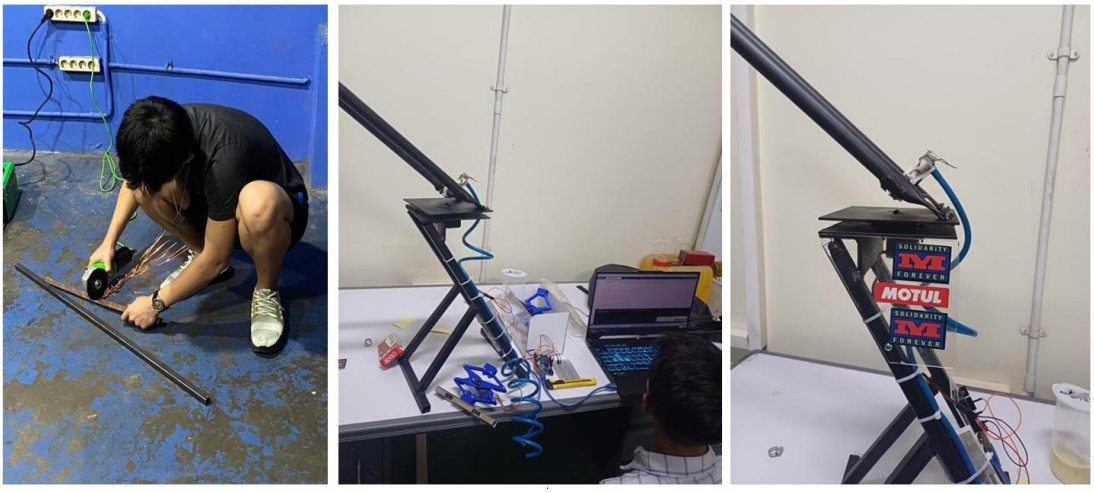


Figure 2. Frame assembly and installation

turnitin Page 9 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 10 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

1.4 Arduino Installation and Coding

Arduino is an open-source microcontroller platform, widely adopted for introducing automation, programming, and sensor data acquisition in classroom environments. Systematic reviews of classroom Arduino use show that it fosters the development of computational thinking, problem-solving, and scientific inquiry [6]. In STEM projects, Arduino provides a bridge between theoretical physics and practical application by allowing real-time measurement, control of system variables (such as launch angle or timing), and digital data logging [6].

As technology advances, the use of Arduino in the development of water rocket launchers has become increasingly popular. Arduino is an affordable and programmable hardware platform that can be used to control a wide variety of experimental tools, including water rocket launchers. With Arduino, teachers can program the device to measure physics parameters during the rocket launch, such as angular projection, velocity, altitude, and air pressure, so that students can see and analyze the experimental results directly [8].

The servo motor is controlled via Arduino Uno and Bluetooth module HC-05 (Fig. 3). Researcher used Bluetooth HC-05 module, male to male cable, Arduino Uno, and a breadboard. The pins of HC-05 module are connected to the Arduino with the following configuration.

- VCC : 5V
- GND : GND
- TXD : RXD
- RXD : TX

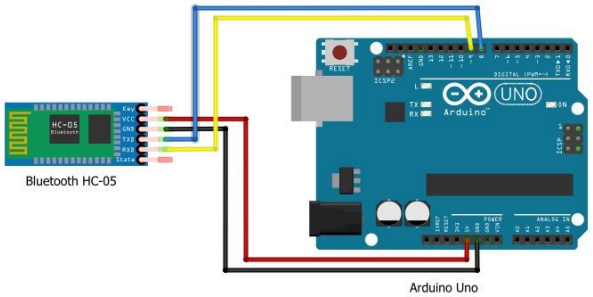


Figure 3. Arduino schemes

turnitin Page 10 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 11 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

Then, researcher installed Arduino IDE from https://www.arduino.cc/en/software, connected Arduino cable to a laptop, and run the software. The following code is written to control the servo motor (Fig. 4).

After the code is installed, researcher connected their phones to HC-05 module via Bluetooth, and control the Arduino using Arduino Controller apps. The rocket launcher then tested with two types of rockets, 3-fins rocket and 4-fins rocket as shown in Fig.5.

```
#include <Servo.h>
Servo servoAxis1;  // Create servo object for first axis
Servo servoAxis2;  // Create servo object for second axis
int posAxis1 = 90;  // Initial value for first axis (90°)
int posAxis2 = 90;  // Initial value for second axis (90°)
char receivedChar;  // Variabel to receive data from Bluetooth
void setup() {
  servoAxis1.attach(9);  // Attach servo motor for first axis to pin no.
9
  servoAxis2.attach(10); // Attach servo motor for first axis to pin no.
10
  Serial.begin(9600);  // Initialize serial communication
  Serial.println("Kendalikan servo dengan tombol 'u', 'd', 'l', 'r' di
ponsel Anda melalui Bluetooth."); // Print servo motor instruction in
Indonesian
}
void loop() {
  if (Serial.available() > 0) {
    receivedChar = Serial.read();
    if (receivedChar == 'u') {
      // Up botton pressed
      posAxis1 = 120;  // Adjust position increment as needed
    } else if (receivedChar == 'd') {
      // Down botton pressed
      posAxis1 = 60;  // Adjust position decrement as needed
    } else if (receivedChar == 'l') {
      // Left button pressed
      posAxis2 = 120;  // Adjust position increment as needed
    } else if (receivedChar == 'r') {
      // Right button pressed
    // Limit servo motor range
    posAxis1 = constrain(posAxis1, 0, 180);
    posAxis2 = constrain(posAxis2, 0, 180);

    // Adjust servo motor position
    servoAxis1.write(posAxis1);
    servoAxis2.write(posAxis2);
  }
}
```

Figure 4. Arduino codes

Figure 5. Three-fins rocket and four-fins rocket

Researchers compile the launch data in Table 1.

turnitin Page 11 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 12 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

Table 1. Experimental data

Number of fins	Launch Angle (º)	T (s)	Powered flight time (s)	Projectile flight time (s)	Total distance/ x total (m)	Air pressure (kPa)	Nozzle diameter (m)	Initial mass (kg)	Final mass (kg)	Ejected water mass (kg)	Max height (m)
3	15	0.82	0.01	0.82	7.4	250	0.012	0.52117	0.20777	0.3134	0.3
3	30	0.92	0.02	0.9	14.35	300	0.014	0.52117	0.18443	0.33674	1.33
3	45	1.24	0.04	1.2	20.86	250	0.016	0.52117	0.17131	0.34986	2.35
3	60	1.5	0.05	1.45	13.51	210	0.018	0.52117	0.16988	0.35129	5.23
3	75	1.69	0.07	1.62	10.34	200	0.02	0.52117	0.15933	0.36184	6.01
3	90	1.87	0.09	1.78	2.52	150	0.024	0.52117	0.15142	0.36975	9.41
4	15	0.68	0.01	0.67	10.15	350	0.012	1.00479	0.30036	0.70443	1.67
4	30	0.77	0.02	0.75	18.13	300	0.014	1.00479	0.34658	0.65821	2.92
4	45	1.15	0.04	1.11	23.1	250	0.016	1.00479	0.35958	0.64521	4.14
4	60	1.44	0.06	1.38	15.58	210	0.018	1.00479	0.23772	0.76707	5.84
4	75	1.66	0.08	1.58	12.96	200	0.02	1.00479	0.20513	0.79966	8.67
4	90	1.95	0.12	1.83	3.79	150	0.024	1.00479	0.18248	0.82231	10.4

turnitin Page 12 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 13 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

2 Material and Methods

This research utilized the Research and Development (R&D) approach, adopting the ADDIE instructional design model, Analysis, Design, Development, Implementation, and Evaluation, as proposed by Dick and Carey in 1996 [9] and adapted widely in educational technology development [10], [11]. The ADDIE model provides a systematic and iterative process well-suited to producing effective educational materials and STEM kits [11].

To begin, the researchers conducted open-ended interviews with physics teachers to identify challenges and needs in conducting water rocket activities. The feedback highlighted practical difficulties in assembling launchers and the need for better alignment with learning objectives. As suggested by prior studies, gathering user input in the early stages supports relevant and effective instructional design [12]. Consequently, this research was undertaken to create an Arduino-based water rocket launcher so that teachers can focus more in the physical concepts rather than the launcher assembly itself.

During the Design stage, the water rocket launcher was designed using 3D modelling software. Particular attention was paid to selecting low-cost, locally available components, ensuring affordability and ease of replication, an important consideration in educational kit design [13]. All parts were chosen based on quality, durability, and their suitability for educational use. Then in the Develop stage, a prototype of the kit was assembled.

During the Implement stage, the prototype was pilot tested with 30 engineering students at Universitas Trisakti, Jakarta, Indonesia. Data collected for each launch angle (repeated 10 times) included air time, maximum distance, maximum height, air pressure, rocket nozzle diameter, initial rocket mass, and final rocket mass. Experiments were conducted using both three- and four-finned rockets to examine stability and performance, consistent with methodologies used in practical physics research [4].

In the final evaluation stage, experimental results were compared with theoretical calculations to assess the kit's effectiveness in demonstrating physics concepts and to identify discrepancies for further improvement. Iterative evaluation and refinement are

turnitin Page 13 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 14 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

essential aspects of the ADDIE approach and are supported by best practices in instructional design [11], [12].

2.1 Development of Research Instrument

Two self-developed questionnaires were used as primary research instruments. The first questionnaire was designed for expert assessment, aiming to evaluate the content accuracy, clarity, and alignment of the Arduino-based water rocket launcher with educational objectives. The second questionnaire targeted end-users (students), focusing on their attitudes and satisfaction with the kit's usability and learning value. Both questionnaires employed twelve statements rated on a four-point Likert scale, ranging from "strongly disagree" to "strongly agree," allowing participants to express their level of agreement with each item [14].

2.2 Validity and Reliability

Content validity was established through expert review: two lecturers in science education and two experienced physics teachers examined the questionnaire drafts for completeness, accuracy, and item clarity. Their feedback was used to revise ambiguous or redundant items, following established guidance for instrument validation [15].

Cronbach's alpha was utilized to assess internal consistency as a measure of reliability. The experts' questionnaire yielded a Cronbach's alpha of .513, indicating weak internal consistency and suggesting that items may assess somewhat different constructs or lack coherence [16]. This result should be interpreted with caution; further item refinement or expansion may be warranted. In contrast, the user attitude questionnaire demonstrated excellent reliability with a Cronbach's alpha of .964, well above the commonly accepted threshold of .7, indicating strong internal consistency and repeatability among items. Together, these steps help ensure that the research instruments are credible for evaluating both expert perspectives and end-user experiences in the context of educational kit development.

2.3 Data Collection Procedure

2.3.1 Target Respondents

To ensure participants were appropriately qualified to address the research objectives, the expert questionnaire was distributed to university lecturers in Indonesia

turnitin Page 14 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 15 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

who specialize in fundamental physics and mechanical engineering, particularly those involved with experimental topics such as water rocket investigations. These experts were selected from departments known to support and engage with the Arduino-based water rocket launcher, ensuring the feedback was grounded in relevant technical and pedagogical experience [17]. The user questionnaire was administered to students enrolled in fundamental physics courses within the mechanical engineering department at the same university. These students had recent hands-on experience with the Arduino-based water rocket launcher developed for this research.

2.3.2 Instrument Delivery and Collection

For the user survey, the procedure was as follows: Researchers collaborated with faculty within the engineering faculty to identify relevant departments and courses where fundamental physics experiments are taught. Course lecturers were briefed about the developed water rocket launcher and its intended educational use. The demonstration of the tool was conducted as part of a laboratory experiment. After participating in the experiment, students were invited to complete the user questionnaire. For the expert evaluation, five lecturers across different subject areas relating to tool development and mechanical engineering were individually contacted and invited to review and test the educational kit. They then completed the expert questionnaire provided by the research team.

2.3.3 Responding Rate

A total of 5 expert questionnaires and 35 user questionnaires were distributed. All 5 experts responded (100% response rate), and 33 out of 35 students completed the user questionnaire, resulting in a response rate of approximately 94%. These response rates are considered high and support the credibility of the dataset [18].

2.3.4 Respondents' Professional Background

The five expert respondents were experienced lecturers teaching subjects associated with industrial automation, materials engineering, machine construction, applied physics, and fluid mechanics. The 33 student participants were undergraduates enrolled in a fundamental physics course within the mechanical engineering department, ensuring familiarity with both the subject matter and the experimental apparatus.

turnitin Page 15 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 16 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

2.3.5 Statistical Analysis

All responses were analyzed using IBM SPSS Statistics version 22.0. Cronbach's alpha was first calculated to assess the internal consistency of the instruments. Descriptive statistics (means and standard deviations) were then computed to summarize participant perceptions of the Arduino-based water rocket launcher and to identify strengths and areas for improvement. Where appropriate, inferential tests such as independent-samples t-tests were used to examine group differences in perception or satisfaction, following standard practice in educational evaluation research [19].

3 Results and Discussions

Expert Evaluation of Arduino-based Water Rocket Launcher

Experts provided high ratings for the launcher kit across multiple dimensions, with mean scores ranging from 3.80 to 4.00 out of 4.00 (Table 2). All respondents agreed that the kit aligns well with key physics concepts, supports project-based learning, and can be safely and effectively utilized in the classroom with minimal teacher supervision.

Each item was rated by experts on a four-point Likert scale:

4 = Strongly agree, 3 = Agree, 2 = Disagree, 1 = Strongly disagree.

Table 2. Expert evaluation of arduino-based water rocket launcher

No	Factors	Mean Score
1	The launcher kit aligns well with physics concepts (e.g., Newton's Laws, projectile motion).	4.00
2	The launcher kit content is appropriate for the intended educational level.	3.80
3	The experiment reflects real-world physics principles accurately.	3.80
4	The design and materials of the launcher are appropriate for school use.	4.00
5	The Arduino programming is relevant and effectively supports the experiment.	4.00

turnitin Page 16 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 17 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

No	Factors	Mean Score
6	The Bluetooth control system operates reliably and enhances interactivity.	4.00
7	The launcher kit helps students understand complex concepts in a simple and engaging way.	4.00
8	The launcher kit supports student-centered, project-based learning methods.	3.80
9	The launcher kit encourages students' curiosity and scientific thinking.	4.00
10	The launcher kit is safe for classroom/laboratory use with minimal risk.	3.40
11	Instructions for assembling and operating the launcher kit are clear and easy to follow.	4.00
12	The launcher kit can be used with minimal teacher supervision.	4.00

User Evaluation on Arduino-based Water Rocket Launcher

As shown in Table 3, user ratings for the Arduino-based water rocket launcher were consistently high across all measured factors, with mean scores generally above 3.8 (on a 4-point Likert scale). Respondents agreed that the kit was easy to use, enhanced engagement through Bluetooth control, and helped clarify important physics concepts such as the relationship between launch angle, pressure, and projectile motion. Most participants indicated that the activity fostered critical thinking, made lessons feel more "real" and hands-on, and increased their interest in physics and technology.

Each item was rated by experts on a four-point Likert scale:
4 = Strongly agree, 3 = Agree, 2 = Disagree, 1 = Strongly disagree.

turnitin Page 17 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 18 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

Table 3. User evaluation on arduino-based water rocket launcher

No.	Factors	Mean Score
1	The launcher kit is easy to set up and operate.	3.85
2	The Bluetooth control makes launching the rocket more engaging.	3.85
3	I am able to control the launcher's angle and timing easily.	3.79
4	The instructions are easy to understand.	3.85
5	The activity helps me understand physics concepts better.	3.91
6	Using the launcher kit makes the physics lesson more enjoyable.	3.91
7	I now have a better understanding of how angle and pressure affect projectile motion.	3.79
8	This activity encourages me to think critically and experiment more.	3.82
9	I enjoy learning physics using this launcher kit.	3.85
10	I would recommend this activity to others learning physics.	3.82
11	This experiment makes me more interested in physics and technology.	3.85
12	The launcher kit makes the lesson feel more real and hands-on.	3.88

3.1 Discussions

Experts Recommendations

Expert evaluations highlighted that the utilization of Arduino as the primary controller was appropriate for facilitating interactive physics experiments, as it simplifies measurement and allows for reproducible trials, an advantage well documented in literature on technology-enhanced science learning [6]. However, experts emphasized the need to further enhance data accuracy through well-defined sensor calibration procedures, particularly for the pressure and angle sensors. Incorporating calibration steps and validating measurements against standardized reference instruments, such as a certified manometer, are essential to ensuring the reliability of experimental data [20].

In addition, experts recommended explicit documentation of safety operating procedures (SOP), including the use of personal protective equipment (PPE), maintaining

turnitin Page 18 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 19 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

a safe distance, and installing protective barriers during launches. Refining the launcher's structural stability, through a stronger support base or reinforced framework, was also suggested to improve operational safety and consistency.

Enhancements in user experience and data management were among the suggestions, specifically the development of a simple graphical user interface (GUI) using platforms such as Processing or web-based dashboards to monitor real-time parameters like pressure and angle. Automated data storage to SD cards or cloud-based systems was recommended to facilitate subsequent data analysis and reporting.

Documentation emerged as a priority; experts urged the inclusion of comprehensive Arduino schematic diagrams, complete source code, and a detailed component list in supplemental materials. Providing an accessible user manual would also allow for the tool's replication and wider adoption in other educational settings [13].

To further strengthen the instructional value, experts recommended a more rigorous theoretical framework, utilizing equations of projectile motion and fluid dynamics to model the rocket's behavior. Direct comparison of experimental outcomes with theoretical predictions would offer students deeper insight into the physical principles at play and promote higher-order analytical skills.

User Feedback

User responses were overwhelmingly positive. Students consistently reported that the Arduino-based water rocket launcher was engaging, easy to operate, and effective in clarifying physics concepts through hands-on investigation. Many respondents expressed increased motivation and interest in physics and technology and viewed the tool as highly beneficial for active learning in engineering education. Several users suggested maintaining or expanding the deployment of this tool, with some proposing commercial development for broader educational access.

Direct comments highlighted that the activity made abstract physics concepts feel more tangible and enjoyable, and that the launcher contributed positively to both their learning and classroom experience. No significant negative feedback or suggestions for major improvements were recorded, indicating a strong alignment of the tool with student expectations and educational needs.

turnitin Page 19 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 20 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

Launch Result and Comparison with Theoretical Value

To evaluate the performance of the Arduino-based launcher and analyze its educational effectiveness, researchers compared empirical launch data with theoretical predictions. Due to the brevity of the rocket's powered flight phase, a simplified model was employed: the mass flow rate ($\dot{m}$) was first calculated using the nozzle area, the water density, and the internal bottle pressure, following Sutton & Biblarz [20]:

$$\dot{m} = C_d A\sqrt{2\rho P} \quad (2)$$

where:

$\dot{m}$ is the mass flow rate (kg/s)

C_d is the discharge coefficient (average is 0.7)

A is the cross-sectional area of the nozzle (m^2)

ρ is the density of water (approximately 1000 kg/m^3)

P is the pressure inside the bottle (Pa)

The exhaust velocity of the water leaving the rocket nozzle was approximated using Bernoulli's equation:

$$v_e = \sqrt{\frac{2(P_{in} \times P_{out})}{\rho}} \quad (3)$$

where:

P_{in} is the pressure inside the bottle

P_{out} is the pressure of air outside the bottle

ρ is the density of water.

Total thrust (T) is then calculated as:

$$T = \dot{m} v_e \quad (4)$$

where:

$\dot{m}$ is the mass flow rate.

v_e is the exhaust velocity.

The initial velocity v_0 is derived using the thrust and the duration of the powered flight.

$$v_0 = \frac{T \times t_{powered}}{m_i} \quad (5)$$

where:

turnitin Page 20 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 21 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

T is the thrust.

$t_{powered}$ is the powered flight time

m_i is the initial mass of the rocket.

For the ballistic (unpowered) phase, standard projectile motion equations give maximum height (hmax) and range (R) [21]:

$$H_{max} = H_{powered} + \frac{v_0^2 \sin^2(\theta)}{2g} \quad (6)$$

$$R = D_{powered} + \frac{v_0^2 \sin(2\theta)}{g} \quad (7)$$

Given the short-powered flight time, the rocket's initial velocity and subsequent projectile motion can be approximated without detailed integration. According to the mentioned equations, the theoretical value compared to the experimental value of maximum height and total distance are as following.

For maximum height, the percentage difference between experimental and theoretical values for the three-finned rocket ranged from 0.0% to 52.6%, whereas for the four-finned rocket, it ranged from 1.2% to 51.8%. In terms of total distance (range), the percentage differences for the three-finned rocket ranged from 3.4% to 36.8%, and for the four-finned rocket from 2.1% to 42.7%, excluding cases where the theoretical value was zero (vertical launches at 90°, for which the theoretical range is always zero and the percentage difference is undefined).

These variations can be attributed to multiple factors, including experimental limitations, air resistance, minor inconsistencies in rocket construction, or deviations in the discharge coefficient from assumed values. Researchers use the average value 0.7 for discharge coefficient due to the limitations of apparatus, while the actual number may vary from 3-fins rocket to 4-fins rockets (Table 4). Another possible cause that causes the difference is the flaw in the rocket design itself, with flaws which make it not following projectile trajectory.

Larger discrepancies, exceeding 50% in some height comparisons, often occurred at lower or intermediate launch angles, which may reflect measurement errors, environmental influences, or instability during flight. Nonetheless, the data generally demonstrate reasonable agreement between theoretical models and empirical outcomes,

turnitin Page 21 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 22 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

underscoring the kit's value as a practical, inquiry-based learning tool. The inclusion of quantitative error analysis not only deepens students' understanding of the underlying physics but also highlights the importance of critical thinking and iterative improvement in experimental science [4], [20].

Table 4. Comparison between experimental and theoretical data

Number of Fins	Launch Angle (°)	Experimental		Theoretical	
		Maximum Height (m)	Total Distance (m)	Maximum Height (m)	Total Distance (m)
3	15	0.30	7.40	0.30	5.63
3	30	1.33	14.35	2.70	22.39
3	45	2.35	20.86	4.96	23.39
3	60	5.23	13.51	6.65	17.19
3	75	6.01	10.34	8.58	10.08
3	90	9.41	2.52	8.30	0.00
4	15	1.67	10.15	1.10	17.71
4	30	2.92	18.13	2.46	23.01
4	45	4.14	23.10	4.46	21.42
4	60	5.84	15.56	7.72	22.08
4	75	8.67	12.96	10.25	13.24
4	90	10.40	3.79	10.53	0.00

4 Conclusions

The development and evaluation of an Arduino-based water rocket launcher demonstrated both strong feasibility and educational value. Quantitative comparisons showed that, while some measurement discrepancies exist due to real-world factors, the experimental results broadly align with theoretical predictions, providing a sound basis for experiential physics education. Expert assessments confirmed that the tool is pedagogically effective, technologically robust, and safe for classroom and laboratory

turnitin Page 22 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 23 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

use, while user feedback underscored its positive impact on student engagement, motivation, and conceptual understanding.

In summary, the Arduino-based water rocket launcher offers a replicable, scalable, and impactful solution for introducing project-based STEM learning. Continued development should focus on enhancing data accuracy, safety, and supporting materials to maximize its educational potential. Broader implementation may contribute to improved science learning outcomes and increased student interest in physics and engineering disciplines.

Acknowledgements

We would like to express my sincere gratitude to Universitas Trisakti for providing the facilities and resources. Our appreciation goes to all participants and colleagues who contributed to this study. Finally, we are deeply grateful to my family and friends for their encouragement throughout this journey.

References

[1] L. D. English, "STEM education K-12: Perspectives on integration," *International Journal of STEM Education*, vol. 3, no. 1, pp. 1–8, March 2016. https://doi.org/10.1186/s40594-016-0036-1

[2] T. Kennedy & M. Odell, "Engaging students in STEM education". *Science Education International*, vol. 25, no. 3, pp. 246–258, Available: https://files.eric.ed.gov/fulltext/EJ1044508.pdf

[3] Z. Abidi, R. A. Annisa, A. R. Arianti, & Y. H. Anggriawan, "Integrating STEM and Environmental Education: Effects On Student Attitudes and Knowledge", *International Journal of Mathematics and Science Education*, vol. 1, no. 1, pp. 48–54. https://doi.org/10.62951/ijmse.v1i1.80

turnitin Page 23 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 24 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

[4] R. J. Beichner, "Instructional technology research and development in a US physics education group," *European Journal of Engineering Education*, vol. 31, no. 4, pp. 383–393, August 2006, https://doi.org/10.1080/03043790600676125

[5] D. Herro & C. Quigley, "Exploring teachers' perceptions of STEAM teaching through professional development: implications for teacher educators," *Professional Development in Education*, vol. 43, no. 3, pp. 416–438, Jul. 2016, https://doi.org/10.1080/19415257.2016.1205507

[6] García-Tudela, Pedro & Marín-Marín, José-Antonio. (2023). Use of Arduino in Primary Education: A Systematic Review. Education Sciences. 13. 134. https://doi.org/10.3390/educsci13020134

[7] Box, S., Bishop, C. M., & Hunt, H. (2014). *Stochastic six-degree-of-freedom flight simulator for passively controlled high-power rockets*. Journal of Aerospace Engineering, 24(1), 31-45. https://doi.org/10.1061/(ASCE)AS.1943-5525.0000252

[8] Muslow, M. (2011). *Modelling and optimization of multi-stage water rockets* (Bachelor's thesis). Ernst-Moritz-Arndt-Universität Greifswald. Retrieved from https://physik.uni-greifswald.de/storages/uni-greifswald/fakultaet/mnf/physik/ag_schneider/Arbeiten/matthiasBA.pdf

[9] Dick, W., & Carey, L. 1996. *The systematic design of instruction 4th ed*. New York, NY: HarperCollins College Publishers.

[10] Molenda, M. (2003). *In search of the elusive ADDIE model.* Performance Improvement, 42(5), 34–36. https://doi.org/10.1002/pfi.4930420508

[11] Branch, R. M. (2009). Instructional design: The ADDIE approach. Springer. https://doi.org/10.1007/978-0-387-09506-6

turnitin Page 24 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 25 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

[12] Gagné, R. M., Wager, W. W., Golas, K. C., & Keller, J. M. (2005). Principles of instructional design (5th ed.). Wadsworth/Thomson Learning.

[13] Mills, Julie & Treagust, David. (2003). *Engineering Education, Is Problem-Based or Project-Based Learning the Answer.* Aust J Eng Educ. 3.

[14] DeVellis, R. F. (2017). *Scale development: Theory and applications* (4th ed.). Sage Publications.

[15] Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). *Best practices for developing and validating scales for health, social, and behavioral research: A primer*. Frontiers in Public Health, 6, 149. https://doi.org/10.3389/fpubh.2018.00149

[16] Tavakol, M., & Dennick, R. (2011). *Making sense of Cronbach's alpha.* International Journal of Medical Education, 2, 53–55.

[17] Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage.

[18] Fowler, F. J. (2014). Survey research methods (5th ed.). Sage.Box, S., Bishop, C. M., & Hunt, H. (2014). Stochastic six-degree-of-freedom flight simulator for passively controlled high-power rockets. *Journal of Aerospace Engineering, 24*(1), 31-45. https://doi.org/10.1061/(ASCE)AS.1943-5525.0000252

[19] Field, A. (2013). *Discovering statistics using IBM SPSS Statistics* (4th ed.). Sage.

[20] Sutton, G. P., & Biblarz, O. (2016). *Rocket propulsion elements* (9th ed.). John Wiley & Sons.

turnitin Page 25 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 26 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

[21] Serway, R. A., & Jewett, J. W. (2014). *Physics for scientists and engineers with modern physics* (9th ed.). Cengage Learning.

[22] Irawati, I. (2016). *Water rocket competition: Application of project-based physics learning.* Proceedings of the National Seminar on Physics (E-Journal) SNF2016, 5, 29-34. https://doi.org/10.21009/0305010207

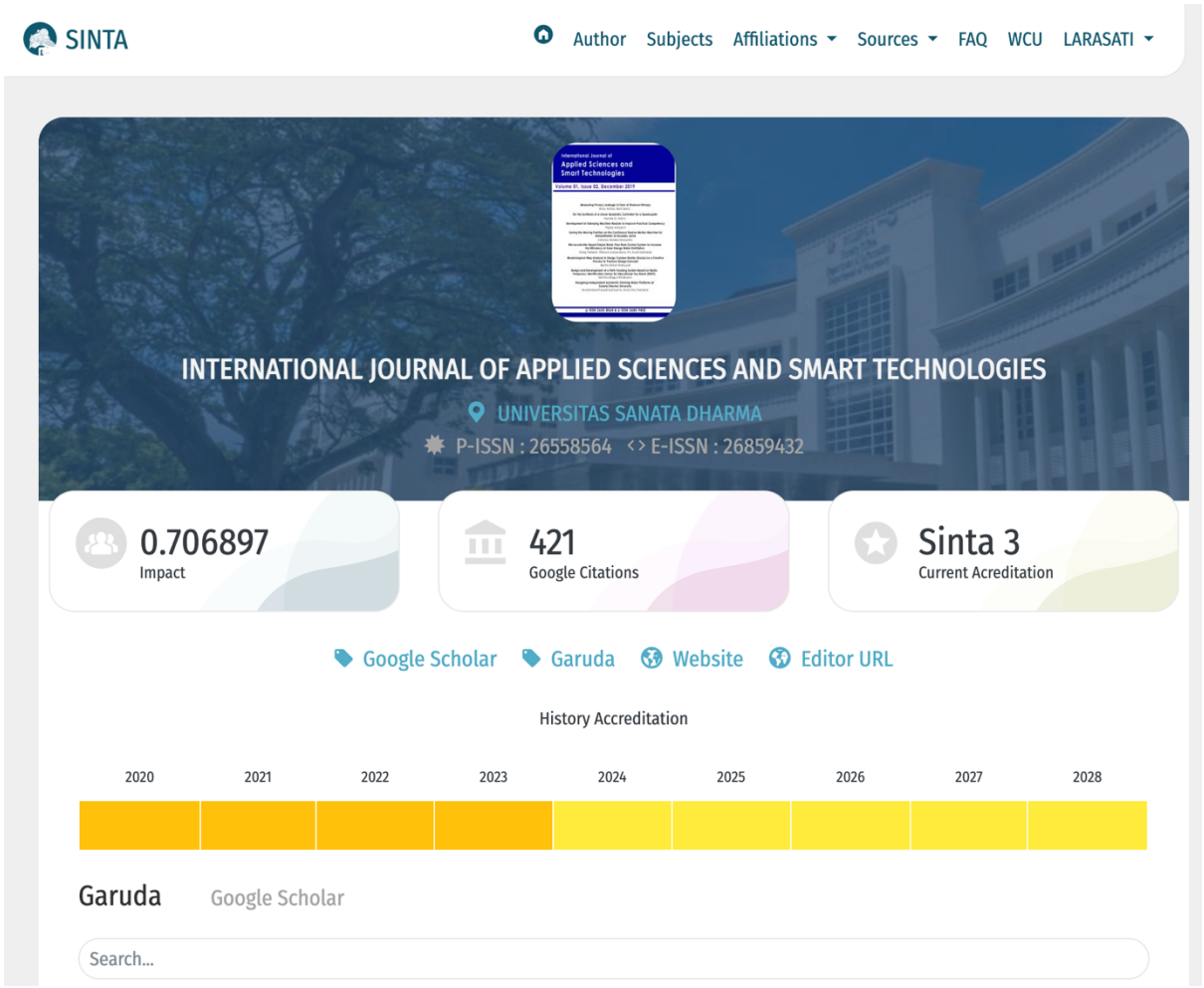
turnitin Page 26 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

turnitin Page 27 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

This page intentionally left

turnitin Page 27 of 27 - Integrity Submission Submission ID trn:oid:::3618:149594481

Terindeks SINTA & DOAJ



Rahmadyah Hamiranti, Nanang Wahyu Prajaka, Yeni Yeni, Desi Maulida, Lisa Erfa 403-416
DOI: https://doi.org/10.24071/ijasst.v7i2.12705 | Abstract views: 286 times

Braille Pattern Detection Modeling Using Inception V3 Architecture Using Median Filter Implementation and Segmentation PDF
Abdul Latif, Siti Yuliyanti, Muhammad Al-Husaini 417-432
DOI: https://doi.org/10.24071/ijasst.v7i2.12781 | Abstract views: 231 times

Sign Language Detection Models using Resnet-34 and Augmentation Techniques PDF
Rizki Ramdhan Hilal, Aradea Aradea, Vega Purwayoga 433-450
DOI: https://doi.org/10.24071/ijasst.v7i2.12888 | Abstract views: 275 times

SVM and Ensemble Majority Voting Algorithm on Sentiment Analysis of Using chatGPT in Education PDF
Hildegardis Yayukristi Weko, Hari Suparwito 451-468
DOI: https://doi.org/10.24071/ijasst.v7i2.12680 | Abstract views: 262 times

Publisher : Faculty of Science and Technology

Society/Institution : Sanata Dharma University

This work is licensed under a Creative Commons Attribution 4.0 International License.

International Journal of
Applied Sciences and Smart
Technologies
IJASST

FAKULTAS SAINS DAN TEKNOLOGI
UNIVERSITAS SANATA DHARMA
Email: editorial.ijasst@usd.ac.id

No. : 09/26/IJASST/XI-b/2025 December 20th, 2025

Re. : Letter of acceptance

Dear Mr/Mrs. Larasati Rizky Putri, Fakhrizal Arsi, Kiar Vansa Febrianti, Sentot Novianto, Ika Wahyu Utami, Sofia Debi Puspa, Muhammad Gilang Ramadhan, Harry Munandar,

Your submission entitled "Development of an Arduino-Based Water Rocket Launcher in Physics Experiments" **has been accepted** for publication in IJASST for Volume 08, edition 01, June 2026. We thank you for your cooperation and patience and look forward to your submissions to IJASST in the future.

Best Regards,

Editor in-Chief

Dr. Eng. Ir. I Made Wiryana Ekapatra

UNIVERSITAS TRISAKTI

Larasati Rizki Putri <larasati.rizki@trisakti.ac.id>

Letter of acceptance

2 pesan

International Journal of Applied Sciences and Smart Technology (19 Januari 2026 pukul 11.18
<editorial.ijasst@usd.ac.id>
Kepada: Larasati Rizki Putri <larasati.rizki@trisakti.ac.id>

Dear Mr/Mrs. Larasati Rizky Putri, Fakhrizal Arsi, Kiar Vansa Febrianti, Sentot Novianto, Ika Wahyu Utami, Sofia Debi Puspa, Muhammad Gilang Ramadhan, Harry Munandar,

Your submission entitled “Development of an Arduino-Based Water Rocket Launcher in Physics Experiments” has been accepted for publication in IJASST for Volume 08, edition 01, June 2026. We thank you for your cooperation and patience and look forward to your submissions to IJASST in the future.

Best Regards,
Editorial Team
IJASST

9. Putri_2 et.al._LoA.pdf
292K

Larasati Rizki Putri <larasati.rizki@trisakti.ac.id> 20 Januari 2026 pukul 11.36
Kepada: "International Journal of Applied Sciences and Smart Technology (" <editorial.ijasst@usd.ac.id>

Dear Editorial Team 🙏,

Thank you for informing us of the acceptance of our manuscript entitled **“Development of an Arduino-Based Water Rocket Launcher in Physics Experiments.”**

We would like to inform you that there has been a **minor administrative revision to the author list**, which does **not affect the content, data, or results of the article**. We kindly request your guidance on how to proceed in accordance with the journal’s procedures.

Please find attached the revised manuscript reflecting the updated author information.

Thank you very much for your attention and cooperation.

Yours sincerely,
Larasati Rizky Putri
Universitas Trisakti

[Kutipan teks disembunyikan]

Manuscript of IJASST (Blind Review).docx
1607K

UNIVERSITAS TRISAKTI

Larasati Rizki Putri <larasati.rizki@trisakti.ac.id>

Fwd: [IJASST] Editor Decision

3 pesan

Larasati Rizky Putri <larasati.rizki@trisakti.ac.id> 13 Oktober 2025 pukul 16.06
Kepada: larasati.rizki@trisakti.ac.id, Fakhrizal Arsi <fakhrizal.arsi@gmail.com>

Best regards,
Larasati Rizky Putri

---------- Forwarded message ---------
From: **Editorial IJASST** <e-journal@administrasi.usd.ac.id>
Date: Sat, Oct 11, 2025, 11:29AM
Subject: [IJASST] Editor Decision
To: Ms Larasati Rizky Putri <larasati.rizki@trisakti.acid>

Dear Ms Larasati Rizky Putri:

We have reached a decision regarding your submission to International Journal of Applied Sciences and Smart Technologies, "Development of an Arduino-Based Water Rocket Launcher in Physics Experiments".

Our decision is: Revisions Required

Editorial IJASST
Sanata Dharma University
editorial.ijasst@usd.ac.id

Reviewer A:

1. Originality of the topic?::
   Average

2. Technical Quality?:
   Average

3. Suitability for the Journal?:
   Good

4. Is the Abstract accurate and concise?:
   Appropriate

5. Are the approach/ methods properly described?:
   Appropriate

6. Are the references properly cited?:
   Appropriate

7. Is this a new/ original/ confirmatory contribution?:
   Appropriate

8. Does the title represent manuscript's contents?:
   Appropriate

9. Adequate Illustrations or Drawings:
   Good

10. Are the conclusions and interpretations sound?:
    Appropriate

11. Comments to Author(s):

The paper needs revision:

1. Please state the aim of the research in the Abstract.
2. Figures 3, 4, and 5 must be called explicitly in the text at least once for each of them.
3. Tables 2 and 4 must be called explicitly in the text at least once for each of them.
4. Regarding equations (6) and (7), please explain what Hpowered and Dpowered mean.
5. Please state the limitations of this research in the Conclusion.
6. VERY IMPORTANT: Some parts of the writings are detected as AI writing. Please check the attached file and please revise them if they are taken from AI tools.

Thank you.

13. Decision:
Revise

Reviewer B:

1. Originality of the topic?::
Average

2. Technical Quality?:
Average

3. Suitability for the Journal?:
Average

4. Is the Abstract accurate and concise?:
Appropriate

5. Are the approach/ methods properly described?:
Appropriate

6. Are the references properly cited?:
Appropriate

7. Is this a new/ original/ confirmatory contribution?:
Appropriate

8. Does the title represent manuscript's contents?:
Appropriate

9. Adequate Illustrations or Drawings:
Average

10. Are the conclusions and interpretations sound?:
Appropriate

11. Comments to Author(s):
1. Limitations are found, particularly in data accuracy, validation, and scalabilit. The need for future improvements such as calibrated sensors, automated data logging, enhanced documentation, and broader testing across varied educational settings.
2. It is recommended to cite at least one more article from the IJASST

13. Decision:
Accept

International Journal of Applied Sciences and Smart Technologies
Faculty of Science and Technology

Sanata Dharma University
http://e-journal.usd.ac.id/index.php/IJASST

Larasati Rizki Putri <larasati.rizki@trisakti.ac.id> 15 Oktober 2025 pukul 13.16
Kepada: Muhammad Najih <Najihmuh@trisakti.ac.id>

[Kutipan teks disembunyikan]

Muhammad Najih <najihmuh@trisakti.ac.id> 15 Oktober 2025 pukul 13.22
Kepada: Larasati Rizki Putri <larasati.rizki@trisakti.ac.id>

Jurnalnya mana?

Muhammad Najih
FTI - Universitas Trisakti
08128087992
'Opportunity prefers the prepared mind.' ~ Linus Pauling

[Kutipan teks disembunyikan]

> [Kutipan teks disembunyikan]
>
> **UNIVERSITAS TRISAKTI**
> ***"Is a one stop learning for sustainable development"***
> Kampus A, Jl. Kyai Tapa No.1, Grogol
> Jakarta Barat 11440 - INDONESIA
> www.trisakti.ac.id
> (t) +62-21.566 3232, (f) +62-21.567 3001

UNIVERSITAS TRISAKTI
"Is a one stop learning for sustainable development"
Kampus A, Jl. Kyai Tapa No.1, Grogol
Jakarta Barat 11440 - INDONESIA
www.trisakti.ac.id
(t) +62-21.566 3232, (f) +62-21.567 3001

Formulir Tanggapan

Editor dan Reviewer yang terhormat,

Kami mengucapkan terima kasih atas masukan dan komentar konstruktif Anda yang sangat berharga. Kami telah merevisi naskah kami. Di bawah ini Adalah tanggapan rinci kami untuk setiap komentar.

Reviewer #A

No.	Komentar	Tanggapan
1.	**Abstrak:** Silakan nyatakan tujuan penelitian dalam Abstrak.	Kami telah merevisi abstrak untuk memastikan bahwa abstrak tersebut mencakup semua elemen yang diperlukan dan melengkapinya dengan manyatakan tujuan dalam penelitian. Berikut narasinya: The effective science education requires practical methods that allow students to explore complex physics concepts. One promising approach is the use of physics experiment as an interactive media. This research focuses on the development of water rocket launcher using an Arduino as an innovative physics experiment. The purpose of this study is to develop and test an Arduino-based automated water rocket launcher with optimized angle control and improved measurement accuracy for physics learning. Arduino in water rocket launcher is used for making the precise control and relevant measurement of variables, such as angle of projection, speed of launch, maximum altitude of launch, and air pressure. The research process followed the ADDIE instructional design model and involved hardware, software prototyping, work testing, and user instruction. The launcher's performance was tested with 33 engineering students and assessed by 5 experts. Expert evaluations rated the relevance, design, and usability of the kit highly (3.4–4.0 on a 4-point Likert scale). User responses from 33 students indicated strong agreement on ease of use and engagement (mean scores 3.79–3.91), with a high reliability (Cronbach's alpha = .964). Experimental launches, using three and four finned rockets, showed maximum height

		percentage differences between theoretical and observed values ranging from 0.0%–52.6% (three fins) and 1.2%–51.8% (four fins); range errors were 3.4%–36.8% (three fins) and 2.1%–42.7% (four fins). The findings confirm that the Arduino-based water rocket launcher provides effective, interactive learning, though further refinement in data accuracy and instructional materials is recommended to maximize its classroom impact and is needed for improved accuracy.
2.	**Pendahuluan:** ▪ Gambar 3, 4, dan 5 harus disebutkan secara eksplisit dalam teks setidaknya sekali untuk masing-masingnya.	Kami juga telah merevisi bagian pendahuluan ini dengan menambahkan pembahasan yang eksplisit pada masing-masing Gambar 3, 4 dan 5. Berikut narasinya pada Gambar 3: Figure 3 illustrates the control system circuit used in the Arduino-based automatic water rocket launcher. This configuration integrates an Arduino Uno, an HC-05 Bluetooth module, and a servo motor responsible for adjusting the launch angle [24]. In this system, the HC-05 serves as a wireless communication interface that enables the Arduino to receive commands from external devices, such as smartphones, with the following pin configuration: VCC: 5V GND: GND TXD: RXD RXD: TX The components are connected using male-to-male jumper wires through a breadboard to ensure circuit stability. The HC-05 is powered through the Arduino's 5V pin, while the GND pin functions as a common ground. Serial communication between the HC-05 and the Arduino is performed using a cross-connection, where the module's TXD pin is connected to the Arduino's RXD pin, and the module's RXD pin is connected to the Arduino's TXD pin. This signal exchange method ensures accurate data input and output processes. Through this configuration, the Arduino is able to process wireless commands and control the servo motor with high angular precision. The

		circuit provides a reliable control mechanism suitable for physics experiments requiring accurate launch-angle adjustments and real-time data processing [23]. Berikut narasinya pada Gambar 4: In Figure 4, the researchers present the main control code used to operate two servo motors via an Arduino Uno platform. The program employs the *Servo.h* library to generate 50 Hz PWM signals required for positioning the actuators. In the *setup()* function, each servo is bound to a dedicated digital pin, while the serial port is initialized at 9600 baud to receive commands from the HC-05 bluetooth module [24]. The *loop()* function operates as an interrupt-free command parser. The Arduino continuously monitors the serial buffer and extracts single-character instructions. The characters 'u' and 'd' adjust the angle variable of the first servo axis, whereas 'l' and 'r' modify the second axis. Angle variations are computed incrementally and constrained within the 0–90° operational range using the *constrain()* function to prevent mechanical overshoot. After boundary validation, the *write()* command transmits the appropriate PWM signal to the servos, resulting in the corresponding physical rotation [25]. This code design provides responsive and stable closed loop command execution and ensures compatibility with short range wireless communication through the HC-05 module. The approach aligns with best practices in embedded system design and microcontroller-based actuator control commonly implemented in STEM education experiments and simple automation devices. Berikut narasinya pada Gambar 5: In figure 5 presents the two rocket configurations used during the performance evaluation of the automated launcher: a three-fin model and a four-fin model. These configurations were selected to compare the aerodynamic stability resulting from different fin counts, as fin geometry significantly influences flight behavior, including lift generation, drag profile, and

	▪ Tabel 2 dan 4 harus disebutkan secara eksplisit dalam teks setidaknya sekali untuk masing-masingnya.	passive stability during ascent. The use of varied fin designs enables systematic observation of launcher performance under differing aerodynamic loads, which is consistent with prior studies emphasizing the role of fin number and layout in improving flight stability in small-scale experimental rockets [26]. Kami juga telah merevisi bagian pendahuluan ini dengan menambahkan pembahasan yang eksplisit pada masing-masing Tabel 2 dan 4. Berikut narasinya pada Tabel 2: As shown in Table 2 summarizes the expert evaluation of the Arduino based water rocket launcher using a four point Likert scale. Overall, the experts assigned consistently high ratings, with mean scores ranging from 3.80 to 4.00, indicating that the launcher kit meets the essential criteria for instructional use in physics education. The highest-rated aspects include the alignment with core physics concepts, the appropriateness of the design and materials, the reliability of the Arduino programming, and the performance of the Bluetooth control system, each receiving a perfect score of 4.00. The experts also noted that the kit effectively supports project-based learning, facilitates the understanding of complex concepts, and promotes students' scientific curiosity. The lowest rating (3.40) was associated with safety considerations for laboratory use, suggesting that additional enhancements to protective mechanisms and safety instructions may further improve its classroom readiness. Overall, the experts concluded that the launcher kit is safe, pedagogically relevant, and can be used effectively with minimal teacher supervision. Berikut narasinya pada Tabel 4: As outlined in the Table 4 for maximum height, the percentage difference between experimental and theoretical values for the three-finned rocket ranged from 0.0% to 52.6%, whereas for the four-finned rocket, it

	▪ Mengenai persamaan (6) dan (7), jelaskan apa arti Hpowered dan Dpowered.	ranged from 1.2% to 51.8%. In terms of total distance (range), the percentage differences for the three-finned rocket ranged from 3.4% to 36.8%, and for the four-finned rocket from 2.1% to 42.7%, excluding cases where the theoretical value was zero (vertical launches at 90°, for which the theoretical range is always zero and the percentage difference is undefined). These variations can be attributed to multiple factors, including experimental limitations, air resistance, minor inconsistencies in rocket construction, or deviations in the discharge coefficient from assumed values. Researchers use the average value 0.7 for discharge coefficient due to the limitations of apparatus, while the actual number may vary from 3-fins rocket to 4-fins rockets. Another possible cause that causes the difference is the flaw in the rocket design itself, with flaws which make it not following projectile trajectory. Kami juga telah merevisi bagian pendahuluan ini dengan menjelaskan apa arti Hpowered dan Dpowered pada persamaan 6 dan 7. Berikut narasinya: where: $H_{powered}$ is the initial vertical displacement generated by the engine thrust/pressure. $D_{powered}$ the initial horizontal displacement generated by the engine thrust/pressure.
4.	**Kesimpulan:** ▪ Sebutkan batasan penelitian ini dalam Kesimpulan.	Kami telah merevisi naskah dengan mencantumkan batasan penelitian pada section kesimpulan. Berikut narasinya: However, this study has several limitations. The accuracy of the sensors was still influenced by vibrations and pressure fluctuations that were difficult to control, and the field measurement conditions introduced variations in the results that were not fully replicable. In addition, the physical models employed in the analysis relied on

		idealized assumptions, which do not entirely capture the complexity of fluid dynamics and aerodynamics in real-scale water rockets.
5.	**SANGAT PENTING:** Beberapa bagian tulisan terdeteksi sebagai tulisan AI. Periksa file terlampir dan revisi bagian tersebut jika diambil dari alat AI.	Kami telah merevisi naskah dengan mengecek keseluruhan tulisan yang dimungkinkan terdeteksi AI

Reviewer #B

No.	Komentar	Tanggapan
1.	**Hasil dan Pembahasan:** Terdapat keterbatasan, terutama dalam akurasi data, validasi, dan skalabilitas. Diperlukan perbaikan di masa depan seperti sensor yang dikalibrasi, pencatatan data otomatis, dokumentasi yang ditingkatkan, dan pengujian yang lebih luas di berbagai lingkungan pendidikan.	Kami telah merevisi naskah dengan mencantumkan batasan penelitian pada section kesimpulan. Berikut narasinya: However, this study has several limitations. The accuracy of the sensors was still influenced by vibrations and pressure fluctuations that were difficult to control, and the field measurement conditions introduced variations in the results that were not fully replicable. In addition, the physical models employed in the analysis relied on idealized assumptions, which do not entirely capture the complexity of fluid dynamics and aerodynamics in real-scale water rockets.
2.	**Daftar Pustaka:** Disarankan untuk mengutip setidaknya satu artikel lagi dari IJASST	Kami telah merevisi naskah dengan mensitasi 1 artikel yang berasal dari IJASST. Berikut narasinya: Enhancements in user experience and data management were among the suggestions, specifically the development of a simple graphical user interface (GUI) using platforms such as Processing or web-based dashboards to monitor real-time parameters like pressure and angle. Automated data storage to SD cards or cloud-based systems was recommended to facilitate subsequent data analysis and reporting [27]. Harini, B, W., Gunadi, T. G., Mahardika, S. G., Pangestu, S. P., Putri, R, C, E., Mardikus, S. (2025). Design of a Speed Sensorless Control System on a DC Motor using a PID Controller. International Journal of Applied Sciences and Smart Technologies, 7(2), 385-402. https://doi.org/10.24071/ijasst.v7i2.13271