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

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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 21stcentury 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

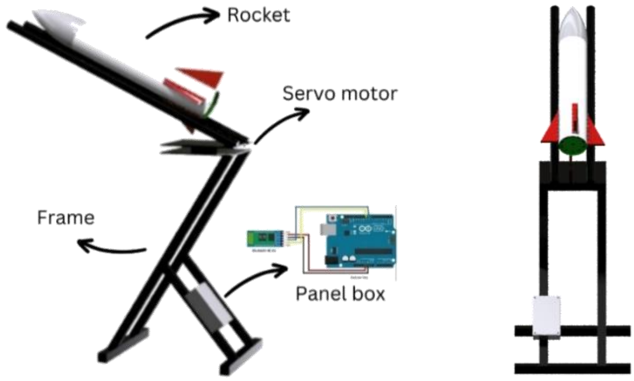
Water rocket experiments are an accessible means to teach principles of mechanics, specifically Newton's laws of motion, conservation of momentum, and projectile motion. When the rocket is launched, expelling water downwards due to the pressurized air creates an upward thrust as described by Newton's 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].



(a) (b)

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.

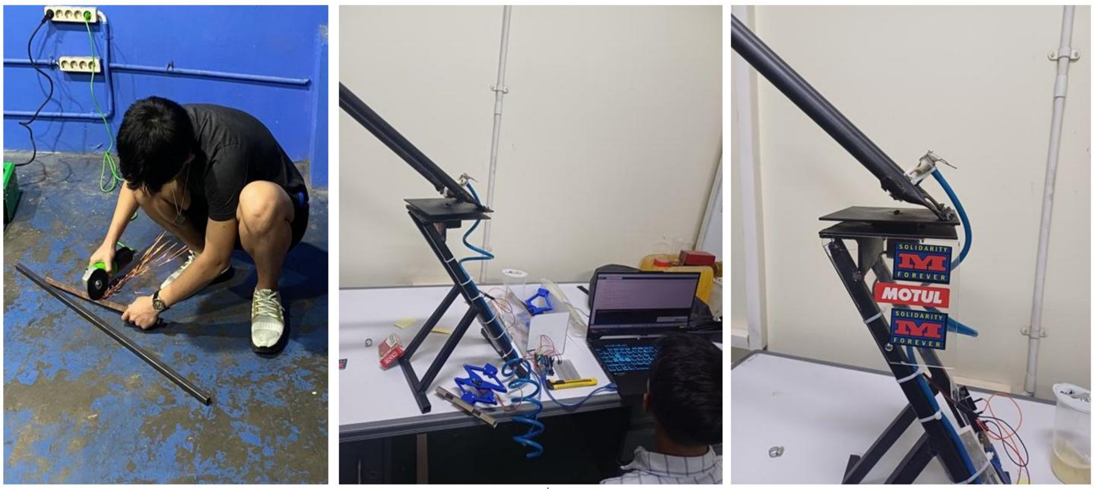


Figure 2. Frame assembly and installation

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

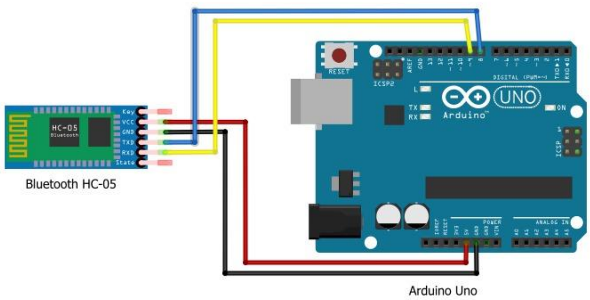


Figure 3. Arduino schemes

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

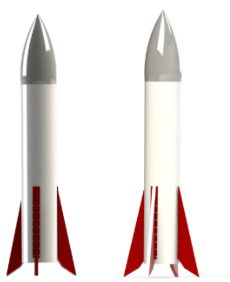


Figure 5. Three-fins rocket and four-fins rocket

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]:

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

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:

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]:

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

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

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.

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