



Research Article

Development of STEM-Based Biology Laboratory Activities in Creating Filter Paper Utilizing Indigenous Materials

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ABSTRACT

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This study aims to develop STEM-based laboratory activities in creating filter paper using indigenous materials. The researcher initially devised a formulation for creating filter papers from indigenous materials (*Corchorus olitorius* leaves and waste papers) and subjected them to various tests. It was determined that Filter Paper B is the most effective among all other formulations. Subsequently, it was compared to Grade 2 Whatman filter paper using the same methodology. These precise procedures were also incorporated into the laboratory activities developed by the researcher and utilized by students during implementation. Following the tests stated in the laboratory manual, the students also determined that filter paper B containing 20 g (40%) of jute mallow leaves and 30 g (60%) of waste paper was the most effective in terms of the criteria and qualities. A pre-and post-test were also administered during the implementation. This is aimed at assessing the degree of STEM literacy among students regarding the topic of Filtration. It is interesting to note that using STEM - Based Biology Laboratory Activities increased the students' STEM literacy. Hence, it is recommended that the STEM – Based Biology Laboratory Activities be used in class to foster scientific learning among students.

Introduction

Laboratories for studying biological organisms, from single-celled organisms to large vegetation and animals, are equipped with the necessary instruments and resources (Megerle

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et al, 2010). Scientists and researchers can use these materials to examine processes and other life forms that are both visible and invisible to the naked eye. Complex equipment is required to investigate the function, respiration, consumption, reproduction, and evolution of biological organisms. Instructors typically introduce students to essential devices in secondary school or biology laboratories.

Instructional materials are essential to the development of laboratory activities in education, particularly the field of Biology. Students can conduct experiments, as opposed to merely reading about them, due to the availability of science laboratory apparatus. Instead of taking mundane notes, they could conduct intriguing experiments and observations (Hofstein, 2004). On the other hand, no course in Biology can be considered complete without practical exercises. As biology is a science, it must be studied through experimentation. The laboratory enhances the significance and relevance of Biology instruction. Laboratory instruction presupposes that direct observation and manipulation of scientific materials are superior to other comprehension and appreciation-enhancing methods. In addition, laboratory training is typically used to develop the skills necessary for advanced study or research. However, rural pupils have fewer opportunities to acquire costly laboratory equipment that is only available in urban areas. Their rural origins make it difficult for them to travel to urban areas, and they may not have sufficient fund to purchase these items. In rural areas, filter paper is one of the most difficult products to locate despite being one of the most frequently used items. It is known that the field of biology has made significant advances in instrumentation. Several do-it-yourself instruments that enhance creativity and interest in learning have been identified. Nonetheless, the inadequate supply of high-quality and sophisticated laboratory materials remains a significant barrier.

In addition to the aforementioned, effective instructional materials are tailored to the subject matter, the students, and the instructor. A study indicates that it is impossible to evaluate a student's mastery of a subject without the student's actual participation and activity. Instructors utilize instructional materials to accelerate student learning. There are still unidentified instructional materials that could serve as alternatives to the standard one, despite the existence of numerous educational materials (Pannekoek and Ally, 2008). This will assist the instructor in incorporating the device so that students can acquire knowledge as rapidly as possible

This study aims to develop STEM-based laboratory activities in order to bridge the gap between students' learning and readiness in comprehending STEM education specializing in science, technology, engineering, and mathematics; to address the issue of the lack of laboratory learning materials; and to engage students in the process of developing filter papers from indigenous materials. Therefore, pupils in remote areas will have no difficulty studying filtration-related topics, as even locally sourced materials such as jute mallow (*Corchorus olitorius*) and waste papers can be developed and utilized. This also aims to determine whether the STEM literacies of students will increase as a result of the implementation of the STEM-Based Biology Laboratory Activities.

Specifically, this study shall endeavor to achieve the following objectives: (1) solicit the views of teachers and students regarding the lack of laboratory materials specifically the filter paper in laboratory activities; (2) develop prototype facility of filter papers using indigenous materials; (3) develop STEM – Based laboratory activities; (4) implement the developed laboratory activities to learners; (5) Evaluate the students prototype in terms of: [a] quality of filter papers in terms of: water permeability, the capacity of the four developed filter papers in

terms of their filtration efficiency in starch solution and in cocoa solution, the pH reading of the developed filter paper, the tensile and wet strength of the developed filter papers, and [b] Comparability of the developed filter papers and that of a commercial filter papers in terms of: water permeability, filtration efficiency, pH reading, and tensile and wet strength; and (6) Determine the level of STEM literacy of students before and after the implementation of laboratory activities.

Materials and Methods

Research Subjects

This study's respondents were Grade Seven (6) elementary students enrolled in the Basic Education of the Pagawan Elementary School, District of Manticao for the School Year 2022-2023 of the Department of Education in the Division of Misamis Oriental. They were chosen as research subjects because this is a simulation and preparation for their seventh-grade topic which focuses on separation techniques and filtration. The activities are pertinent and appropriate for them.

Research Design

This study employed both qualitative and quantitative experimental methodologies for STEM Education. The quantitative method is used to analyze the numerical data from the students' in-depth evaluation of filter papers made from indigenous materials. This also included the data collected during the implementation of the pre-and post-tests, as well as the validation of the designed laboratory activities. The laboratory activities were validated and evaluated by the advisor, panel members, experts, and master instructors in the field of education. In addition, a rubric was adapted as a tool for evaluating and assessing the material and revealing the opinions of the evaluators regarding the correctness and applicability of the laboratory activities for students in a laboratory classroom setting. Following evaluation and validation, implementation happened. The responding students were given a pre-and post-test in order to determine if there was a particular impact on the application of learning. The collected data was analyzed using statistical instruments.

Research Instruments Used

The researcher used the following instruments in gathering the data: STEM-based laboratory activities – this is developed as a guide for classroom laboratory activities by the researcher. This entails the overview, background, necessary materials, management and procedures for the production of filter papers from indigenous materials and the series of tests to determine its quality. The laboratory activities devised were validated and evaluated by the adviser, panel members, and experts in the field.

- a. Rating sheet for the developed STEM Education Laboratory Activities – a rating sheet was adapted by the researcher from Anduyan (2020) to assess the appropriateness of the laboratory activities
- b. STEM Literacy Questionnaire - this is a pre-and post-test used to evaluate the learners' STEM literacy before and after participating in STEM – Based Biology laboratory activities. This was used both in the pilot test and final implementation. This consists of six contemplation questions in which students are required to come up with a solution to

a problem. This is an adaptation of the action research conducted by Barquilla *et al.*, 2023, for their study entitled Enhancing In-Service Teachers' STEM Literacy through a Professional Development Model Centered on Outdoor Learning Resources in the Philippines.

- c. Interview questions for Rural Area Instructors - this is an open-ended questionnaire given to rural instructors by the researcher to solicit their views and opinions regarding their laboratory classroom experiences and the scarcity of laboratory materials, particularly filter papers.
- d. STEM literacy Rubric – a rubric adapted from Chamrat *et al.* (2018) is used to assess and evaluate the level of STEM literacy among students according to the following criteria: STEM concept, STEM integration, STEM practice, STEM participation, STEM evaluation, and STEM awareness. Both the pilot test and final implementation utilized this.

Data Gathering Procedure

The initial phase consisted of soliciting the perspectives and opinions of teachers in remote areas regarding their laboratory classroom experiences. This allowed the researcher to define the issue and develop possible solutions. Using only native materials, the researcher created a prototype of filter paper to address the issue at hand. After conducting experiments, STEM-based Biology Laboratory Activities were developed. The laboratory activity includes a student guide and a worksheet for the students. The background concepts, activity materials, instructions and procedures, questions to answer, and reflection forms are included in the student's worksheets. It was then validated by the adviser and panel members and then evaluated using a rubric by the experts and master teachers. Following the procedure of validation was the revision. After being approved by the experts, laboratory activities were carried out. The researcher asked the Division Office and School principal of the designated responding school for permission to conduct the study. Then, a pretest was administered to determine the students' STEM literacy level. The students conducted the activities outlined in the researcher-developed laboratory activities. The developed filter papers were then evaluated based on their functionality and filter paper quality. The most efficient filter paper was then compared to the Grade 2 Whatman Filter paper based on its permeability, filter efficiency, acidity and basicity, and tensile and wet strength. Accordingly, a post-test was administered to determine the STEM Literacy level of the students. Overall, readily available laboratory activities and a filter paper created from indigenous materials and enhanced STEM literacy among students were the final outputs of this study. This research analyzed the collected data using statistical methods mean, frequency, standard deviation and paired t-test.

Data Analysis

The quantitative data from the pre- and post-tests are statistically analyzed using mean, frequency, standard deviation, and the paired t-test. A paired t-test was used to compare the effectiveness of the developed STEM – based Biology Laboratory Activities before and after usage in order to determine whether statistical evidence indicates that the results are substantially different. In order to determine the quality of the respondents' output products, testing procedures and qualitative methods are utilized.

Mean

The average value, or center point, of a dataset, is represented by a single number known as the mean. The most typical way to measure central tendency is what is also referred to as the arithmetic mean. It is often referred to as the "average." It is very easy to determine the mean. Just add all the values and divide by the number of observations. The mean formula is below:

Frequency

The number of times a specific value for a variable (data item) has been noted to occur is known as the frequency.

$$\frac{x_1 + x_2 + \cdots + x_n}{n}$$

Standard Deviation

The term "standard deviation" (or σ) refers to a measurement of the data's dispersion from the mean. When the standard deviation is low, the data are concentrated around the mean, and when it is high, the data are more dispersed.

Paired T-Test

To ascertain whether the mean difference between two sets of observations is zero, statisticians use the paired sample t-test, also known as the dependent sample t-test. Each subject or thing is measured twice, yielding pairs of observations, in a paired sample t-test.

Results and Discussion

Analyzing the Learners and Community Resources

Prior to the development of the STEM based - Biology Laboratory Activities, the researcher solicited the opinions of remote-area school instructors. The researcher interviewed at least eight public high school Science instructors about their perceptions of the lack of laboratory materials, specifically filter papers, at their school. Teachers primarily required filter papers because these laboratory instruments are the least mastered in terms of application. Even as high school students, they never had the opportunity to participate in laboratory procedures and activities involving filter papers. As a result, when they arrived at college, they were so naive and uninformed about filtration processes involving sophisticated filter papers. Today, teachers are frustrated that they are unable to instruct their students on certain laboratory activities, which renders their instruction ineffective. Students are only familiar with rudimentary filtrations using sifters and cloth. In contrast, when queried about filter papers in the laboratory, they had no idea. According to the instructors, the students are unaware of the appearance and function of filter paper. Since they haven't performed basic laboratory procedures, such as filtration, in their earlier years, the majority of them enter higher education with insufficient knowledge.

Development of Prototype by the Researcher

The researcher experimented with jute mallow (*Corchorus olitorius*) leaves and waste papers. The objective of the experiment was to create filter papers from jute mallow (*Corchorus olitorius*) leaves and waste papers. This development of Biology laboratory equipment was

undertaken by the researcher to address the difficulty faced by students, particularly in rural areas, in acquiring costly filter papers from the market. To determine the most effective filter paper, four mixtures of jute mallow leaves and waste papers were created (Filter Paper Prototypes A, B, C, and D). The developed filter papers were then subjected to a series of experiments to ascertain their effectiveness. These tests include Permeability, capacity to filter starch solution, capacity to filter cocoa solution, Acidity and Basicity, Tensile and Wet Strength. After determining their efficiency, the developed filter paper with the highest number of “points” of favorability as a filter device was then compared to the commercial filter paper Grade 2 Whatman to determine which between the two filter papers is better in terms of the said tests.

Table 1. Comparison Between Filter Paper Prototype B and Grade 2 Whatman Filter Paper

CRITERIA	Prototype B	Grade 2 Whatman
Permeability test		✓
Capacity to filter 50 mL water with 10g starch		✓
Capacity to filter 50 mL water with 10g cocoa solution	✓	
Acidity and Basicity	✓	✓
Tensile Strength		✓
Wet Strength	✓	
Total Number of Checks	3	4*

*Legend: * - Highest Total Number of Checkmarks*

To summarize all of the test results, Table 1 was created. The researcher determined that each checkmark is worth one point, and the developed filter paper with the maximum number of checkmarks was deemed the more ideal filtering device, and thus the superior filter paper. Table 1 provides a summary of all comparison results between filter Prototype B and commercial filter paper Whatman (Grade 2). The checkmarks in the two columns represent the total number of points earned by each filter paper with the highest score on each test. Clearly, filter paper prototype B earned three (3) points while Grade 2 Whatman earned four (4). This indicates that Grade 2 Whatman filter paper remains a superior filtering medium than its modern counterpart. Since the difference was only one point, the researcher concluded that Filter Paper Prototype B 20 g (40%) of jute mallow leaves and 30 g (60 %) of waste papers) is still an effective filtering medium.

Development STEM-Based Laboratory Activities

Due to the initiative to address the problem of scarcity of laboratory materials specifically in remote areas and after a successful experiment, the researcher developed STEM-based Biology Laboratory Activities as a reference for teachers and students in creating filter papers from Indigenous materials. This initiative seeks to involve the students in the process. The students will develop their own filter papers and subject these to testing. The techniques employed to produce filter papers from indigenous materials were derived from those utilized by the researcher during the development of the prototype.

Validation and Assessment of the STEM Based – Biology Laboratory Activities

The validation of the devised STEM based - Biology Laboratory Activities was one of the most important stages of this research. It was reviewed and revised by the adviser and panelists, who

also made corrections. It was then subjected to a rigorous validation and evaluation test conducted by experts and master teachers, and passed with go signal for use in the classroom and with students. The researcher adapted an evaluation sheet specifically for the STEM Based – Laboratory Activities that were developed. There were crucial evaluation criteria. The seven stages of the STEM Education - Biology Laboratory Activities are contained in this component. At the first stage, which is the identification of social issues stage, the significance of the identified issue must be evaluated. The second stage focused on the viability of the identified solution and the safety of the learners when implementing the identified solution to the problem. At the third stage, the application of the topic "filtration" to the laboratory experiment procedure and the effectiveness of the outlined steps for teaching the topic were evaluated. The fourth stage was the evaluation of the decision-making stage's allocated time and the appropriateness of the stated approach. At the fifth stage, the development of the product was prioritized, and the lucidity and appropriateness of instructions were evaluated more thoroughly. At the sixth stage, clarity of instruction and appropriateness were emphasized further. At the seventh stage, the lucidity and suitability of the instructions were evaluated. The final two criteria focused on the grammar and layout of the STEM Based – Biology Laboratory Activities document.

Implementation of STEM-Based Biology Laboratory Activities

Students are instructed to collect waste papers and soak them for one week prior to the implementation of the study. The wet waste papers were then extracted from the water. Additionally, excess water is removed. The 34 students enrolled in sixth grade were divided into six categories. Four groups, had six members, while two groups had five. They completed the task hand in hand. They effectively created their own filter papers using the concentrations: FILTER PAPER A: 10 g (20%) jute mallow leaves and 40 g (80%) waste paper; FILTER PAPER B: (20 g (40%) jute mallow leaves and 30 g (60%) waste paper; FILTER PAPER C: (30 g (60%) jute mallow leaves and 20 g (40%) waste paper; and FILTER PAPER D: (40 g (80%) jute mallow leaves and 10 g (20%) waste papers). The researcher provided a molding silk screen, shredder and nutrient extractor blender to guarantee the smooth and rapid flow of activities. The leaves of jute mallow are gathered from the residence gardens of the responding students.

Experimentation by the Students

The students adhered to the procedures outlined in the laboratory manual. The entire student section was divided into six groups, each tasked with crafting their own filter papers and subsequently subjecting them to tests to assess quality. Evaluating the quality of filter papers produced by students is an important task that requires attention to detail and precision. To evaluate the quality of filter papers, several tests are done. The permeability, filtration efficiency, pH reading, tensile and wet strength of the developed filters papers are assessed by the students.

Water Permeability

A highly permeable filter paper can lead to accelerated separation periods and enhanced efficiency. All of the developed filter paper's permeability is determined by its pore size, thickness, and porosity. One such article published by Todaro (2014) highlights the significance of measuring the permeability of filter paper for membrane filtration applications.

The author suggests that accurate determination of permeability can aid in selecting appropriate filter materials and optimizing filtration conditions for maximum efficiency. The paper's pores must be small enough to capture particles but large enough to allow for adequate airflow (Xu, 2013). These two characteristics will be balanced in high-quality filter paper. In this activity, the students subjected their filter papers to this test and got different results (Table 2).

Table 2. Data on water permeability from the different groups

Group number	Filter Paper	Volume of Filtrate (mL)	Rank in Permeability	Remarks (Damaged or Undamaged)
1	A	55	1	<i>Undamaged</i>
	B	45	2	Undamaged
	C	35	3	Undamaged
	D	170	4	damaged
2	A	70	1	<i>Undamaged</i>
	B	65	2	Undamaged
	C	55	3	Undamaged
	D	120	4	damaged
3	A	50	1	<i>Undamaged</i>
	B	40	2	Undamaged
	C	30	3	Undamaged
	D	160	4	Damaged
4	A	60	1	<i>Undamaged</i>
	B	40	2	Undamaged
	C	35	3	Undamaged
	D	180	4	Damaged
5	A	80	1	<i>Undamaged</i>
	B	50	2	Undamaged
	C	45	3	Undamaged
	D	196	4	Damaged
6	A	75	1	<i>Undamaged</i>
	B	60	2	Undamaged
	C	50	3	Undamaged
	D	180	4	damaged

The groups' tests to determine which of the four developed filter papers is the most permeable concluded that filter paper A (10 grams (20%) of jute mallow leaves and 40 grams (80%) of waste paper) is the most permeable. This indicates that the filter papers A developed by the six student groups have larger pores and permit faster flow. This property makes it suitable for applications requiring rapid filtration without sacrificing precision or effectiveness.

Effectiveness in Filtering Starch Solution

Filtration efficiency is defined as the number of particles of a certain size that the medium used can filter. It is determined by physical characteristics, such as grain size, shape, porosity, and bed depth/media grain size ratio (McGivney and Kawamura, 2008). Students filtered 50 mL of water and 10 g of starch solution in 15 minutes, sorted filter papers, and measured residue. They analyzed the amount of residue by covering wet filter paper with aluminum foil, drying

it, and weighing it. The residue amount was calculated by subtracting the weight of the used filter paper from the original, unused paper.

Table 3. Data on the effectiveness in filtering starch solution

Group number	Filter Paper	Initial Weight of filter papers (g)	Final Weight of Papers (g)	Amount of residue (g)	Remarks (Damaged or Undamaged)
1	A	2.236	2.425	0.189	Undamaged
	B	2.148	2.405	0.16	Undamaged
	C	1.988	2.020	0.082	Undamaged
	D	1.886	1.836	-0.05	damaged
2	A	1.999	2.389	0.39	Undamaged
	B	1.950	2.090	0.34	Undamaged
	C	1.960	2.010	0.05	Undamaged
	D	1.880	1.7	-0.18	damaged
3	A	1.230	1.42	0.19	Undamaged
	B	2.235	1.830	0.07	Undamaged
	C	1.938	1.305	0.027	Undamaged
	D	1.886	1.826	-0.006	Damaged
4	A	1.88	2.289	0.4	Undamaged
	B	1.930	2.193	0.263	Undamaged
	C	1.950	2.003	0.053	Undamaged
	D	1.780	1.767	-0.013	Damaged
5	A	1.990	2.290	0.3	Undamaged
	B	1.830	2.180	0.35	Undamaged
	C	1.973	2.025	0.052	Undamaged
	D	1.886	1.825	0.061	Damaged
6	A	2.222	2.422	0.19	Undamaged
	B	2.231	2.302	0.071	Undamaged
	C	1.578	1.752	0.174	Undamaged
	D	1.886	1.836	-0.05	damaged

Based on the data gathered by the six groups of students, all the weights increased for all filter papers except for filter paper D (40 grams (80%) jute mallow leaves and 10 grams (20%) waste papers) which has a negative result. This means that the filter device has not filtered any residue and, furthermore, has been damaged (Table 3).

The data from Group 1, Group 2, Group 3, Group 4, and Group 6 indicate that filter papers A (10 grams (20%) of jute mallow leaves and 40 grams (80%) of waste paper) is the most effective in this test, as it leaves behind the most residue and is undamaged. While group 5's data indicate that Filter Paper B (20 grams (40%) jute mallow leaves and 30 grams (60%) waste paper) is the most effective filter paper in this test since it leaves behind the most residue compared to the other filter papers.

Effectiveness in Filtering Cocoa solution

The purpose of this experiment was to examine the ability of filter paper to filter cocoa solution. The students created a cocoa solution by combining 10 g of cocoa powder with 50 mL of water. The students then poured the cocoa solution through a funnel containing the filter paper, similarly to what they had done with the starch solution. After filtration, they observed that the filter paper had effectively removed the majority of the cocoa solution's solid particles. The various filter papers from the various groups exhibit varying amounts of residue (Table 4).

Table 4. Data on the effectiveness in filtering the cocoa solution

Group number	Filter Paper	Initial Weight of filter papers (g)	Final Weight of Papers (g)	Amount of residue (g)	Remarks (Damaged or Undamaged)
1	A	1.230	2.080	0.85	Undamaged
	B	2.170	2.198	0.028	Undamaged
	C	1.990	2.110	0.12	Undamaged
	D	1.850	1.980	-0.13	damaged
2	A	2.003	2.065	0.062	Undamaged
	B	2.165	2.260	0.095	Undamaged
	C	2.900	3.100	0.8	Undamaged
	D	1.815	1.980	-0.165	damaged
3	A	1.220	2.080	0.86	Undamaged
	B	2.160	2.178	0.18	Undamaged
	C	1.990	2.110	0.12	Undamaged
	D	1.852	1.998	-0.146	Damaged
4	A	1.200	2.080	0.88	Undamaged
	B	2.140	2.158	0.018	Undamaged
	C	1.980	2.100	0.12	Undamaged
	D	1.822	1.998	-0.176	Damaged
5	A	1.995	2.098	0.103	Undamaged
	B	2.155	2.202	0.047	Undamaged
	C	1.975	2.120	0.145	Undamaged
	D	1.986	1.995	-0.009	Damaged
6	A	1.990	2.056	0.066	Undamaged
	B	2.140	2.158	0.018	Undamaged
	C	1.940	2.033	0.093	Undamaged
	D	1.823	1.990	-0.167	damaged

Similar to the filtration of starch solution, filter papers D (40 grams (80%) jute mallow leaves and 10 grams (20%) waste papers) from all groups exhibit a negative quantity of residue and are damaged during filtration, indicating that they are ineffective as a filtration device. Groups 1, 3, and 4's data indicate that filter paper A (10 grams (20%) of jute mallow leaves and 40 grams (80%) of waste paper) is the most effective in the test, while Group 2's data indicate that filter paper B (20 grams (40%) jute mallow leaves and 30 grams (60%) waste paper) is the most effective; filter papers C (30 grams (60%) jute mallow leaves and 20 grams (40%) waste paper) for Groups 5 and 6.

The pH Reading of the Developed Filter Paper

The pH reading of a filter paper is an important aspect that should not be overlooked. The pH value indicates the acidity or alkalinity of a solution, and it can affect the outcome of experiments or analyses performed on the filter paper.

Table 5. Data on the pH reading of the developed filter paper

Group number	Filter Paper	Color of the solution	pH Reading (neutral/acidic/basic)
1	A	No color	Neutral
	B	Orange red	Acidic
	C	Orange red	Acidic
	D	No color	Neutral
2	A	No color	Neutral
	B	orange	Acidic
	C	orange	Acidic
	D	No color	Neutral
3	A	No color	neutral
	B	red	Acidic
	C	red	Acidic
	D	No color	Neutral
4	A	No color	Neutral
	B	Brownish red	Acidic
	C	Red orange	Acidic
	D	No color	Neutral
5	A	No color	Neutral
	B	Red	Acidic
	C	Red orange	Acidic
	D	No color	Neutral
6	A	No color	Neutral
	B	Reddish brown	Acidic
	C	red	Acidic
	D	No color	Neutral

The data gathered by the students depict that none of the developed filter papers created by the six groups of students were designated as basic (Table 5). Both A and D filter papers yielded neutral and neutral pH readings on a scale of 7. However, both filter papers B and C were acidic. According to Scribner and Wilson (1945), for good stability, the pH value of a filter paper should not be below 5, which is acidic. Since filter papers B and C are acidic and their physical appearances are not excessively dark, they are deemed to have a pH reading between 7 and 5, inclusive. This further demonstrates that none of the developed filter papers are suboptimal in terms of basicity and acidity. Because none of the filter papers are light in color, they shouldn't have a pH below 5, so they are all optimal filtering devices. Even though filter papers B and C have a different pH level than A and D, they are still effective because they are pale in color and so their pH must not be below 5.

The Tensile Strength of the Developed Filter Papers

To assure the quality and efficacy of filter paper in filtration processes, its tensile strength must be determined. The tensile strength of a material is the utmost force it can withstand before breaking or deforming (Corrosionpedia, 2023). It determines the ability of filter paper to resist tearing or fracturing during filtration.

Table 6. Data on the tensile strength of the developed filter papers

Group number	Filter Paper	Mass of #2 iron nails held (g)
1	A	460
	B	940
	C	510
	D	655
2	A	360
	B	760
	C	348
	D	400
3	A	490
	B	950
	C	450
	D	520
4	A	392
	B	866
	C	302
	D	499
5	A	365
	B	905
	C	300
	D	480
6	A	380
	B	800
	C	300
	D	500

The tensile strength of filter paper enables teacher and students to select the appropriate grade of paper for particular applications. For example, filter paper with a low tensile strength may not be suitable for filtering large volumes of liquid or particulate.

In contrast, filter paper with a high tensile strength can withstand greater pressure and provide superior filtration efficiency. The study of Hunter & Fan in 2019 found that higher tensile strength leads to better filtration efficiency, as it prevents tearing or breaking during use.

In this test, the students evaluated the developed filter paper's tensile strength by attaching #2 iron nails with a paper clip and ice wrapper to the filter paper. They recorded the mass of the attached nails and gradually increased that mass until the filter paper broke (Table 6).

Results of the experiment show that filter papers B (20 grams (40%) jute mallow leaves and 30 grams (60%) waste paper) from the 6 groups exhibit the greatest number of #2 iron nails

held, indicating that they are the strongest filter papers or possess the greatest tensile strength. This indicates that the filter papers are resistant to shredding and rupture under high pressure and tension.

The Wet Strength of the Developed Filter Papers

In this activity, the students assessed the quality of developed filter paper by soaking it in water for 1 minute and removing it. The same procedure done to determination of tensile strength was also used to determine the wet strength.

The results of the experiment indicate that filter papers B 20 grams (40%) jute mallow leaves and 30 grams (60%) waste paper) from the six groups hold the most #2 iron nails, indicating that it is the strongest filter paper or has the maximum wet strength (Table 7). This indicates that its structural integrity can be maintained even when subjected to moisture.

The filter paper can withstand liquid pressure without separating or disintegrating. This filter paper may make the filtration process efficient and effective, as there is no particle leakage or bypassing through perforations in the paper. It can also reduce downtime and maintenance costs, as there is less need to replace torn or damaged filter papers.

Table 7. Wet strength of the developed filter papers

Group number	Filter Paper	Mass of #2 iron nails held (g)
1	A	405
	B	685
	C	335
	D	410
2	A	230
	B	440
	C	150
	D	300
3	A	410
	B	680
	C	320
	D	398
4	A	401
	B	670
	C	300
	D	370
5	A	302
	B	659
	C	255
	D	380
6	A	270
	B	650
	C	200
	D	350

The Most Efficient Developed Filter Paper

Separating liquids from solids is one example of how different components of a mixture can be divided using filter paper. In addition, filter paper is frequently used in scientific investigations to gather and examine samples. It is crucial for teaching students how to filter substances in lab classes. Filter paper is quite strong and can withstand a lot of pressure despite being very thin (Admin, & Admin, 2022). However, not all filter paper is the same. Some are more effective at removing particulates of a certain size or type than others (Qoybr, 2023). For this reason, it is essential to identify the most effective filter paper for a given application. Identifying the most effective filter paper is crucial for accurate experiments and procedures. Ineffective filter paper can lead to skewed results, time and resource waste, and safety risks. Choosing the most effective filter paper is essential, as excessively costly options can be unnecessary and require repeated experiments for satisfactory results. In conclusion, determining the most effective filter paper for a particular application guarantees precision, dependability, and cost-effectiveness in scientific and industrial processes (Barton, 2021). It saves time and money while enhancing safety by ensuring that only purified substances are used in experiments or production lines.

Table 8. Summary checklist of all the results for determining the quality of the developed filter papers

CRITERIA	Filter Paper A	Filter Paper B	Filter Paper C	Filter Paper D
Permeability test	✓			
Filtration efficiency test				
1. Starch Solution	✓	✓		
2. Cocoa Solution	✓	✓	✓	
pH Reading	✓	✓	✓	✓
Tensile Strength		✓		
Wet Strength		✓		
TOTAL	4	5*	2	1

*Legend: * - Highest Total Number of Checkmarks*

Table 8 shows the summary of all the results from the different tests conducted by the students in their experiment following the utilization of the Laboratory manual provided by the researcher. For the permeability test, all of the groups' observational data indicate that filter paper A is superior to the others; for the ability to filter starch solution, filter papers A and B performed best; and for the ability to filter cocoa solution, filter papers A, B, and C are superior. All filter papers are acidic, making them optimal for this pH reading test. For both tensile and wet strength tests, all groups concluded that filter paper B is the most capable of supporting a substantial amount of mass. To summarize the results of the evaluations and observations conducted by 6 groups of sixth-grade students, the above table was created. Each checkmark is worth one point, and the developed filter paper with the most checkmarks was compared to the Grade 2 filter paper Whatman. The table displays a summary of all results for determining the quality of developed filter papers, as well as the overall number of checks, which corresponds to the total number of points earned by the highest-scoring sample on each test. Four points belong to filter papers A, five to filter papers B, two to filter papers C, and one to

filter papers D. Prototype B has the filter papers with the maximum number of points, five, which indicates that it is the most effective in all the tests conducted. In conclusion, filter paper B, comprised of 20 grams (40%) of jute mallow (*Chorcorus olitorius*) leaves and 30 grams (60%) of waste paper, is the best of the developed filter papers and was compared to commercial filter paper.

Filter Paper B vs Grade 2 Whatman Filter Paper

Since Filter paper B demonstrated superior performance among all setups in the series of tests, it was subsequently compared to Whatman filter paper. The same procedures were conducted, comparing them. These steps mirrored the researcher's procedure during the prototype creation, as mentioned earlier. Following the completion of all procedures on both the developed filter papers and the Grade 2 Whatman filter paper, a checklist was compiled to highlight relevant aspects. Students synthesized the comparison results, assigning one point for each checkmark. The developed filter paper with the highest tally of marks was deemed the superior filtering device, hence, the better filter paper.

Table 9. Summary checklist of all the results for comparing filter papers b and grade 2 whatman filter paper

CRITERIA	FILTER PAPER B	WHATMAN FILTER PAPER
Permeability		✓
Filtration Efficiency		
1. Starch solution		✓
2. Cocoa Solution	✓	
p H Reading	✓	
Tensile strength	✓	✓
Wet strength		✓
Total Number of Checks	3	4

Table 9 provides a summary of observations on all comparison results between filter paper B (20 grams (40%) jute mallow leaves and 30 grams (60%) waste paper) and commercial filter paper Grade 2 Whatman. The checkmarks in the two columns represent the total number of points. Clearly, filter paper B earned three (3) points on its capacity to filter cocoa solution, its pH reading, and tensile strength. Grade 2 Whatman earned four (4), one for the permeability test, one for the capacity to filter starch solution, one for its pH reading and one for its wet strength. This indicates that Grade 2 Whatman filter paper remains a superior filtering device than its counterpart.

STEM Literacy of the Student Participants Before and After the Implementation of the Laboratory Activities

In determining or assessing the STEM literacy level of students, a pre-and post-test was administered, which assisted in evaluating the effectiveness of the laboratory activities designed to improve STEM literacy.

This provided valuable information in Table 10 that can be used to enhance instructional strategies, curriculum development, and student outcomes. Initially, assessing STEM literacy can aid in identifying problem areas for students. This information can be used to develop

interventions that target particular vulnerabilities. Assessing STEM literacy helped determine the effectiveness of educational programs and curricula. This determined whether the devised STEM – based biology laboratory activities are effective or if modifications are required.

Table 10. Paired t-test results on the STEM literacy level components before and after the implementation of the developed STEM-based biology laboratory activities.

Level Components	Paired Differences					t-value	df	Sig (2-tailed)	Remarks
(Pre-test versus Posttest)	Mean difference	Std. Deviation	Std. Error Mean	95% Confidence Interval					
				Lower	Upper				
STEM Concept (Pre-test versus Posttest)	-1.882	0.88	0.151	-2.189	-1.575	-12.479	33	<0.001	Significant
STEM Integration (Pre-test versus Posttest)	-1.706	0.719	0.123	-1.957	-1.455	-13.835	33	<0.001	Significant
STEM Practice (Pre-test versus Posttest)	-1.5	0.862	0.148	-1.801	-1.199	-10.151	33	<0.001	Significant
STEM Participation (Pre-test versus Posttest)	-1.382	0.817	0.14	-1.667	-1.097	-9.865	33	<0.001	Significant
STEM Evaluation (Pre-test versus Posttest)	-1.706	0.719	0.123	-1.957	-1.455	-13.835	33	<0.001	Significant
STEM Awareness (Pre-test versus Posttest)	-1.647	0.884	0.152	-1.955	-1.339	-10.869	33	<0.001	Significant
Total Scores (Pre-test versus Posttest)	-9.794	3.337	0.572	-10.959	-8.63	-17.112	33	<0.001	Significant

As shown in the Table 10, all level components namely, STEM concept, STEM, integration, STEM practice, STEM participation, STEM evaluation, STEM awareness, and the total scores for all components are significant. This implies that the hypothesis suggesting that there is no significant difference on the level of STEM literacy before and after the implementation of the developed STEM – based biology laboratory activities is rejected. Furthermore, results suggest that there is sufficient evidence to conclude that the students' pre-test scores are significantly different from the posttest scores.

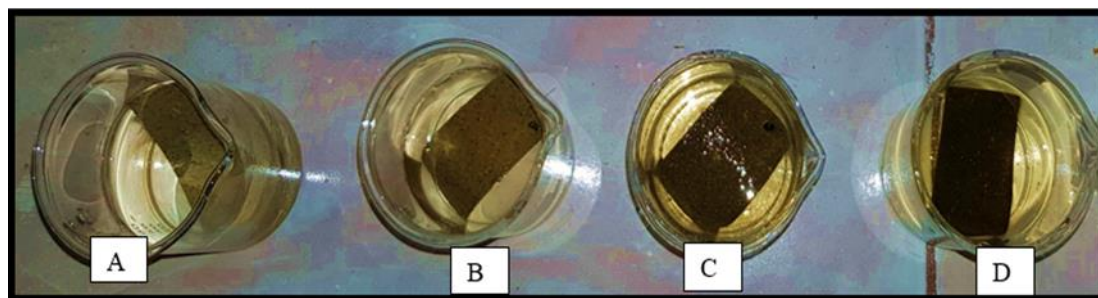


Figure 1. Filter Papers Submerged in Onion Extract

For example, the filter paper submerged in onion extracts as observed in Figure 1 determines the pH qualitatively. The pH value indicates the acidity or alkalinity of a solution, and it can affect the outcome of experiments or analyses performed on the filter paper. In this part of the test, the students independently execute the procedures and evaluate the filter paper's quality based on its pH reading. They immersed the filter paper to a glass of onion extract to know its pH reading. The solution turned red when added to an acid, and turned green when added to a base. The darker the color, the more is it acidic or basic. If there is no change in color, it means that it is neutral (Instructables, 2021).

In a nutshell, measuring STEM literacy assists students in preparing for professions in fields such as engineering and computer science. To ensure that students have the skills necessary to succeed in the rapidly changing technological landscape of the twenty-first century, it is essential to determine and measure their STEM literacy levels. It enables us to identify areas in need of improvement while simultaneously preparing students for careers in disciplines with high demand. The STEM literacy pretest and posttest are effective instruments that measure a student's STEM literacy level prior to and following a learning intervention. The pretest served as a preview of what students learned in terms of the science concepts covered in the activities rather than a final evaluation of what they did not know. The post-test is administered to students upon completion of the laboratory activities in conjunction with a pretest to assess their understanding of science concepts and the effectiveness of the STEM - based biology laboratory activities.

Conclusion

According to the results of the empathy map, teachers believe that a lack of laboratory materials for classroom activities prevented them from conducting laboratory activities. Students are frustrated that they are unable to partake in required laboratory activities due to a lack of materials and that simple laboratory materials such as filter paper are unavailable. Furthermore, teachers and students agree that laboratory experiments cannot be conducted due to a lack of

necessary materials. Following a series of experiments, the researcher was able to create a prototype that is optimal in permeability test, capacity to filter 50 mL water with 10g starch, capacity to filter 50 mL water with 10g cocoa, acidity, and basicity test, tensile and wet strength test. The researcher concluded that the developed filter paper prototype B could be a viable solution to the problems and frustrations rural students and teachers confront. The developed STEM-based biology laboratory activities received an excellent rating for nearly all criteria. This means almost all experts and master teachers gave positive feedback. The results of the evaluations and observations conducted by six groups of responding students indicate that filter paper A performed the best in the permeability test; filter papers A and B performed the best in their ability to filter starch solution; and filter papers A, B, and C performed the best in their ability to filter cocoa solution. Since all filter papers are acidic, they are ideal for this pH test. All groups concluded, based on tensile and wet strength tests, that filter paper B is the most capable of supporting a substantial amount of mass. Among all of the developed filter papers, it was concluded that filter papers B (20 g (40%) jute mallow leaves and 30 g (60%) waste paper) garnered the highest score in terms of permeability, filtration efficiency, pH reading, tensile and wet strength. The filter paper B (20 g (40%) jute mallow leaves and 30 g (60%) waste paper) was compared to Grade 2 Whatman filter paper in terms of permeability, filtration efficiency, pH reading, tensile and wet strength. The Grade 2 Whatman filter paper is still superior over the developed filter paper because it got the highest number of checks. However, they only differ in one point, so the newly developed filter paper is still effective. Although the researcher's formulation was also used in the activities performed by the students, the results of certain tests performed by the students on their developed filter papers differ from those of the researcher. In conclusion, these differences may have been caused by factors such as the maturity of jute mallow leaves and the composition of used waste papers. The success of the implemented STEM Based - Biology Laboratory Activities is demonstrated in the results collected from the students' pre- and post-test scores. Based on the analyzed data, it can be concluded that the students who participated in the implementation demonstrated improved STEM literacy after completing the laboratory activities designed for them.

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Statement of Conflict of Interest

The authors declare that they have no financial or personal relationships with organizations or individuals that could inappropriately influence their work, including but not limited to employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications, and grants or other funding. Additionally, the authors declare no competing interests related to the publication of this research.

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