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The Development of Thermal Expansion Practicum Sets to Improve Science Process Skills of High-School Students

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Abstract

This study aims to develop thermal length expansion practicum sets that are expected to improve high-school science process skills (SPS) in expansion material on metal rods. This research was conducted at SMAN 2 Bekasi in class XI by comparing the control and the experimental class. This study uses the ADDIE approach to analyze, design, develop, implement, and evaluate the thermal expansion length practicum sets. The feasibility test of this practicum sets was carried out in two ways: conducting experiments and validating tests from experts. The experimental results for the linear expansion coefficient of an iron bar are 3.09%, the brass is 5.81%, and the aluminum is 7.39% from the reference value. All of the experimental data still below the error acceptance level which is below 10%. The validation results give 85.5% from media experts and 86.1% from material experts. The trials on users obtained 93.9% of teachers and 85.4% of students. The N-gain in control and experiment class then compared to see the increase in SPS in each category. There was an increase in the experimental class SPS value 7.3% higher than the control class, where the SPS value in the experimental class increased by 47.8%. Therefore, it can conclude that the thermal expansion practicum sets is feasible to use and can improve the science process skills of high school students.

Keywords: thermal expansion practicum sets, expansion of metal rods, science process skills

INTRODUCTION

The 2013 Curriculum emphasizes the scientific approach; the students are required to have excellent skills in performing processes such as observing, classifying, measuring, predicting, explaining and also concluding. Permendikbud No. 65 of 2013 concerning Basic and Secondary Education Process Standards have even hinted at the importance of the learning process that is guided by scientific approaches. The effort to apply the scientific method in the learning process is often referred to as a distinctive feature and becomes a strength of the existence of the 2013 Curriculum, which is indeed interesting to study and further elaborate.

Things that can be achieved by conducting practical activities in the laboratory are: 1) Acquisition of skills, including, observing, investigating, manipulating, organizing and communicating; 2) Increased cognitive abilities, such as the ability to think critically, solve problems, analyze and synthesize; 3) increased attitudes, such as curiosity, courage to take risks, confidence, independence, satisfaction, and responsibility.

One of the phenomena in physics learning is about temperature, heat and heat transfer. This material discusses about: temperature, expansion, heat relations with object temperature, Black principle and heat transfer by conduction, convection, and radiation, in the SMA Physics syllabus issued by the Ministry of Education and Culture clearly stated the ability of high-school students to formulate problems, submit and test hypotheses, determine variables, design an experiment, collect and process data, draw conclusions, and communicate verbally and in writing, so that practicum-based learning is urgent.

From literacy analysis, teaching experience, and needs analysis, we obtained information that the practicum on expansion using long expansion tools Muschenbroek is still manual measurements with ordinary thermometers and changes in expansion length. It measured by a protractor, so students have difficulty in accurate of temperature measurement, and the data obtained is limited, the impact on the ability of students regarding analyzing graphics is very weak. To solve this problem, necessary to develop a thermal expansion practicum sets using an electronic sensor and a microcontroller circuit system, so that it is expected to enhance students' science process skills.

RESEARCH METHODOLOGY

The research method used in this study is the research and development method. This method was chosen to see the feasibility of the product in the field of education. The product developed is a thermal expansion device on metal rods that can be used in physics learning to improve science process skills.

The development model used is the ADDIE (Analyze, Design, Development, Implement, and Evaluation) model. ADDIE is the process of making effective learning media. ADDIE is used in developing learning media and for designing systematic learning.

The feasibility test of the set of thermal expansion instruments in metal rods in this study, we saw the differences before and after using these sets. The difference test uses the N-gain test by comparing the gain between the experimental group and the control group. The pretest value obtained by spreading the question of science process skills before students used the practicum set of thermal expansion tools on metal rods and the posttest value was obtained from the questions after students used a thermal expansion tool on the metal rod. The research flow is shown in FIGURE 1.

ADDIE Step in Planning for Practicum Set Development

Analyze

Preliminary research was conducted to obtain information and analyze the problems and needs of teachers in schools to convey the concept of expansion and the results of measurements through practicum. Preliminary research in the form of distributing questionnaires needs analysis to teachers and students. In addition, at this stage, the formulation of learning objective is also carried out.

Design

This stage begins by determining the tools and materials that will be used to make the expansion practicum on the rod using electronic sensors, taking into account the size and shape. Then make a design of expansion practicum on the rod using electronic sensors. At this stage, a grid of instruments and testing instruments for feasibility and effectiveness was also carried out.

Develop

This stage is the product development stage according to the design in the form of an expansion practicum on the rod using electronic sensors. Practical tools that have been completed are then made through validation tests by experts and physics teachers. Validation test aims to determine the validity of the product produced. Then the practicum tool will be evaluated for its feasibility to see the extent to which practicum tools can and can be used as learning media. The results of the feasibility evaluation will be used to revise the learning media in the form of a practical tool that will be better.

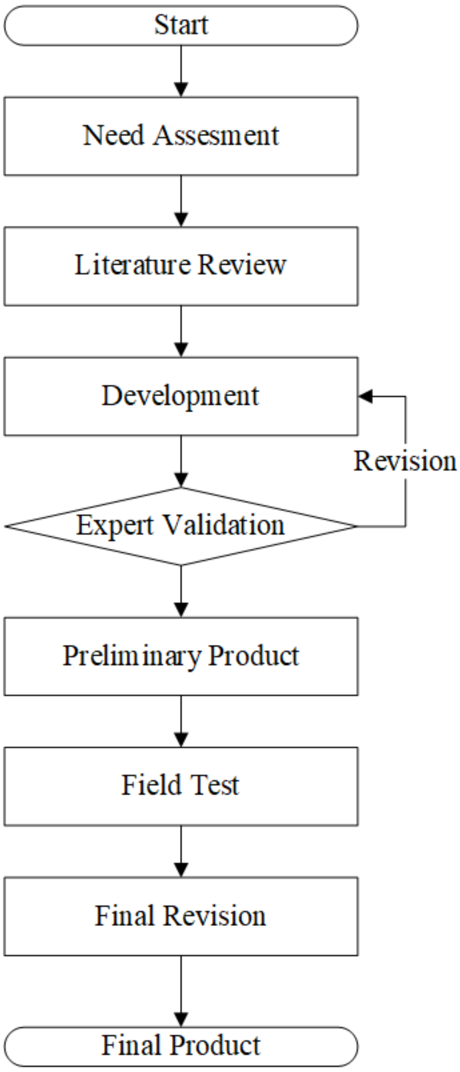

FIGURE 1. Research Flowchart

Implement

Practical tools that have been tested for feasibility and revised then tested on class XI high-school students. Students who follow the observation of practicum tools as much as one class. After students take the practicum test, students are then asked to fill out a field trial questionnaire.

Evaluate

At this stage, students are given a questionnaire to find out the science skills of students after learning to use long-expansion practicum sets with electronic sensors and digital readings.

RESULTS AND DISCUSSION

Thermal length of practicum tool on the metal rod

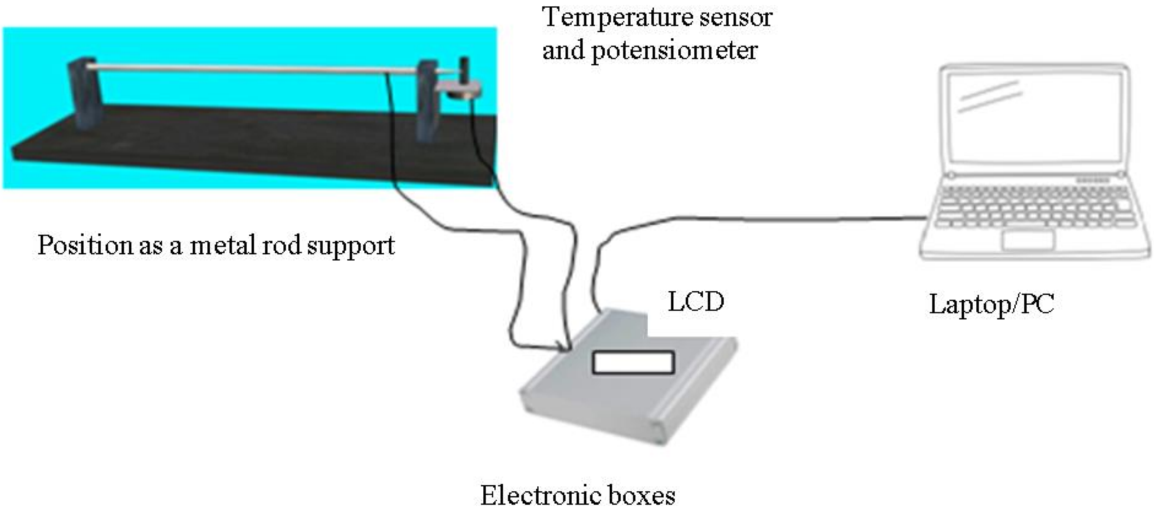

FIGURE 2. The Practicum Sets

The scheme of thermal expansion practicum sets on metal rods described in FIGURE 3.

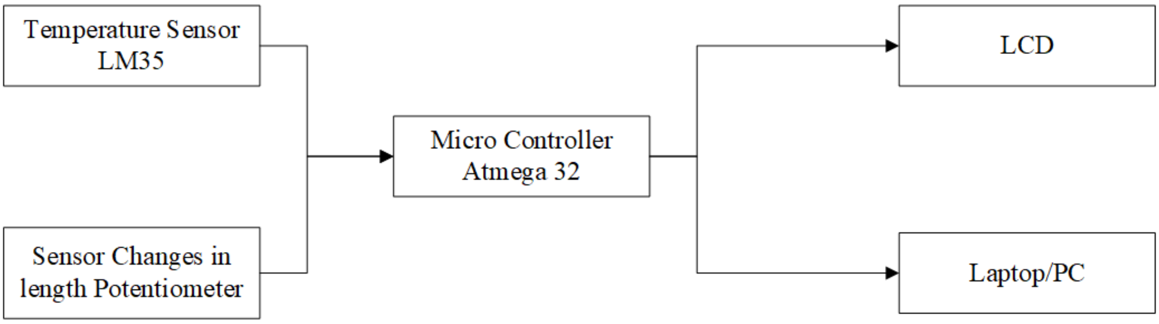

FIGURE 3. Scheme of Thermal Expansion Practicum Sets

While the circuit scheme in the electronic box shown by FIGURE 4.

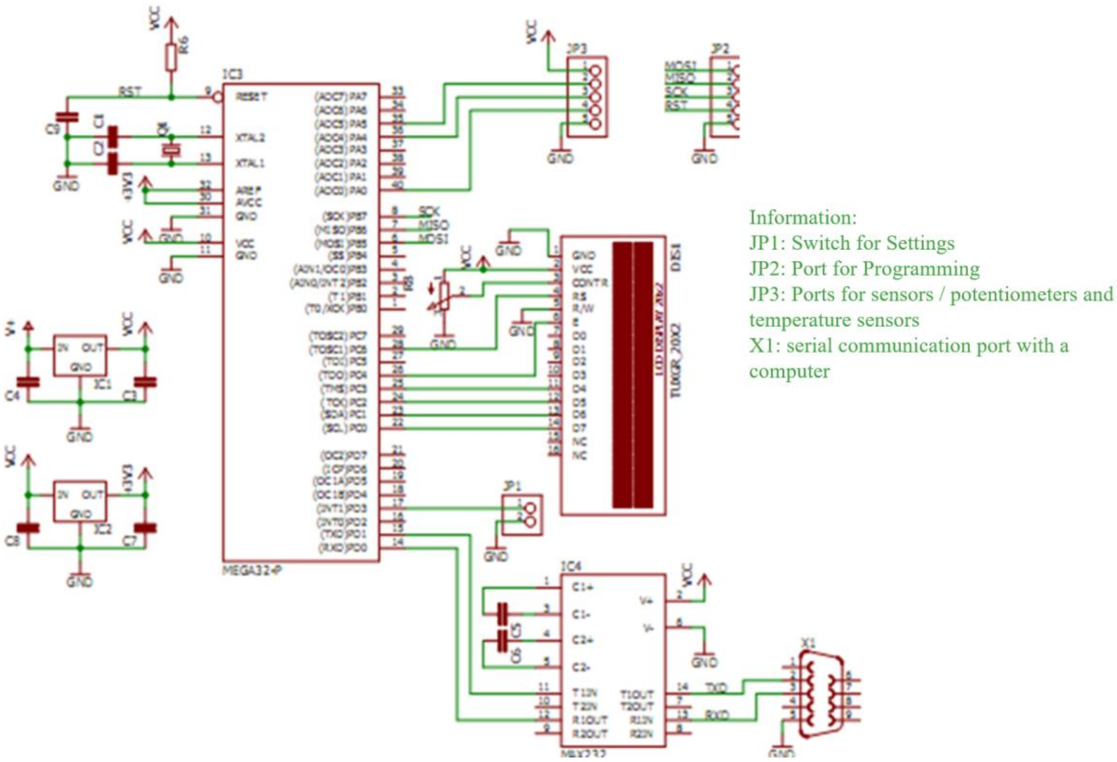

FIGURE 4. Schematic of a thermal expansion electronic circuit on a metal rod

Tools and Materials needed for practicing long expansion on metal rods as follows:
1) Position as a metal rod support
2) Burning place
3) Electronic boxes, as circuit board's protectors that have programmed microcontroller ICs in Computer, LCD, PC programmer sockets, DC power sockets, power buttons and switch buttons
4) Metal rods consisting of aluminum, iron and brass as objects that are sought for the long expansion coefficient value
5) Adapter 7-12V AC / DC or battery 9V box and socket as power to activate the circuit
6) Spirts, as fuel
7) USB serial adapter cable, to connect electronic boxes to a computer (PC) or laptop
8) Computer (PC) or laptop to display experimental data and store it in the form of MS Excel files

TABLE 1. Results of Material Expert Validation

No.	Assessment Aspect	Average Score Percentage	Interpretation
1	Quality content	85.00 %	Very good
2	Accuracy	88.00%	Very good
3	Presentation	90.00%	Very good
	Average	87.67%	Very good

Range of interpretation:
0% - 20% : Very not good
21% - 40%: Not good
41% - 60%: Enough
61% - 80% : Good
81% - 100%: Very good

TABLE 2. Results of Media Expert Validation

No.	Assessment Aspect	Average Score Percentage	Interpretation
1	Display quality	86.67%	Very good
2	Technical quality	90.00%	Very good
3	Worksheet	82.86%	Very good
4	Presentation	85.00%	Very good
	Average	86.13%	Very good

Range of interpretation:
0% - 20% : Very not good
21% - 40%: Not good
41% - 60%: Enough
61% - 80% : Good
81% - 100%: Very good

Experiments of thermal expansion of three rods (iron, brass, and aluminum) are as follows:

1. Expansion of iron

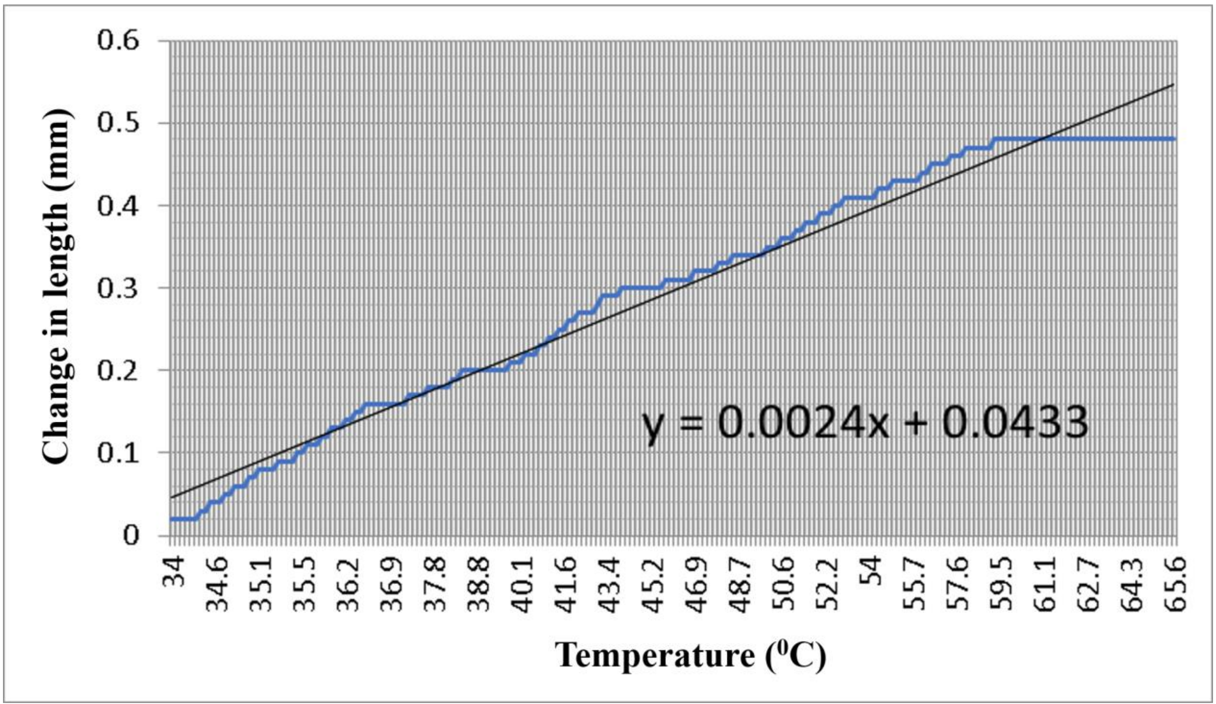

FIGURE 5. Graph of thermal expansion results on iron bars

Calculating:
The initial length of iron Lo = 194 mm
From the trend line equation and the expansion equation on the stem is obtained:

$$y = 0.0024x + 0.0433$$

$$\Delta L = Lo.\ \alpha.\ \Delta T$$

Then the value of the iron expansion length coefficient $\alpha = 1.24 \times 10^{-5}/^{o}C$, while
The long expansion coefficient of iron reference $\alpha = 1.2 \times 10^{-5/o}C$, so the percentage difference 3.09%.

TABLE 3. Average Expansion Coefficients for Some Materials Near Room Temperature
(Resource: Raymond A. Serway, John W. Jewett. (2004) Physics for Scientists and Engineers, 6th Edition)

Material	Average Linear Expansion Coefficient $(\alpha)(^0C)^{-1}$	Material	Average Volume Expansion Coefficient $(\beta)(^0C)^{-1}$
Aluminum	24×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Brass and bronze	19×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Acetone	1.5×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	$3{,}2 \times 10^{-6}$	Mercury	1.82×10^{-4}
Lead	29×10^{-6}	Turpentine	9.0×10^{-4}
Steel	11×10^{-6}	Gasoline	9.6×10^{-4}
Invar (Ni-Fe alloy)	$0{,}9 \times 10^{-6}$	Air[2] at 0^0 C	3.67×10^{-3}
Concrete	12×10^{-6}	Helium[2]	3.665×10^{-3}

2. Expansion of aluminum

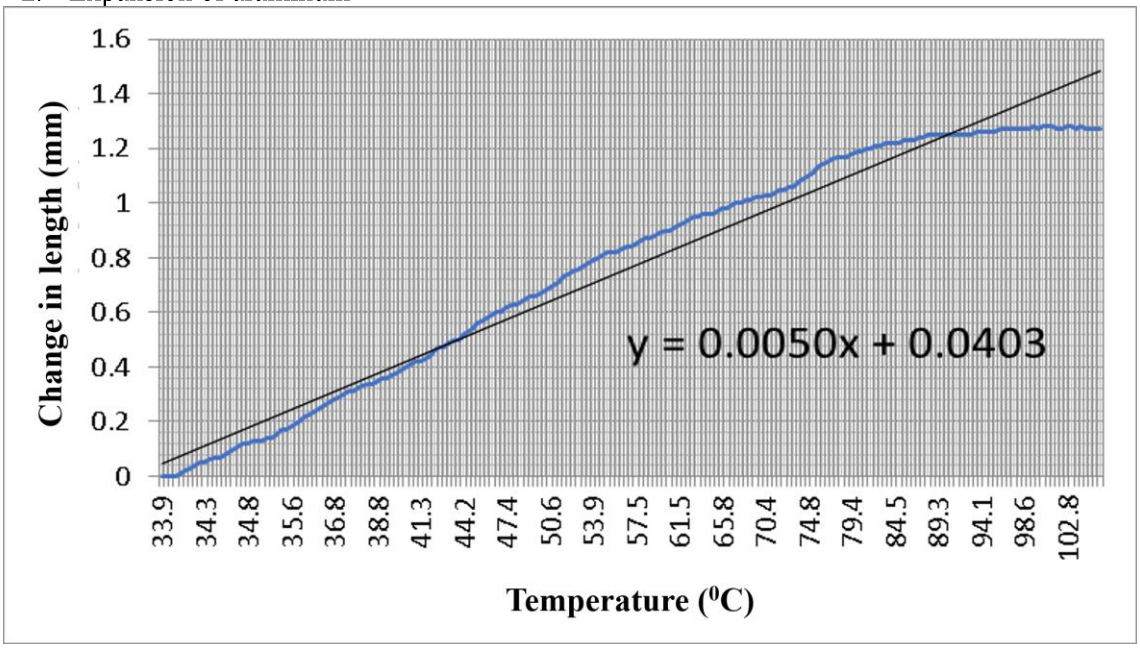

FIGURE 6. Graph of thermal expansion results on aluminum bars

Calculating:
The initial length of aluminum Lo = 194 mm
From the trend line equation and the expansion equation on the stem is obtained:

$$y = 0.0050x + 0.0403$$

$$\Delta L = Lo.\ \alpha.\ \Delta T$$

Then the value of the aluminum expansion length coefficient $\alpha = 2.58\ \ 10^{-5}/^{o}C$, while
The long expansion coefficient of aluminum reference $\alpha = 2.4\ \ 10^{-5}/^{o}C$, so the percentage difference 7.39%.

3. Expansion of brass

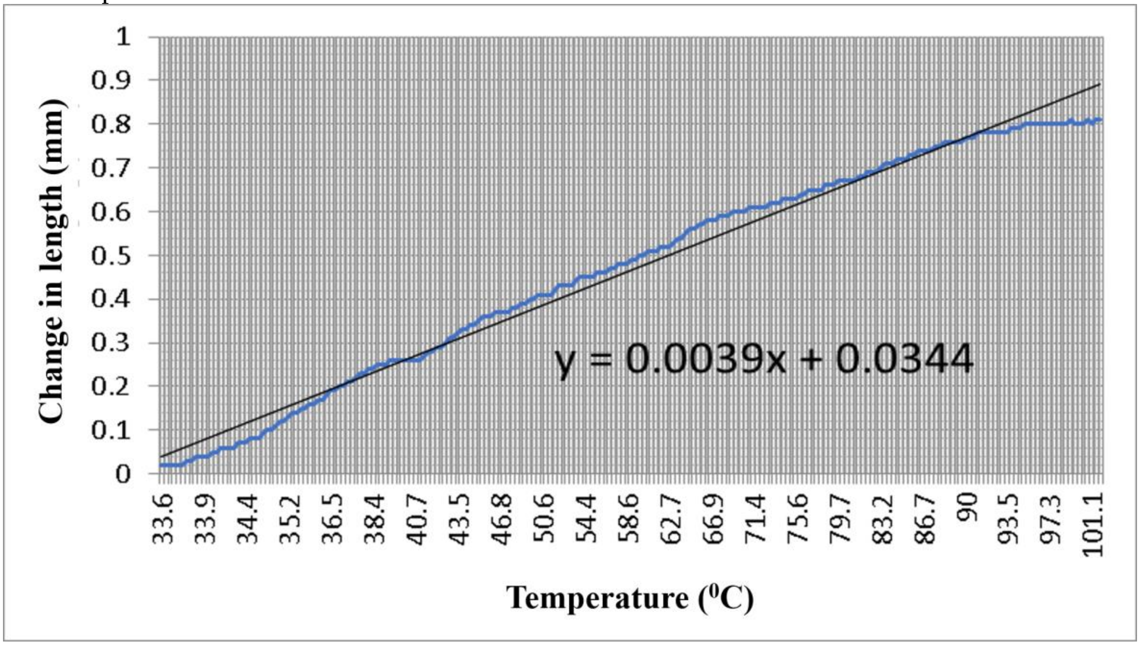

FIGURE 7. Graph of thermal expansion results on brass bars

Calculating:
The initial length of brass Lo = 194 mm
From the trend line equation and the expansion equation on the stem is obtained:

$$y = 0.0039x + 0.0344$$

$$\Delta L = Lo.\ \alpha.\ \Delta T$$

Then the value of the brass expansion length coefficient $\alpha = 2.01\ \ 10^{-5}/^{o}C$, while
The long expansion coefficient of brass reference $\alpha = 1.9\ \ 10^{-5}/^{o}C$, so the percentage difference 5,81%

From experiments and calculations, the length expansion coefficient (α) of each metal is obtained as follows:

TABLE 4. Long expansion coefficient values of experimental results and reference values

No	Metal	expansion length coefficient (/ºC) from experimental	expansion length coefficient (/ºC) from reference
1	Iron	$1{,}24.10^{-5}$	$1{,}2.\ 10^{-5}$
2	Aluminum	$2{,}58.10^{-5}$	$2{,}4.\ 10^{-5}$
3	Brass	$2{,}01.10^{-5}$	$1{,}9.\ 10^{-5}$

From TABLE 4, it can be seen that there are differences in the length of the expansion coefficient values of several materials measured by measuring the length of thermal expansion by reference, not too far away, still at the level of acceptance of errors below 10%.

Trend line graph of the relationship between ΔL and ΔT combined from the experimental results for three different metal bars, as follows:

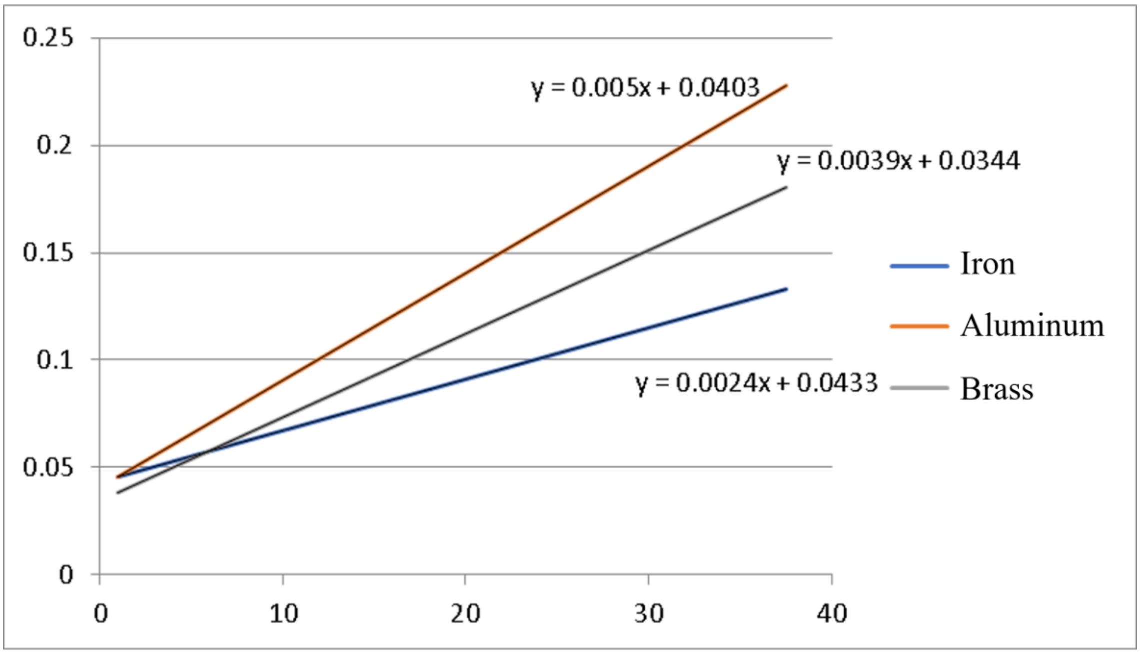

FIGURE 8. Graph ΔL relationships with ΔT of three different metal bars

From FIGURE 8 clearly shows that aluminum expansion has the steepest slope gradient, so that it has the largest expansion coefficient, while iron has a sloping slope, so it has the smallest expansion coefficient.

$$(\alpha \text{ iron} < \alpha \text{ brass} < \alpha \text{ aluminum})$$

The results of the design tools and results of the material and media expert validation were tested together with the test of the Science Process Skills (SPS) in the field, the results of which were as follows:

TABLE 5. Field Test Validation Results

No.	Assessment Aspect	Average Score Presentation	Interpretation
1	Display quality	80.6%	Good
2	Technical quality	80.0%	Good
3	Accuracy	91.8%	Very good
4	Presentation	89.2%	Very good
	Average Percentage	Average Percentage	85.4%

Range of interpretation:
0% - 20% : Very not good
21% - 40%: Not good
41% - 60%: Enough
61% - 80% : Good
81% - 100%: Very good

Posttest results in the experimental class and control class are as follows:

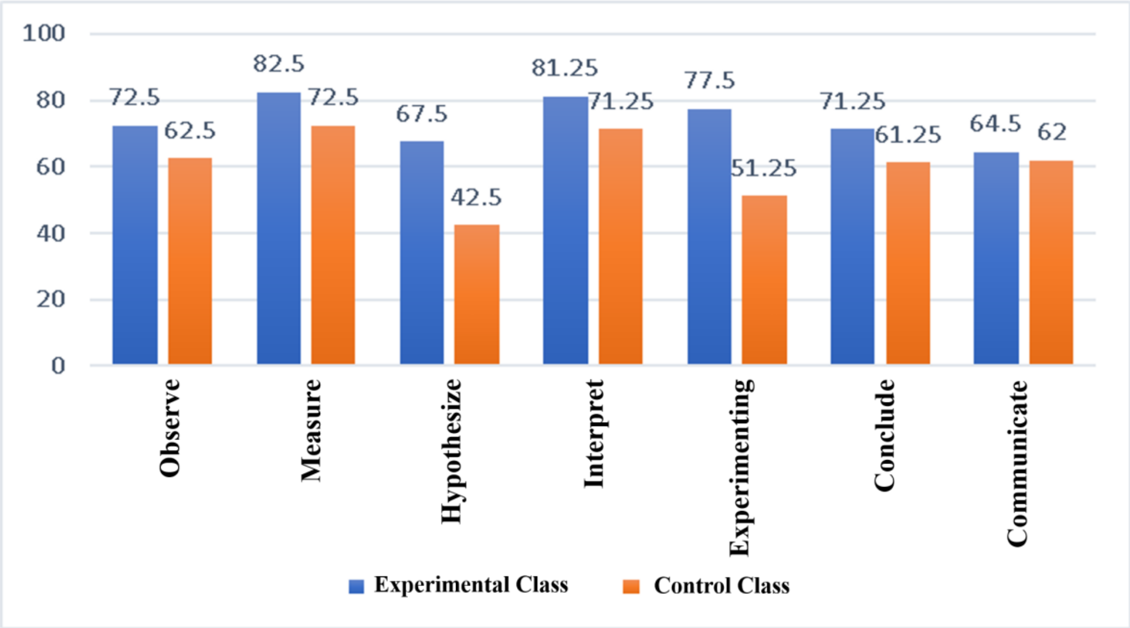

FIGURE 9. Graph of posttest results from experimental and control classes

The increase in the value of students is seen by comparing the value of the pretest, namely the value before using the practicum length expansion tool and the posttest value, namely the value after using the thermal expansion practicum. The results of the posttest and pretest scores in the control and experiment classes are as follows:

TABLE 6. Increase the value of science process skills in the Control and Experiment Classes

Class	Control Class		Experiment Class	
TEST TYPE	PRE	POST	PRE	POST
Average	53	62	50	75
Increase Difference	9		25	
N-GAIN	0,405		0,478	

Based on the calculation it is found that n-gain in the control class is 0.405, this states that there has been an increase of 40.5% and n-gain including the moderate classification. The n-gain calculation in the experimental class is 0.478; it indicates that there has been an increase of 47.8% and n-gain including the reasonable classification, which means that the thermal length practicum tool can increase student SPS by 7.3% from the Muschenbroek tool used by the school.

CONCLUSIONS

The thermal expansion tool is very well used as a learning medium in high school physics learning and can improve the science process skills of high-school students.

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