© Universiti Tun Hussein Onn Malaysia Publisher's Office

JTET

http://penerbit.uthm.edu.my/ojs/index.php/jtet
ISSN 2229-8932 e-ISSN 2600-7932

Journal of Technical Education and Training

Low Cost and Portable Laboratory Kit for Teaching and Learning of Air Conditioning Process in Vocational Education

Ega Taqwali Berman[1], Ida Hamidah[2*], Budi Mulyanti[3], Agus Setiawan[2]

[1]Program Studi Pendidikan Teknologi dan Kejuruan, Sekolah Pascasarjana,
Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Bandung, 40154, INDONESIA

[2]Departemen Pendidikan Teknik Mesin, FPTK,
Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Bandung, 40154, INDONESIA

[3]Departemen Pendidikan Teknik Elektro, FPTK,
Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Bandung, 40154, INDONESIA

*Corresponding Author

DOI: https://doi.org/10.30880/jtet.2021.13.03.013
Received 19th June 2021; Accepted 03rd August 2021; Available online 30th September 2021

Abstract: The purpose of this research is to develop a low-cost and portable air conditioning teaching and learning kits for vocational education. Unlike the existing commercial products that available in the market, this product is based on a low-cost concept using simple design, as well as affordable materials and components. This research is according to a product development process flow, followed by a technical analysis and testing, especially for targeted end users. The development if this product consists of the main components of a four inch diameter round air duct made of PVC, a blower, 5 temperature sensors, five humidity sensors, an air flow sensor, a refrigeration system, two electric heaters and an ultrasonic humidifier. In addition, this kit is relatively small with dimensions of 1500 x 600 x 700 mm and is easy to move and can be used in various places. Total analysis costs less than 3,000 USD, while commercially available offer prices are more than 5,000 USD. Thus the manufacture of this kit is suitable for developing countries with a lot of trial space and limited funding. The performance test results from this kit are also able to show psychometric processes that can be directly observed on the monitor display. Based on open-ended question, student indicated that this product facilitates their learning, improves understanding of the air conditioning process, and increases creativity in problem solving. In the future, this kit can be integrated with computer devices so that measurement data recording can be more accurate and automatically stored safely.

Keywords: Air conditioning, low-cost, laboratory kit, portable, psychrometric, vocational education

1. Introduction

Nowadays, human daily activities are mostly carried out indoors, generally for those who are in offices and the commercial sector (Qi, Lu, & Yang, 2012). Air conditioning is used to create comfortable conditions in the room by controlling and maintaining temperature and reducing humidity (Niemann & Schmitz, 2020). The level of comfort is adjusted to the needs of the occupants and this requires special skills to work. For vocational students in the field of refrigeration, the subject of design and operation of air conditioning systems is a major competency. They must understand the processes of air conditioning which include cooling, heating, humidification, and a combination of all of them (Mago & Long, 2016). In vocational education, these lessons are carried out in theory and practice. The composition of practical learning is more dominant to facilitate students to gain hands-on experience (Berman et al., 2020). The first experience for students in learning, thinking, and solving problems can be obtained through practical activities. Strengthening basic knowledge in the fields of science and engineering can be done in practical activities in the laboratory

*Corresponding author: egatb@upi.edu.my

(Ma & Nickerson, 2006). Practical activities in the laboratory are very crucial activities in vocational education (Scott et al., 2015).

Practicum is an activity to introduce conceptual, procedural, and skill knowledge. Experience in the laboratory is the key to achieving learning objectives because students can engage and learn from every practical activity and acquire skills needed for the scientific community as well as possible work assignments in the industry (Van De Heyde & Siebrits, 2019; Rosina et al., 2021). In addition, the practicum is useful in strengthening, constructing, and reconstructing scientific knowledge (Chacon et al., 2017; Leite & Dourado, 2013). Practicum can also equip students with practical skills (Lampon, Costa-Castello, & Dormido, 2016) and can be used as a medium to deal with student prejudice (Srisawasdi & Kroothkeaw, 2014). Experience in applying knowledge can make it easier for students to solve problems in the workplace in the future (Posadas & Villar, 2016). Practical activities in the laboratory can be carried out if they are supported by complete facilities, talented human resources, and appropriate supporting components.

Previous researchers have carried out various ways to equip students with lessons on the process of air conditioning. This material is presented about psychometrics. Learning about psychrometric processes has been carried out with computational simulations using Microsoft Excel and MATLAB applications (Gupta & Patel, 2017; Mago & Long, 2016). Other researchers also use open-source and platform-independent interactive websites using HTML standards and JavaScript technology by providing psychrometric workbooks in them (Erdélyi & Rajkó, 2016). All these methods have proven to be able to explain the concept of psychometrics and can simulate them. However, there are still problems that must be faced, additional instruments are needed to obtain data on the properties of the air to be analyzed. Generally, a sling psychrometer is used to measure ambient air temperature as a database (Rondet, Baylac, & Bataille, 2008). In doing so, students must rotate the sling psychrometer in the air for about one minute, and then data from both thermometers will be recorded. This process is repeated several times to ensure that the wet-bulb temperature is recorded accurately (Madu, 2018). In addition, simulation practicum activities cannot replace student experience when carrying out practical work using physical equipment (Feisel & Rosa, 2005; Potkonjak et al., 2016). The use of physical laboratory equipment involves an actual process of investigating and discovering unexpected events during practice. The difference between theory and practice is an important part for students to understand their role in carrying out practical. Such experiences cannot be found in laboratories using computer simulations (Rivera, 2016).

In developed countries, the teaching and learning process is usually supported by modern learning tools to carry out the practicum process in ideal conditions. However, in some developing countries such as Indonesia, learning resources and practical tools have always been an obstacle in the learning process (Tazkia & Suherman, 2016). In general, the ratio of the number of tools and students is not comparable, so they practice in groups (Taylor, Eastwood, & Jones, 2014). In addition, physical equipment for practicum purchased from commercial products is very expensive and difficult to provide by vocational schools (Abdullah et al., 2018). Whereas the acquisition of knowledge in the laboratory will occur when students can develop ideas about what they will learn and observe and what is expected of them during practicum in the laboratory (Gunasekaran & Potluri, 2012; Lal et al., 2017). That is why teachers must add their creativity for improving practicum in the vocational school (Ana, 2020; Nandiyanto et al., 2020a; Nandiyanto et al., 2020b; Nandiyanto et al., 2020c; Handayani et al., 2020; Hidayat, et al. 2020). Then, this creativity must be improved when facing Covid-19 pandemic (Mulyanti, Purnama, and Pawinanto, 2020; Hashim et al., 2020; Sangsawang, 2020; Hernawati & Nandiyanto, 2021; Nasution & Nandiyanto, 2021; Huwaidi, Nandiyanto, and Muhammad, 2021; Maryanti, 2021; Ganesha, Nandiyanto, & Razon, 2021; Ramdhani & Nandiyanto, 2021).

Therefore, based on our previous studies (Miftakhudin, Suherman, & Berman, 2020; Tasyarahmanto, Kusuma, & Berman, 2020; Berman et al., 2021), to solve this problem, it is necessary to make low-cost and portable practicum equipment that is in accordance with the achievement of student competencies (Nandiyanto et al., 2019). The purpose of this research is to demonstrate low-cost and portable air conditioning practicum equipment for vocational education. The difference between our kits and other commercial products is their simple design and the components available in the market. So we can make this kit ourselves because the price is affordable. In addition, the main novelties from this kit are relatively small with dimensions of 1500 x 600 x 700 mm and is easy to reach because it is easy to move and can be used in various places and classrooms. This novelty makes this kit suitable for developing countries with a lot of trial space and limited funding.

1.1 Practical-based Learning

Practical learning is a process to improve the skills of students using various methods in accordance with the skills provided and the equipment used. In addition, practical learning is an educational process that functions to guide students in a systematic and directed manner to be able to perform a skill. Practice is an attempt to allow participants to get hands-on experience (Matthews, 1992). The basic idea of experiential learning encourages trainees to reflect or look back on the experiences they have had. Vocational relates to practicum (Ana, 2020; Handayani et al., 2020).

Practical-based learning is directed at experimental learning, which is learning based on concrete experiences, discussions with friends from which new ideas and concepts can be obtained. Learning is seen as a process of constructing knowledge from concrete experiences, collaborative activities, reflection, and interpretation. Practical-based learning strategies can support students to develop hands-on and minds. Therefore, practicum-based learning can be used as alternative learning that can encourage students to learn actively to reconstruct their conceptual understanding (Duda, 2010). The implementation of practical work is important to (1) generate motivation for science learning, (2) improve basic experimental skills, (3) apply scientific approaches, and (4) support mastery of learning materials (Hofstein & Lunetta, 2004). In addition, the practicum also offers a context-rich learning experience, enhances conceptual understanding, develops practical skills, and is the best way to learn the nature of science (Brewe et al., 2006).

The purpose of practicum activities is to provide students with an understanding of scientific knowledge and convince them of the scientific method used in learning that knowledge (Kang & Wallace, 2005). Scientists believe that there is no best way for students to learn about the scientific method, except to position them as if they were scientists. Some experts have different views on laboratory activities, resulting in several designs and practicum models, including the problem-solving laboratory model (Docktor et al., 2015). This practicum model presents contextual problems whose solutions are carried out through laboratory activities. After the problem is solved through laboratory activities, students conduct class discussions to present the concepts that have been found (Ellianawati & Subali, 2010). Characteristics of problems solved through a problem-solving laboratory must be context-rich problems designed to encourage students (a) to consider concepts in the context of real objects in the real world; (b) view problem solving as a series of decisions; and (c) using basic concepts to analyze the problem qualitatively before manipulating mathematical formulas (Docktor et al., 2015).

3. Methods

This report in this section is according to a product development process flow, followed by a technical analysis and testing, especially for targeted end users.

3.1 Design of Psychrometric Laboratory Kit

Generally, the design and development of air-conditioning kit is based on general flow including analysis (product requirement and problem analysis), design, development and testing. The main components of this kit consist of a 4" PVC round air duct (Rucika), a blower (Imatsu; CDI-100P-CY), an electric resistance heater (Teach; 1200 Watt, 220 VAC/50Hz, with thermostat), a refrigeration system (Teach; Qo = 1340 Btu/h, 220VAC/50Hz), gauge pressure (Blue; BLB, BLR/OPG-63), multimeter (Peacefolr; PZEM), anemometer (UNI-T; UT363BT), temperature-humidity meter (UNI-T; UT333BT), pilot lamp (Hager; 220VAC/50Hz, dia. 22 mm Red), circuit breaker (Hager; Single Phase, 6A), ultrasonic humidifier (Warmtoo; 24 VDC), power supply (220 VAC to 5 VDC, 3A), a variable power control (100-220 VAC, 2000 Watt), and sensor cable (Belden; AWG18x4 w/shielding). Insulation is installed throughout the air ducts to prevent condensation along the air ducts during the test. All components are assembled on an aluminium frame measuring length x width x height is 1500 mm x 600 mm x 700 mm. All measuring instruments are mounted on an acrylic laser cutting and printing panel to facilitate psychrometric analysis. This display can make it easier for students to operate this laboratory kit, observe the data parameters detected on each measuring instrument, and record any data changes during the test. Figure 1 shows a schematic illustration of the psychrometric kit laboratory.

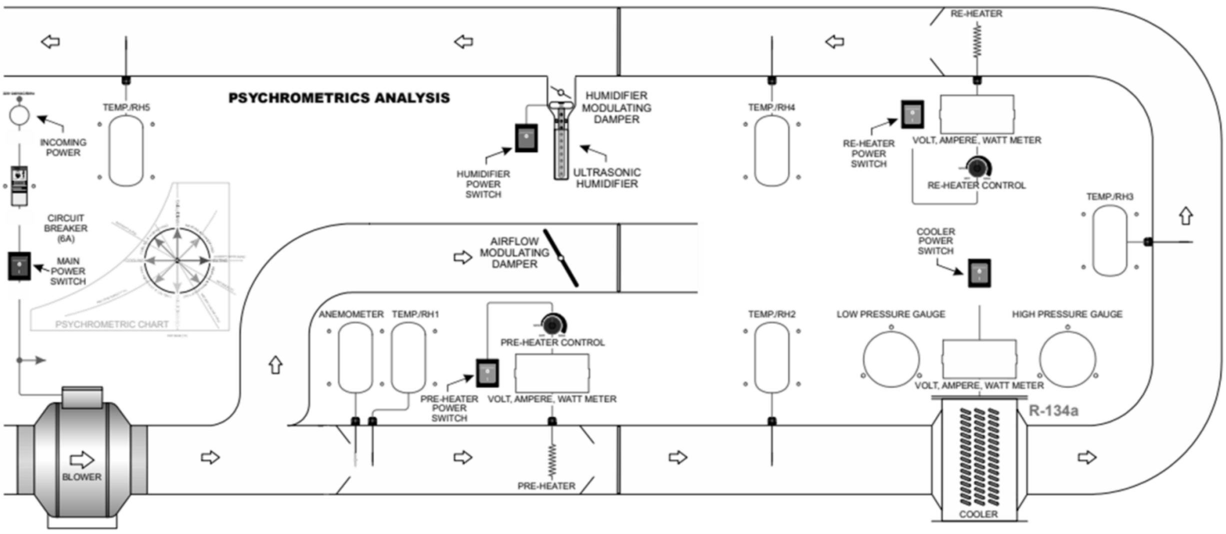

Fig. 1 - Schematic diagram of psychrometric laboratory kit

3.2 Procedure For Operating The Kit

The stages of operating the psychrometric laboratory kit with the first step turn on the circuit breaker and main power switch. Furthermore, the blower will work blowing air along the round air duct. The amount of airflow is adjusted by the airflow modulating damper. The anemometer and Temp./RH1 sensors will detect the value of air velocity and temperature. Increasing the airflow temperature is done by turning on the pre-heater power switch. The amount of heater power can be varied from 0 – 1200 Watt, and the Temp./RH2 sensor shows the measurement results.

The second step is to turn on the more relaxed power to activate the refrigeration system and start the air cooling process. The indicator for recording the cooling process is if the low-pressure value is 2.75 bar (steady-state condition). After that value is reached, any changes in temperature and relative humidity of air flowing through the evaporator coil are recorded. The Temp./RH3 sensor displays the air-cooling measurement results. Then the air will continue to flow along the duct and through the re-heater. If the air temperature is to be raised, the re-heater power switch must be activated. The Temp./RH4 sensor indicates changes in temperature and relative humidity data.

The final step is to turn on the humidifier power switch to add water content to the duct's air. The Temp./RH5 sensor detects data on changes in air characteristics passing through the humidifier. All recorded measurement data are then plotted on a psychrometric diagram to determine other data parameters required for further analysis. In this study, the plotting of the measured data was assisted by the psychrometric diagram viewer software made by Daikin, shown in Figure 2. This application is beneficial for knowing the properties of the air we are going to process.

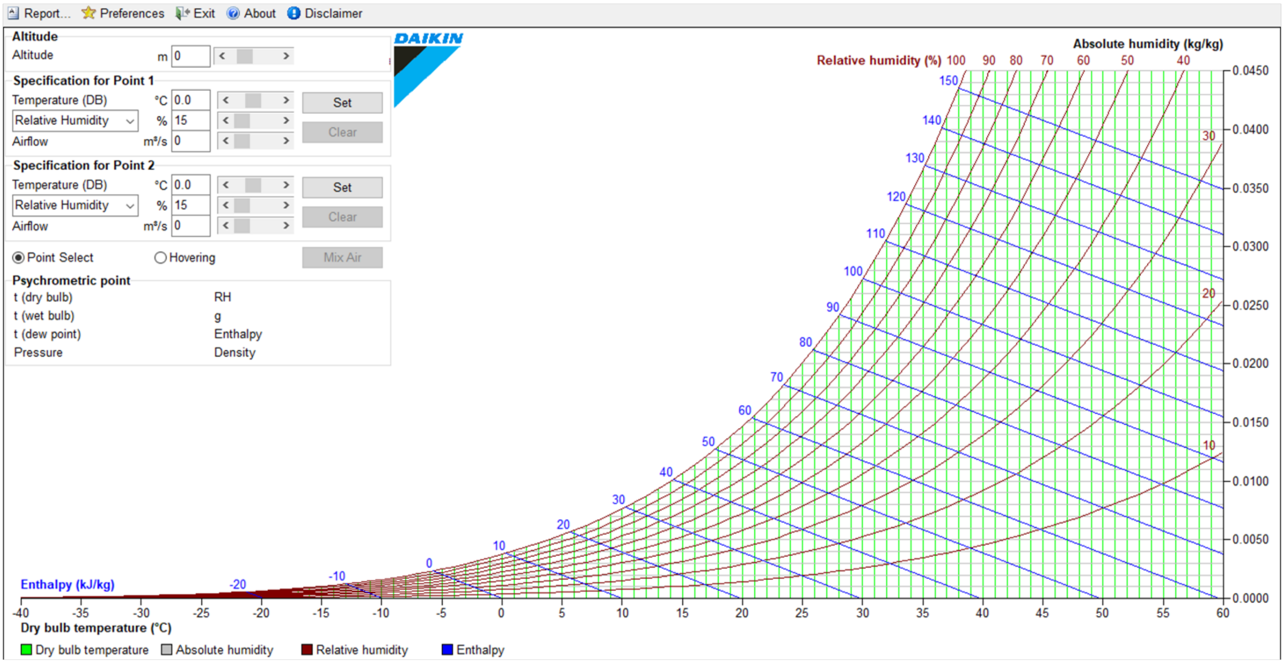

Fig. 2 - Psychrometric Diagram Viewer (Daikin)

In air conditioning, psychrometric includes measuring and calculating the properties of the outdoor air and the air in the conditioned space. Psychrometrics is also used to look for air conditions that will be more comfortable in a conditioned room. In psychrometric, several processes can be analyzed for sensible heating or cooling, humidifying or dehumidifying, cooling and dehumidifying, heating and humidifying. In this kit, each process can be varied based on the difference in air heat load, by adjusting the electric power value of the heater and by varying the velocity of air flowing along the channel. Based on this method students can learn various phenomena that occur in the air conditioning process so that they get more learning experiences.

3.3 Product Development and Materials

3.3.1 Economic Analysis

Tables 1 through 3 show a list of components used to make a psychrometric kit. As shown in the table, the components for designing a psychrometric kit consist of two parts: main and supporting parts. The main part is the main component that cannot be replaced, which contains the refrigeration system, measuring instrument, heater, humidifier, and electrical components. Supporting components are parts that can be modified. These components include accessories, service orders, frames, instrument panels, and air ducts. The price of each component is written in Rupiah with an exchange rate of 1 USD which is equivalent to Rp. 14,500. All cost analyzes are calculated under ideal conditions, where, there are no economic fluctuations (either inflation or deflation) for labor, utility, and raw material costs. All costs are stable during the kit manufacturing process. Based on the recapitulation, the total cost incurred to make this kit is IDR 40,000,000.00 or equivalent to USD 2,758.62. This nominal price is still cheaper than similar commercial products on the market with a price range of over USD 5,000.00. Based on the availability of components and spare parts on the market, the production process of this psychrometric kit can be carried out by small industries or households (Nandiyanto, 2018).

Table 1 - List of main parts for psychrometric laboratory kit

Component	Price (Rp)	Qty		Total (Rp)
Blower	1,036,500	1	unit	1,036,500
Electric Resistance Heater	950,000	2	unit	1,900,000
Refrigeration system	7,400,000	1	unit	7,400,000
Low Pressure Gauge	250,000	1	unit	250,000
High Pressure Gauge	250,000	1	unit	250,000
Multimeter	174,000	3	unit	522,000
Anemometer	524,500	1	unit	524,500
Temperature-Humidity Meter	524,500	5	unit	2,622,500
Pilot Lamp	25,000	1	unit	25,000
Circuit Breaker	45,000	1	unit	45,000
Rocker Switch	25,000	5	unit	125,000
Ultrasonic Humidifier	275,000	1	unit	275,000
Power Supply	75,000	1	unit	75,000
Variable Power Control	77,000	2	unit	154,000
Cable sensor	20,000	20	m	400,000
		Sub Total 1		15,604,500

The list of main components shown in Table 1 is the items that are widely available in the market. The price of these components is very affordable and can be purchased at online stores. With the ease of getting these main components, it will make it easier to assemble a low-cost and portable kit (Nandiyanto et al., 2019).

Table 2 - The material of accessories and service order for the kit

Component	Price (Rp)	Qty		Total (Rp)
Quick connect	33,000	1	pc.	33,000
PTFE Seal	6,000	1	roll	6,000
Cable	250,000	2	roll	500,000
Power Cable	125,000	1	pc	125,000
Power Socket	65,000	1	pc.	65,000
Cable Gland	2,000	34	pcs	68,000
Silicone Rubber Seal	50,000	2	tube	100,000
Nylon nut	3,500	4	pcs	14,000
Bolt Nut Set	7,000	3	set	21,000
Pipe Insulation	27,500	1	pc.	27,500
Bolt and nut	150,000	1	lot	150,000
Bolt and nut	220,000	1	lot	220,000
Bolt and nut	75,000	1	lot	75,000
DIN Rail	25,000	1	btg	25,000
Inline Receptacle Connector	45,000	2	box	90,000
Heat shrink sleeve	230,000	1	set	230,000
Plastic Bottle	17,500	1	pc.	17,500
Cable Duct	33,000	1	btg.	33,000
Double Tape	76,000	1	roll	76,000
Pneumatic Plastic Hose	27,000	1	m	27,000
Laboratory kit design	3,500,000	1	pack	3,500,000
Manufacture of a laboratory kit	5,500,000	1	pack	5,500,000
Transportation cost	3,075,500	1	pack	3,075,500
		Sub Total 2		13,978,500

The supporting materials for the manufacture of psychrometric kits are presented in Tables 2 and 3 are components that we often find daily. All of these items are commonly used in engineering work. This material is a complement to the main part so that the appearance of this kit becomes more elegant and attractive.

Table 3 - List material of ducting, frame, and instrument panel for the kit

Component	Price (Rp)	Qty		Total (Rp)
PVC Pipe	185,000	2	btg	370,000
Large radius PVC Elbow	65,000	2	pcs	130,000
PVC Wye	87,000	1	pcs	87,000
PVC Tee	57,000	1	pcs	57,000
PVC Socket	35,000	6	pcs	210,000
PVC Reducer	45,000	2	pcs	90,000
PVC Reducer	30,000	2	pcs	60,000
PVC Sheet	750,000	1	sht	750,000
PVC Sheet	65,000	1	sht	65,000
PVC Sheet	180,000	1	sht	180,000
PVC stick	250,000	1	kg	250,000
Insulation Sheet	78,000	6	pcs	468,000
Neophrene Glue	225,000	1	kg	225,000
Threaded rod	76,000	1	m	76,000
Plastic Knob	30,000	2	pcs	60,000
Heat Insulator	175,000	1	sht	175,000
Duct Tape	15,000	6	roll	90,000
Aluminum Profile	750,000	3	btg	2,250,000
Aluminum rod	350,000	1	btg	350,000
Bubut aluminum	65,000	8	pcs	520,000
SS Button Head	5,500	16	pcs	88,000
SS Allen Head	6,000	24	pcs	144,000
Hex Bolt	3,000	4	pcs	12,000
Rubber Base	28,000	4	pcs	112,000
Acrylic Sheet	1,450,000	1	sht	1,450,000
Acrylic Laser Cutting and Printing	675,000	2	sht	1,350,000
T Nut Hammer Bolt	8,000	6	pcs	48,000
Aluminum Composite Panel	750,000	1	sht	750,000
		Sub Total 3		10,417,000

3.4 Product Validity and Field Testing

The product validity of the practicum kit has been carried out in a previous study (Berman et al., 2021). Complete product for psychrometric testing involving a laboratory assistant and industry practitioner. A questionnaire consisting of 10 statement items was used to collect technical and aesthetic data from the kit. Furthermore, the performance test is carried out through an alpha test by giving input and seeing the results of the output through laboratory experiments.

In addition, the full product is also tested on users through a limited beta test. Because at the time of this study the Covid-19 pandemic was still ongoing, field testing involved five students in one class session. Several question items were given to capture student feedback. These questions are shown in Table 4.

Table 4 - Beta test instruments on the use of practicum kits by students

No	Question Items	Scale of grading				
		1	2	3	4	5
1	This learning media is equipped with a guidebook to learn the basic concepts of air conditioning					
2	The lessons presented in the manual are explained in detail					
3	Learning media contains complete components that support air conditioning practicum activities					
4	The use of this learning media provides independent learning opportunities for you					

5	You find it helpful when you learn by using this learning media
6	This learning media is easy to operate
7	This learning media is equipped with a guidebook to learn the basic concepts of air conditioning
8	The lessons presented in the manual are explained in detail
9	Learning media contains complete components that support air conditioning practicum activities
10	The use of this learning media provides independent learning opportunities for you
11	You find it helpful when you learn by using this learning media
12	This learning media is easy to operate
13	Setting the measurement variable on this learning media is very easy to operate
14	The availability of manuals makes this learning media safe when used in learning
15	This learning media can increase your creativity in solving problems
16	This learning media can encourage you to do experiments during practicum
17	This learning media helps to understand the concept of the air conditioning process
18	The layout of the components in the learning media is arranged informatively
19	Description of the components in the learning media is easy to read
20	Color illustrations displayed on learning media help explain the air conditioning process
21	The illustrations (graphs, pictures, and tables) in the manual are very clear

*Scale of grading: 5= Strongly Agree, 4= Agree, 3= Neutral, 2= Disagree, 1= Strongly Disagree

3. The Technical Analysis and Result

This section to determine that the teaching aids is fit for classroom teaching and learning session. This low-cost and portable laboratory kit for practicum learning of air conditioning process was tested its performance test (psychometric analysis) and students' feedback upon field test is used to determine the feasibility and ease of use during learning.

3.1 Performance Test of the Psychrometric Kit

The performance test of the psychrometric kit is carried out by analyzing the psychometric process in turn. The data parameters are the measurement and calculation of the characteristics of the conditioned outdoor and indoor air (Laaraba & Khechekhouche, 2018). The first test is the cooling and dehumidifying process with the initial data as shown in Table 5.

Table 5 - Measurement data for cooling and dehumidifying process

Variable	Unit	Value
Pre- Heater Power	watt	800
Airflow rate	m^3/s	0.058
Temperature (T2)	°C	40.1
Relative Humdity (RH2)	%	38.5
Low-Pressure Gauge	bar	3
High-Pressure Gauge	bar	11.2
Cooling Power	watt	205
Temperature (T3)	°C	23.5
Relative Humidity (RH3)	%	80
Re- Heater Power	watt	200
Temperature (T4)	°C	28.5
Relative Humidity (RH4)	%	63.9

Air temperature is 40.1 C and RH 38.5% flowing through the air duct to the cooling coil. The refrigeration system is conditioned at a low pressure of 3 bar and a high pressure of 11.2 bar. The air passing through the cooling coil produces a change in temperature and RH of 23.5 C and 80%, respectively. Then the air is flowed through the re-heater to reduce the water vapor content so that the air characteristics change again so that it produces a temperature of 28.5 C and an RH of 63.9%. The resulting data is then plotted on the psychrometric diagram shown in Figure 3.

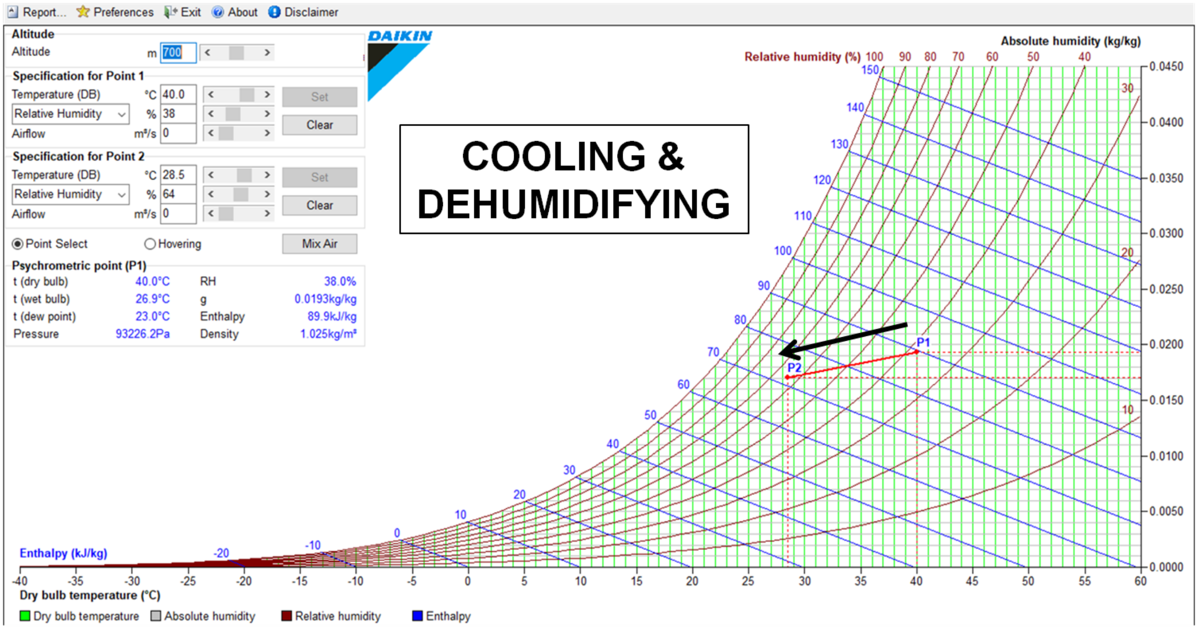

Fig. 3 - Psychrometric diagram of cooling and dehumidifying process

On the psychrometric chart (Figure 3), the cooling and dehumidifying processes are represented as downward and left sloping lines (P1 - P2). Based on the data from these two points, other parameters can be seen, as shown in Table 6. Referring to these data, we can determine the cooling process by looking at the temperature change data for the dry bulb, wet bulb, and dew. Points in columns P1 and P2. While the dehumidifying process can be seen from the changes in the value of density, enthalpy, and humidity (g) in the same column. When sensible heat and latent heat are transferred to moist air, the situation is characterized by changes in dry bulb temperature and relative humidity (Ghiaus, 2014).

Table 6 - Plotting results in the psychrometric graph of cooling and dehumidifying process

Variable data	P1	P2
T (dry bulb)	40.1°C	28.5°C
T (wet bulb)	27.0°C	23.0°C
T (dew point)	23.1°C	21.0°C
Pressure	93226.2Pa	93226.2Pa
RH	38.00%	64.00%
g	0.0194kg/kg	0.0171kg/kg
Enthalpy	90.3kJ/kg	72.3kJ/kg
Density	1.025kg/m³	1.066kg/m³
Airflow	5.8 m/s	5.8 m/s

The second test is the heating and humidification process, with the measurement results presented in Table 7. The air temperature is 35.7 C, and the relative humidity is 47% flowing in the circular air duct. Furthermore, the air flows through a reheater which has a power of 800 Watt so that there is a change in temperature and relative humidity of 45.6 C and 29.9%, respectively. All data are then recorded, and then the data is plotted on a psychrometric diagram, see Figure 4.

Table 7 - Measurement data for of heating and humidifying process

Variable	Unit	Value
Pre- Heater Power	watt	800
Airflow rate	m^3/s	0.058
Temperature (T3)	°C	35.7
Relative Humidity (RH3)	%	47.1
Re- Heater Power	watt	800

Table 7 - Continue

Variable	Unit	Value
Temperature (T5)	°C	45.6
Relative Humidity (RH5)	%	29.9

Heating and humidifying increase the dry-bulb temperature and humidity ratio. The total heat obtained from the initial state to the final state can be broken down into sensible heat and latent heat. In winter, humidification is often necessary because the cold outside air, seeping into the heated space or being deliberately brought in to meet the ventilation requirements of the space, is too dry. In summer, humidification is usually done as part of an evaporative cooling system. On the psychrometric chart (Figure 4), this process is shown as sloping lines up and to the right (P1 - P2). After the two points are known, other data conditions can be seen as shown in Table 8. The heating process is indicated by changes in dry bulb temperature, wet bulb temperature, and dew point from column P1 to P2.

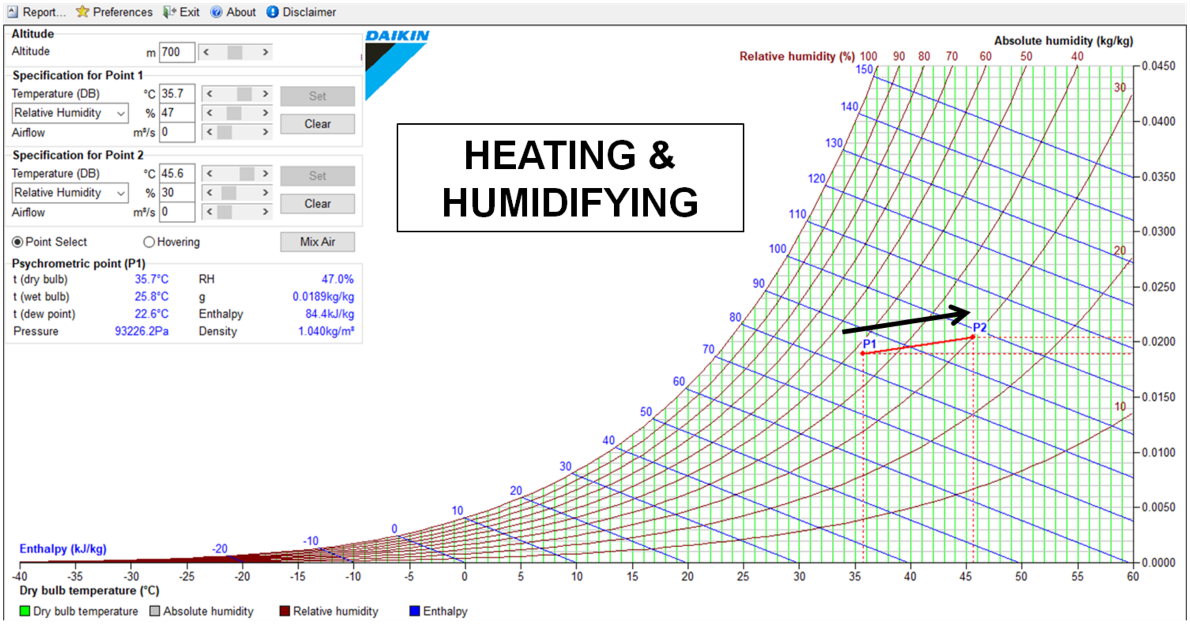

Fig. 4 - Psychrometric diagram of heating and humidifying process

Similarly, the humidification process can be witnessed by looking at changes in the value of humidity (g), enthalpy, and density of the same column. The heating and humidification processes occur sequentially. It starts with increasing the dry-bulb temperature, i.e. the sensible heating that occurs when air passes through the heat exchanger. Then proceed with the humidification process, namely adding water vapor to the air using an ultrasonic humidifier. During this process, both the sensible heat and the latent heat change (Gupta & Patel, 2017).

Table 8 - Plotting Results in the Psychrometric Graph of the Heating and Humidifying Process.

Variable data	P1	P2
T (dry bulb)	35.7°C	45.6°C
T (wet bulb)	25.8°C	28.7°C
T (dew point)	22.6°C	23.9°C
Pressure	93226.2Pa	93226.2Pa
RH	47.00%	30.00%
g	0.0189kg/kg	0.0205kg/kg
Enthalpy	84.4kJ/kg	98.7kJ/kg
Density	1.040kg/m³	1.007kg/m³
Airflow	5.8 m/s	5.8 m/s

4.2 Students' Feedback During Field Testing

Student feedback was captured during field testing. Based on open-ended questions, students indicated that this product facilitates their learning, improves understanding of the air conditioning process, increases creativity in problem-solving. Students also expressed their ease in operating the practicum kit and they were able to study independently. Furthermore, the students said that the availability of a manual for using the practicum kit made them feel safe while studying. The layout of the components that are arranged informatively makes it easier for students to adjust the measurement variables during practical activities. In addition, the color illustrations on the display kit help explain the air conditioning process to students. Complete student feedback as given in Table 9.

Table 9 - Feedback from students after using the practicum kit

No	Question Items	R1	R2	R3	R4	R5	Total	Average
1	This learning media is equipped with a guidebook to learn the basic concepts of air conditioning	4	4	5	5	4	22	4.4
2	The lessons presented in the manual are explained in detail	4	4	5	5	4	22	4.4
3	Learning media contains complete components that support air conditioning practicum activities	5	5	5	5	5	25	5
4	The use of this learning media provides independent learning opportunities for you	4	4	5	5	4	22	4.4
5	You find it helpful when you learn by using this learning media	4	4	5	5	4	22	4.4
6	This learning media is easy to operate	5	5	5	5	5	25	5
7	Setting the measurement variable on this learning media is very easy to operate	4	4	5	5	4	22	4.4
8	The availability of manuals makes this learning media safe when used in learning	5	5	5	5	5	25	5
9	This learning media can increase your creativity in solving problems	4	4	5	5	4	22	4.4
10	This learning media can encourage you to do experiments during practicum	4	4	5	5	4	22	4.4
11	This learning media helps to understand the concept of the air conditioning process	4	4	5	5	4	22	4.4
12	The layout of the components in the learning media is arranged informatively	5	5	5	5	5	25	5
13	Description of the components in the learning media is easy to read	5	5	5	5	5	25	5
14	Color illustrations displayed on learning media help explain the air conditioning process	5	5	5	5	5	25	5
15	The illustrations (graphs, pictures, and tables) in the manual are very clear	4	4	5	5	4	22	4.4
	Total	66	66	75	75	66	348	69.6
	Average	4.4	4.4	5	5	4.4	232	4.64

*Note: R = Respondent

4. Conclusion

This paper presents a method for developing laboratory equipment for an inexpensive and portable AC hands-on skills. An analysis indicates that this kit is categorized as a low-cost and portable device, which is prospective to be applied in developing countries. To demonstrate the performance of this kit, we conducted tests on the psychrometric process with the results observed directly on the monitor screen. The use of the kit during the practical hands-on training can simulate the air conditioning process related to everyday phenomena that are applied in various household and industrial applications. Thus, students practice using the kit could strengthen their skills and competency in the field of air conditioning.

Acknowledgement

The authors would like to thank the Ministry of Education and Culture Republic of Indonesia for Doctoral Dissertation Grant funding with the number of 10/E1/KP.PTNBH/2021.

References

Abdullah, A. G., Hakim, D. L., Auliya, M. A., Nandiyanto, A. B. D., and Riza, L. S. (2018). Low-cost and portable process control laboratory kit. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, 16(1), 232

Ana, A. (2020). Trends in expert system development: A practicum content analysis in vocational education for over grow pandemic learning problems. *Indonesian Journal of Science and Technology*, 5(2), 246-260

Berman, E. T., Hamidah, I., Mulyanti, B., and Setiawan, A. (2020). Study of students' experiences of air conditioning practices in vocational education. *IOP Conference Series: Materials Science and Engineering*, 830(4).

Berman, E., Hamidah, I., Mulyanti, B., and Setiawan, A. (2021). The use of psychrometric analysis kit for learning air conditioning process in vocational education. *Journal of Engineering Science and Technology*, 16(1), 470-481

Chacon, J., Saenz, J., de la Torre, L., Diaz, J., and Esquembre, F. (2017). Design of a low-cost air levitation system for teaching control engineering. *Sensors (Switzerland)*, 17(10), 1–18

Docktor, J. L., Strand, N. E., Mestre, J. P., and Ross, B. H. (2015). Conceptual problem solving in high school physics. *Physical Review Special Topics-Physics Education Research*, 11(2), 020106

Duda, H. J. (2010). Pembelajaran berbasis praktikum dan asesmennya pada konsep sistem ekskresi untuk meningkatkan kemampuan berpikir kritis siswa kelas XI. *VOX edukasi*, 1(2), 29-39

Ellianawati, and Subali, B. (2010). Penerapan model praktikum problem solving laboratory. *Jurnal Pendidikan Fisika Indonesia*, 6, 90–97

Feisel, L. D., and Rosa, A. J. (2005). The role of the laboratory in undergraduate engineering education. *Journal of Engineering Education*, 94(1), 121–130

Ganesha, P., Nandiyanto, A.B.D., and Razon, B.C. (2021). Application of online learning during the Covid-19 pandemic through zoom meeting at karya mekar elementary school. Indonesian Journal of Teaching in Science, 1(1), 1-8

Ghiaus, C. (2014). Linear algebra solution to psychometric analysis of air-conditioning systems. *Energy*, 74(C), 555–566

Gunasekaran, M., and Potluri, R. (2012). Low-cost undergraduate control systems experiments using microcontroller-based control of a dc motor. *IEEE Transactions on Education*, 55(4), 508–516

Gupta, P. K., and Patel, R. N. (2017). A teaching–learning tool for elementary psychrometric processes on psychrometric chart using MATLAB. *Computer Applications in Engineering Education*, 25(3), 458–467

Handayani, M. N., Ali, M., Wahyudin, D., and Mukhidin, M. (2020). Green skills understanding of agricultural vocational school teachers around West Java Indonesia. *Indonesian Journal of Science and Technology*, 5(1), 21-30

Hashim, S., Masek, A., Abdullah, N. S., Paimin, A. N., and Muda, W. H. N. W. (2020). Students' intention to share information via social media: A case study of COVID-19 pandemic. *Indonesian Journal of Science and Technology*, 5(2), 236-245

Hernawati, D., and Nandiyanto, A. B. D. (2021). The Use of Learning Videos in Order to Increase Student Motivation and Learning Outcomes During The COVID-19 Pandemic. *ASEAN Journal of Science and Engineering Education*, 1(2), 77-80

Hidayat, D. S., Rahmat, C., Fattah, N., Rochyadi, E., Nandiyanto, A., and Maryanti, R. (2020). Understanding Archimedes law: What the best teaching strategies for vocational high school students with hearing impairment. *Journal of Technical Education and Training*, 12(1), 229-237

Hofstein, A., and Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education*, 88(1), 28–54

Huwaidi, F., Nandiyanto, A. B. D., and Muhammad, N. (2021). The urgency of online learning media during the Covid-19 pandemic at the vocational school in Indonesia. *Indonesian Journal of Educational Research and Technology*, 1(2), 35-40

Kang, N. H., ad Wallace, C. S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science education*, 89(1), 140-165

Laaraba, A., and Khechekhouche, A. (2018). Numerical simulation of natural convection in the air gap of a vertical flat plat thermal solar collector with partitions attached to its glazing. *Indonesian Journal of Science and Technology*, 3(2), 95–104

Lal, S., Lucey, A. D., Lindsay, E. D., Sarukkalige, P. R., Mocerino, M., Treagust, D. F., and Zadnik, M. G. (2017). An alternative approach to student assessment for engineering–laboratory learning. *Australasian Journal of Engineering Education*, 22(2), 81–94

Lampon, C., Costa-Castello, R., and Dormido, S. (2016). Hands on laboratory for classical nonlinear control systems: The dead-zone case. *2016 IEEE Conference on Control Applications, CCA 2016*, 816–820

Leite, L., and Dourado, L. (2013). Laboratory activities, science education and problem-solving skills. *Procedia - Social and Behavioral Sciences*, 106, 1677–1686

Ma, J., and Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. *ACM Computing Surveys*, 38(3), 1. https://doi.org/10.1145/1132960.1132961

Madu, K. E. (2018). Psychrometric Analysis of an air-conditioning system operating under given ambient conditions. *International Journal of Innovation and Sustainability*, 2, 34–40

Mago, P. J., and Long, W. (2016). Implementation of a computational tool to study psychrometric processes in mechanical engineering courses. *International Journal of Mechanical Engineering Education*, 44(1), 29–55

Maryanti, R. (2021). Assessment of mathematical abilities of students with intellectual disabilities during the COVID-19 pandemic. *Indonesian Journal of Community and Special Needs Education*. 1(2), 47-52

Matthews, M. R. (1992). History, philosophy, and science teaching: The present rapprochement. *Science and Education,* 1(1), 11–47

Miftakhudin, M., Suherman, A., and Berman, E. T. (2020). Determining standard time of practicums in maintenance domestic air conditioning system for vocational schools student. *Journal of Mechanical Engineering Education*, 7(1), 17-24

Mulyanti, B., Purnama, W., and Pawinanto, R. E. (2020). Distance learning in vocational high schools during the covid-19 pandemic in West Java province, Indonesia. *Indonesian Journal of Science and Technology*, 5(2), 271-282

Nandiyanto, A. B. D. (2018). Cost analysis and economic evaluation for the fabrication of activated carbon and silica particles from rice straw waste. *Journal of Engineering Science and Technology*, 13(6), 1523-1539

Nandiyanto, A. B. D., Ragadhita, R., Abdullah, A. G., Triawan, F., Ketut, G., and Sunnardianto, M. A. (2019). Techno-economic feasibility study of low-cost and portable home-made spectrophotometer for analyzing solution concentration. *Journal of Engineering Science and Technology*, 14(2), 599-609

Nandiyanto, A. B. D., Raziqi, G. Y., Dallyono, R., and Sumardi, K. (2020c). Experimental demonstration for enhancing vocational students' comprehension on heat transfer through conduction and radiation of light bulb. *Journal of Technical Education and Training*, 12(3), 189-195

Nandiyanto, A. B. D., Rohman, E., Handayani, M. N., and Putri, S. R. (2020a). E-Module in producing briquettes from melinjo (gnetum gnemon) shell with various particle sizes and binder concentrations for vocational school students. *Journal of Engineering Education Transformations*, 34, 57-64

Nandiyanto, A. B. D., Tiyana, R., Azizah, D. N., and Hofifah, S. N. (2020b). Demonstrating the biobriquettes production using variations in particle size and binder concentration using audio-visual to vocational students. *Journal of Engineering Education Transformations*, 34, 87-94

Nasution, A. R., and Nandiyanto, A. B. D. (2021). Utilization of the google meet and quiziz applications in the assistance and strengthening process of online learning during the COVID-19 pandemic. *Indonesian Journal of Educational Research and Technology*, 1(1), 31-34

Niemann, P., and Schmitz, G. (2020). Air conditioning system with enthalpy recovery for space heating and air humidification: An experimental and numerical investigation. *Energy*, 213

Posadas, H., and Villar, E. (2016). Using Professional Resources for Teaching Embedded SW Development. *Revista Iberoamericana de Tecnologias Del Aprendizaje*, 11(4), 248–255

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., and Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers and Education*, 95, 309–327

Qi, R., Lu, L., and Yang, H. (2012). Investigation on air-conditioning load profile and energy consumption of desiccant cooling system for commercial buildings in Hong Kong. *Energy and Buildings*, 49, 509–518

Ramdhani, T., Nandiyanto, A.B.D. (2021). The use of Whatsapp social media as reinforcement online learning during the COVID-19 pandemic, *Indonesian Journal of Multidisciplinary Research*, 1(1), 107-112

Rivera, J. H. (2016). Science-based laboratory comprehension: an examination of effective practices within traditional, online and blended learning environments. *Open Learning*, 31(3), 209–218

Rondet, E., Baylac, G., and Bataille, B. (2008). Psychrometry as a methodological tool for optimizing the spray drying process. *Drug Development and Industrial Pharmacy*, 34(3), 235–247

Rosina, H., Virgantina, V., Ayyash, V., and Dwiyanti, V. (2021). Vocational education curriculum: Between vocational education and industrial needs. *ASEAN Journal of Science and Engineering Education*, 1(2), 105-110

Sangsawang, T. (2020). An instructional design for online learning in vocational education according to a self-regulated learning framework for problem solving during the CoViD-19 crisis. *Indonesian Journal of Science and Technology*, 5(2), 283-198

Srisawasdi, N., and Kroothkeaw, S. (2014). Supporting students' conceptual development of light refraction by simulation-based open inquiry with dual-situated learning model. *Journal of Computers in Education*, 1(1), 49–79

Tasyarahmanto, B., Kusuma, I. H., and Berman, E. T. (2020). The use of multimedia animation for improving student learning outcomes at vocational education of refrigeration and air conditioning. *Journal of Mechanical Engineering Education*, 7(1), 51-56

Taylor, B., Eastwood, P., and Jones, B. L. (2014). Development of a low-cost, portable hardware platform to support hands-on learning in the teaching of control and systems theory. *Engineering Education*, 9(1), 62–73.

Tazkia, S. R., and Suherman, A. (2016). Optimalisasi Fasilitas Alat Praktik Untuk Mencapai Tuntutan Kompetensi Siswa Smk. *Journal of Mechanical Engineering Education*, 3(2), 263

Van De Heyde, V., and Siebrits, A. (2019). Students' attitudes towards online pre-laboratory exercises for a physics extended curriculum programme. *Research in Science and Technological Education*, 37(2), 168–192