ARTICLE

Design of lesson plans for Internet of Things products in science learning by teachers to improve the quality of education

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ABSTRACT

This study described the results of training for science teachers in the form of lesson plan products for learning with a science, technology, engineering, and mathematics (STEM) approach by utilizing Internet of Things (IoT) technology. The lesson plan created the learning process to help students design IoT products as solutions for problems in everyday life. The research method was descriptive. The subject research was 89 science teachers in West Java, Indonesia. The results obtained the ability of science teachers who participated in the training to create lesson plans using the STEM-IoT approach with various IoT products that were planned to be designed by students in class. They had several creative ideas for emerging the lesson plans that had been made and presented. These were follow-up plans that would be implemented in their respective classes. The impact of the results of this training can be implemented in the classroom, providing more benefits to improve the quality of education, especially in science learning as an effort to achieve sustainable development goals (SDGs).

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INTRODUCTION

The United Nations (UN) in this case instructs all countries to achieve a better sustainable life based on 17 sustainable development goals (SDGs) (Pogge and Sengupta 2015; Elavarasan et al. 2021; Vasconcelos et al. 2022). There are many reports regarding the SDGs, one of the appeals is towards quality education (Nurramdani et al. 2024; Krishnan et al. 2024; Djirong et al. 2024; Kerans et al. 2024; Makinde et al. 2024; Gemil et al. 2024; Haq et al. 2024; Basnur et al. 2024; Maulana et al. 2023; Nurnabila et al. 2023; Awalussillmi et al. 2023; Rahmah et al. 2024). Aspects that need to be considered in realizing quality education include: promoting justice, holistic development, empowering individuals, and fostering social cohesion. Quality education promotes tolerance and prosperity (Rousseau 2016; Abera 2023; Jones et al. 2019; Friedman and Westring 2015; Rubagiza 2016; Aderibigbe 2023; and Hosseini 2023). It enables social and economic progress and improves living standards and overall well-being.

Achieving quality education requires a comprehensive approach involving various stakeholders (Sulthani and Thoifah 2022). The following are some of the key factors that contribute to achieving quality education: adequate investment, qualified and motivated teachers, curriculum design and relevance, and

KEYWORDS

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inclusive education (Kester and Owojuyigbe 2015; Annan 2020; Alhassan et al. 2024; Boon 2020). Academic knowledge, real-world skills, and values-based education must all be balanced in the curriculum. (Namasivay et al. 2023; Djirong et al. 2024; Landero et al. 2022; Tungtawee and Chano 2024; Rozak et al. 2024; Maryanti and Nandiyanto 2021; Rosina et al. 2021). All people should have equal access to high-quality education, regardless of their financial status, gender, race, or disability (Azizah et al. 2022; Rizqita et al. 2024; Faddillah et al. 2022; Musayaroh et al. 2023; Adesokan and Bojuwoye 2023). Every student is given the proper assistance, accommodations, and chances to succeed both academically and personally thanks to inclusive education. (Bailey 2015).

Teachers are one of the subjects that play a very important role in the advancement of education (Avalos 2011). Because teachers are facilitators who are directly involved in learning with students in class. Therefore, the competence possessed by teachers must be measurable and directed. Thus, there are no conditions for practice errors in teaching in the classroom (Massadah and Widaningsih 2024; Saadu et al. 2024; Shahroni et al. 2022; Agarry et al. 2022; Shahroni et al. 2022; Aquino 2024; Haasanovna 2023). The ability of teachers to deliver and provide teaching and education in the classroom must always be innovative and literate in technology (Fishman 2016). Therefore, technological pedagogical content and knowledge (TPACK) competence must be possessed by a teacher as a provision in carrying out their duties (Maknun 2022; Jibril and Adedokun-Shittu 2024; Ibarrientos 2024). TPACK abilities possessed by teachers, not only professionally in their scientific fields, but they will also be able to innovate by utilizing technological advances that are associated with the pedagogical competence they have in carrying out learning. This shows that teacher competency training is very necessary, especially for science teachers (Kember et al. 2008; Drane et al. 2005; Yeung et al. 2011; Salvado et al. 2021; Stephenson et al. 2019).

The development of technology that continues to grow provides opportunities for teachers to be able to utilize technology in learning. A key competency for natural science subject teachers is the ability to help students connect scientific content with its relevance and application in everyday life (Stuckey 2013; Al Husaeni and Al Husaeni 2022; Effiong and Aya 2022; Maryanti and Nandiyanto 2021; Maryanti et al. 2021; Maryanti and Asjjari 2022; Nursaniah 2023). In implementing science in life, it must be linked to the use of current technology, such as the use of the Internet of Things (IoT) which plays a role in facilitating human work in life (Susilawati et al. 2022; Susilawati et al. 2023). Many reports relating to IoT have been well-documented (Luckyardi et al. 2022; Anh 2022; Thapwiroch et al. 2021; Jebur 2023). The competence possessed by teachers to update knowledge can be achieved by holding lesson plan design workshops as an effort to innovate and upgrade knowledge, both pedagogical and expertise (Saavedra and Opfer 2012).

The purpose of this study is to describe the results of training given to science teachers in compiling lesson plans using the science, technology, engineering, and mathematics (STEM) approach to design IoT products in science learning in schools, as an effort to improve the quality of education which is one of the goals of the SDGs. STEM is one of the interesting subjects, and many reports relating to STEM have been well-developed (Lestari et al. 2024; Fajarwati et al. 2024; Tipmontiane and Williams 2022). The novelties of this study are the presentation of the training process to teachers, the STEM approach to producing IoT-based products, and the planning of IoT product designs produced by science teachers to be taught to their students at school.

METHOD

We used a qualitative description method. The needs analysis based on curriculum and technological developments was explained, and the training was conducted on the use of STEM-IoT in science learning. The workshop was conducted in three stages. The first stage was carried out by providing material on STEM learning, the IoT, and the application of STEM-IoT in science learning. The second stage was the practice of designing and programming energy-saving IoT products using the STEM-IoT KIT for remote LED control. The third stage was evaluation and follow-up plans.

This workshop was attended by 89 science teachers (21 male, and 68 female), 35 elementary education teachers, and 54 secondary education science teachers) from various public and private schools in West Java, Indonesia.

RESULTS AND DISCUSSION

Teacher Competence in Improving the Quality of Education

According to Kim et al. (2019), teacher abilities comprise a variety of competencies that enable educators to organize, deliver, and evaluate content in ways that enlighten and engage students. According to Day et al. (2016), these include recognizing the needs of students, fostering a supportive learning environment, putting successful teaching practices into practice, and using feedback to modify instruction and encourage student success. For instance: lesson planning, which involves creating lessons that are organized, instructive, and goal-oriented; classroom management, which involves employing efficient techniques to keep a learning atmosphere; and differentiated instruction, which involves customizing teaching strategies and materials to meet the individual needs of every student.

To prepare for the future, educators need to plan what they can accomplish (Epstein 2013). The response to the query, "How can the preparation of future teachers be quality-assured?" is shown in Figure 1. The three preparations for the answer are (i) looking inward, which involves knowing ourselves thoroughly through effective self-evaluation; (ii) looking outward, which involves challenging our thinking by learning from what occurs elsewhere; and (iii) looking forward, which involves examining what the future may hold for today's students and making plans for how to get there.

Figure 1: Preparation of future teacher.

Science materials related to the Internet of Things

The material in the science subject is closely related to automation sensors that can be used for IoT technology (see **Table 1**) (Susilawati et al. 2024). This shows that the material in the science subject is the basic material that must be learned to solve problems or create products as solutions to every problem in life (Aydin and Aytekin 2018). If the product design is based on a problem, then the product will be useful for use in everyday life (Oda et al. 2017). Therefore, IoT technology is closely related and needed to improve the understanding of science material in learning.

Table 1: Relationship between science material and the types of sensors used based on IoT

No.	Content science	Type of sensor	Benefits in daily life	Ref.
1.	Temperature, heat	Temperature sensor, Thermocouple. RTD, thermistor, semiconductor-based, thermopile, liquid thermometer	Air conditioning and heating systems, microwaves, industrial machines, and aircraft to measure temperature.	(Li et al. 2021)
2.	Wave vibration, mechanical vibration, electrical, distance	Ultrasonic sensor,	Detect objects and measure distances without physical contact.	(Cristani et al. 2020)
3.	Sound	Vibration sensor, buzzer	Detect objects and measure distances without physical contact, and sound	(Wilshin et al. 2023)
4.	Light	LDR (light Dependent Resistor), Photosensitive sensors, Photodetector	Equipment that requires automatic switching on and off according to the light level. Photodetectors can also be used to adjust screen brightness or monitor weather	(Zou et al. 2023)
5.	Acidity or Alkalinity	pH sensor	Specifically designed to measure the pH value of the solution and reflect the acidity or alkalinity.	Grafe et al. 2011)
6.	Humidity	Soil moisture sensor	Sensor to detect soil moisture with adjustable humidity threshold.	Placidi et al. 2021)

Science learning that utilizes IoT technology to carry out product design as a solution to problems can be done by utilizing Arduino software and STEM-IoT Kit hardware as a product automation process (Ocak 2018). After the product is assembled and programmed according to the command, then the process of connecting or activating the device, and automation tools with the internet is carried out so that commands can be controlled via the internet. This is called IoT. The types of software that can be used to help implement IoT include Thinger.io, Blynk, Remote, ThingSpeak, MQTT, Google Assistant, IFTTT, Firebase, Adafruit, and Telegram.

The need for teacher competency development is essential to improving the quality of education. The continuous advancement of educational science and the evolving characteristics of students also require teachers to enhance their pedagogical and scientific competencies. The curriculum used is also continuously developing. This is a strong reason that a teacher is not only tasked with doing homework. However, a teacher must also be willing to be a learner with a strong motivation to continue to upgrade their knowledge, so that the quality of what is done in class is even better. Based on the needs analysis, the training organizers also need to analyze the themes and types of training material. Based on the needs analysis, the training organizers must also analyze the themes and types of training materials required, especially for science teachers. Technological advances must also be taken into account. Additionally, the curriculum recommends learning characteristics that are project-based to solve problems, and student-centered. The trend of technology media that is currently being widely researched and utilized in certain fields, including the education sector, is the IoT (Susilawati et al. 2022). In addition, IoT is very relevant to the needs of science learning as a solution to problems raised in the learning process (Susilawati et al. 2023). Such as the presence of LDR as a product that can be used to reduce problems in the use of light intensity that does not match needs (Susilawati et al. 2024).

In this study, training was carried out with a workshop implementation flow as in **Figure 2**. The training process is carried out in three stages, including the material presentation stage where participants begin by filling out a pretest and attendance sheet. This is followed by an opening session, general material presentations on STEM learning, the Internet of Things (IoT), and the application of STEM-IoT in science education. Group assignments for the LK-making task, scheduled for the next day, are also done during this stage. The second stage is the STEM-IoT design practice. At this stage, participants carry out STEM-IoT application practicums, starting from installing software, introducing hardware devices or STEM-IoT KITs, and programming. Then, the third stage is an evaluation in the form of a posttest and designing a lesson plan using an IoT-based STEM approach, the lesson plan that has been designed is then presented, and a follow-up plan for this training activity is carried out.

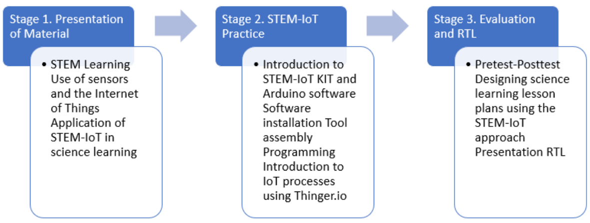

Figure 2: Workshop implementation flow.

In this study, the results discussed from the implementation of the training are lesson plans that have been made by participants. The results are summarized in **Table 2**, which explained that the focus taken from the results of the lesson plan that was designed is the selection of science topics and the IoT product design plan that will be developed during the learning process. This will show the relationship between the main material in the science subject and the IoT products that will be used in everyday life (Nobre and Tavares 2017).

Based on the results of this research, the workshop for science teachers produced a lesson plan design using an IoT-based STEM learning approach (STEM-IoT). The success of this design shows that the importance of science learning is always linked to problems in life and makes science learning a solution to problems and fulfillment of human needs. Teachers who continually innovate in the implementation of learning will produce students who are creative, critical, problem solvers, and can be useful in their lives (Henriksen et al. 2017). A simple example of a product that can be utilized through STEM-IoT design is smart-home design (Al-Ghaili et al. 2023; Alam 2021). All the equipment around us, including at home, can be an inspiration for the need to develop IoT-based products for equipment at home, to make human work easier, especially at home (Shi et al. 2022). In addition, IoT products are designed as engineering process plans that will be practiced with students in class. Modified to suit the existing time duration, intake, and carrying capacity.

Table 2: Results of the STEM-IoT lesson plan and design of IoT product types

No.	Level	Science and Mathematics	Product IoT
1.	High school and vocational school	Work and energy, calculating water discharge	Use of water tap sensors to save water usage.
2.		Energy and its changes, calculating power efficiency, electrical energy	The practice of using light sensors for automatic light switches.
3.		Living things and their environment, ecosystems, biotic and abiotic components, calculating the volume and shape of space in making an aquarium	Make a water filter in the aquarium automatically.
4.		Electrical Energy, calculating the duration of time the lights are on and off automatically.	Making automatic lights to save electricity.
5.		Measurement and electrical energy, Statistics, Algebra Basic arithmetic	Making a smart meter: This smart meter technology functions to record information on the use of electrical energy, the amount of voltage, and the electric current. The goal is to provide information and monitor consumption behavior whether it is wise or wasteful.
6.		Magnetism and electromagnetic induction, Use of Time Concept, Processing of Time Sensor Data, Use of Mathematical Logic, Processing of Measurement Data	This automatic school bell system. And develop the appropriate programming code for the microcontroller, integrate the time sensor, buzzer, and schedule button, and connect this system to the IoT platform.
7.		Energy and its changes, renewable energy, energy efficiency	Smart Home for Energy Efficiency: IoT technology can be used in smart homes to automate energy usage. For example, smart sensors and connected devices can control lighting, air conditioning, water heating, and other appliances based on user preferences and environmental conditions. In doing so, smart homes can reduce energy waste and increase energy efficiency.
8.		Simple machines Calculating mechanical advantage	Designing and modifying simple aircraft tools using motion sensors.
9.		Biotechnology, Hydroponic, pH water, Build space	Designing aquaponic structures and schemes using temperature, pH, and motion sensors.
10.		Fluids Simple Machines Water discharge Space structures	Smart water pumps use infrared and ultrasonic sensors as a substitute for water taps. Assisted by the WhatsApp application as a tool for monitoring the volume of gallons of water.
11.		Conventional Biotechnology (Making Tempeh, Donuts and Yogurt) Calculation of time, temperature, spatial structure, light intensity	IoT technology to be designed: Students use microorganisms and tools that support their growth with the help of IoT such as temperature, time, and light sensors in the process of making conventional biotechnology products that can be controlled on a cellphone as a form of smart agriculture.
12.		Temperature and Heat	Designing the manufacture of temperature sensors and buzzers on several electronic devices.
13.		Substances and Their Changes	Making a sensor to measure acid-base pH using the Arduino application.
14.		Simple machine	Automatic fruit cutter using a simple machine concept.
15.		Temperature and heat, environmentally friendly technology, temperature conversion	IoT-based automatic temperature detector sensor.
16.		Vibrations and Waves	Designing a miniature seismograph based on IoT.
17.		Diversity of living things and their roles Measurement, Mass, time, temperature	Creating smart agriculture by utilizing digital plant growth sensors to monitor nutrition, temperature, humidity, sunlight, and physical measurements in the STEM learning process.

CONCLUSION

This study aims to discuss the trend and position of research on the relationship between IoT, SDGs, and quality of science education using the bibliometric analysis research method assisted by Publish or Perish and Vos viewer. The results obtained show that research on IoT, SDGs, and quality of science education is the latest research with significant research opportunities. This is indicated by the limited visualization of strong networking between keywords, as well as the relatively new research overlay, which was recorded in 2021. Since then, there has been no specific research on the relationship between

IoT, the SDGs, and science education—particularly regarding the depth of discussion on the quality of science education, which remains very shallow. This research is expected to be able to provide positive impact and opportunities to conduct the latest research that can be more widely tested and implemented both in the development of media, strategies, or products related to IoT technology, and SDGs, as well as in improving the quality of science learning.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

DR is the main contributor, providing support for the grant and editing the final manuscript. AS is primarily responsible for conducting teacher training and drafting the initial manuscript. IK and LH contributed by offering support and guidance throughout the research.

REFERENCES

Abera HG. The role of education in achieving the sustainable development goals (SDGs): A global evidence-based research article. International Journal of Social Science Education Research Studies 2023; 3(01): 67-81.

Aderibigbe SA, Idriz M, Alzouebi K, AlOthman H, Hamdi WB, Companioni AA. Fostering tolerance respect for diversity through the fundamentals of Islamic education. Religions 2023; 14(2): 212.

Adesokan A, Bojuwoye O. Teachers' perceived barriers to inclusive education. ASEAN Journal of Community and Special Needs Education 2023; 2(2): 91-96.

Agarry RO, Omolafe EV, Animashaun VO, Babalola EO. Primary education undergraduates' competency in the use of artificial intelligence for learning in Kwara State. ASEAN Journal of Educational Research and Technology 2022; 1(2): 111-118.

Al Husaeni DN, Al Husaeni DF. How to calculate bibliometric using VOSviewer with Publish or Perish (using Scopus data): Science education keywords. Indonesian Journal of Educational Research and Technology 2022; 2(3): 247-274.

Alam T. Cloud-based IoT applications their roles in smart cities. Smart Cities 2021; 4(3): 1196-1219.

Al-Ghaili AM, Kasim H, Hassan Z, Al-Hada NM, Othman, M, Kasmani, RM, Shayea, I. A review: Image processing techniques' roles towards energy-efficient secure IoT. Applied Sciences 2023; 13(4): 2098.

Alhassan N, Alhassan A, Chioma AF. Examining the role of biology teachers' beliefs, motivations, and self-reported practices in constructing curves for biology class. Indonesian Journal of Teaching in Science 2024; 4(1): 11-26.

Anh DHM. Mesh network based on MQTT broker for smart home and IIoT factory. ASEAN Journal of Science and Engineering 2022; 2(2): 173-180.

Annan JK. Preparing globally competent teachers: A paradigm shift for teacher education in Ghana. Education Research International 2020; 2020(1): 8841653.

Aquino PMM. Sustainability of performance of teacher-awardees' instructional competence and teaching effectiveness. ASEAN Journal of Educational Research and Technology 2024; 3(3): 205-214.

Avalos B. Teacher professional development in teaching teacher education over ten years. Teaching Teacher Education 2011; 27(1): 10-20.

Awalussillmi I, Febriyana KR, Padilah N, Saadah NA. Efforts to improve sustainable development goals (SDGs) through education on diversification of food using infographic: Animal and vegetable protein. ASEAN Journal of Agricultural and Food Engineering 2023; 2(2): 113-120.

Aydin A, Aytekin C. Teaching materials development meeting the needs of the subject: A sample application. International Education Studies 2018; 11(8): 27-38.

Azizah N, Prasetyo AC, Dini N, Wulandari V, Kruesa M. Social inclusive education project (SIEP) as a community for handling children with special needs in rural areas. Indonesian Journal of Community and Special Needs Education 2022; 2(2): 89-98.

Bailey L, Nomanbhoy A, Tubpun T. Inclusive education: Teacher perspectives from Malaysia. International Journal of Inclusive Education 2015; 19(5): 547-559.

Basnur J, Putra MFF, Jayusman SVA, Zulhilmi Z. Sustainable packaging: Bioplastics as a low-carbon future step for the sustainable development goals (SDGs). ASEAN Journal for Science and Engineering in Materials 2024; 3(1): 51-58.

Boon NS. Developing curriculum design for the 21st century–Balancing the need of character building meeting other emerging needs of the future. Asia Pacific Journal on Curriculum Studies 2020; 3(2): 1-10.

Cristani M, Del Bue A, Murino V, Setti F, Vinciarelli A. The visual social distancing problem. IEEE Access 2020; 8: 126876-126886.

Day C, Gu Q, Sammons P. The impact of leadership on student outcomes: How successful school leaders use transformational instructional strategies to make a difference. Educational Administration Quarterly 2016; 52(2): 221-258.

Djirong A, Jayadi K, Abduh A, Mutolib A, Mustofa RF, Rahmat A. Assessment of student awareness and application of eco-friendly curriculum and technologies in Indonesian higher education for supporting sustainable development goals (SDGs): A case study on environmental challenges. Indonesian Journal of Science and Technology 2024; 9(3): 657-678.

Djirong A, Jayadi K, Abduh A, Mutolib A, Mustofa RF, Rahmat A. Assessment of student awareness and application of eco-friendly curriculum and technologies in Indonesian higher education for supporting sustainable development goals (SDGs): A case study on environmental challenges. Indonesian Journal of Science and Technology 2024; 9(3): 657-678.

Effiong JB, Aya CF. Rural-urban migration among women farmers: Science education, survey, and implication for food crop production in Cross River State, Nigeria. Indonesian Journal of Teaching in Science 2022; 2(1): 75-80.

Elavarasan RM, Pugazhendhi R, Jamal T, Dyduch J, Arif MT, Kumar NM, Nadarajah M. Envisioning the UN sustainable development goals (SDGs) through the lens of energy sustainability (SDG 7) in the post-COVID-19 world. Applied Energy 2021; 292: 116665.

Epstein JL. Ready or not? Preparing future educators for school, family, community partnerships. Teaching Education 2013; 24(2): 115-118.

Faddillah RN, Nandiyanto ABD, Bilad MR. Literacy program for elementary school students about inclusive education in recognizing children with special needs. ASEAN Journal of Community and Special Needs Education 2022; 1(1): 1-8.

Fajarwati A, Winarno N, Prima EC. Investigating students' creativity through STEM-engineering design process in element, compound, and mixture topic. Indonesian Journal of Teaching in Science 2024; 4(1): 69-84.

Fishman B, Dede C, Means B. Teaching technology: New tools for new times. Hbook of Research on Teaching 2016; 5: 1269-1334.

Friedman SD, Westring A. Empowering individuals to integrate work life: Insights for management development. Journal of Management Development 2015; 34(3): 299-315.

Gemil KW, Na'ila DS, Ardila NZ, Sarahah ZU. The relationship of vocational education skills in agribusiness processing agricultural products in achieving sustainable development goals (SDGs). ASEAN Journal of Science and Engineering Education 2024; 4(2): 181-192.

Gräfe M, Power G, Klauber C. Bauxite residue issues: III. Alkalinity associated chemistry. Hydrometallurgy 2011; 108(1-2): 60-79.

Haq MRI, Nurhaliza DV, Rahmat LN, Ruchiat RNA. The influence of environmentally friendly packaging on consumer interest in implementing zero waste in the food industry to meet sustainable development goals (SDGs) needs. ASEAN Journal of Economic and Economic Education 2024; 3(2): 111-116.

Hasanovna HM. The mechanism of development of professional and pedagogical creativity of future physical education teachers based on a competent approach. ASEAN Journal of Physical Education and Sport Science 2023; 2(1): 17-22.

Henriksen D, Richardson C, Mehta R. Design thinking: A creative approach to educational problems of practice. Thinking Skills Creativity 2017; 26: 140-153.

Hosseini SH. The well-living paradigm: Reimagining quality of life in our turbulent world. Discover Global Society 2023; 1(1): 19.

Ibarrientos JN. Competency level in information and communications technology (ICT) of teachers: Basis for a technological, pedagogical and content knowledge (TPACK) readiness training program. Indonesian Journal of Teaching in Science 2024; 4(1): 47-60.

Jebur TK. Greening the internet of things: A comprehensive review of sustainable IOT solutions from an educational perspective. Indonesian Journal of Educational Research and Technology 2023; 3(3): 247-256.

Jibril M, Adedokun-Shittu NA. Enhancing education: A comprehensive framework for integrating technological pedagogical content knowledge (TPACK) into teaching and learning. Indonesian Journal of Multidiciplinary Research 2024; 4(1): 181-188.

Jones SM, McGarrah MW, Kahn J. Social emotional learning: A principled science of human development in context. Educational Psychologist 2019; 54(3): 129-143.

Kember D, Leung DY, McNaught C. A workshop activity to demonstrate that approaches to learning are influenced by the teaching learning environment. Active Learning in Higher Education 2008; 9(1): 43-56.

Kerans G, Sanjaya Y, Liliasari L, Pamungkas J, Ate GY. Effect of substrate and water on cultivation of Sumba seaworm (nyale) and experimental practicum design for improving critical and creative thinking skills of prospective science teacher in biology and supporting sustainable development goals (SDGs). ASEAN Journal of Science and Engineering 2024; 4(3): 383-404.

Kester KO, Owojuyigbe OB. An exploration of the prediction of resource availability, allocation utilisation on organisational performance in the Nigerian adult non-formal education sector. African Journal of Educational Management 2015; 16(2): 45-62.

Kim S, Raza M, Seidman E. Improving 21st-century teaching skills: The key to effective 21st-century learners. Research in Comparative International Education 2019; 14(1): 99-117.

Krishnan A, Al-Obaidi ASM, Hao LC. Towards sustainable wind energy: A systematic review of airfoil and blade technologies over the past 25 years for supporting sustainable development goals (SDGs). Indonesian Journal of Science and Technology 2024; 9(3): 623-656.

Landero DJM, Gadayan DV, Valderama IM, Falle JA, Calixtro JrVL. Implementation and acceptance of Latin dances in senior high school curriculum. Indonesian Journal of Educational Research and Technology 2022; 2(2): 117-122.

Lestari DA, Suwarma IR, Suhendi E. Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics. Indonesian Journal of Teaching in Science 2024; 4(1): 1-10.

Li Z, Wang P, Haigh A, Soutis C, Gibson A. Review of microwave techniques used in the manufacture fault detection of aircraft composites. The Aeronautical Journal 2021; 125(1283): 151-179.

Luckyardi S, Hurriyati R, Disman D, Dirgantari PD. A systematic review of the IoT in smart university: Model and contribution. Indonesian Journal of Science and Technology 2022; 7(3): 529-550.

Makinde SO, Ajani YA, Abdulrahman MR. Smart learning as transformative impact of technology: A paradigm for accomplishing sustainable development goals (SDGs) in education. Indonesian Journal of Educational Research and Technology 2024; 4(3): 213-224.

Maknun J. The technological pedagogical content knowledge (TPACK) competence of vocational high school teacher. Jurnal Pendidikan Teknologi dan Kejuruan 2022; 28(1): 63-75.

Maryanti R, Asjjari M. Family as an educational environment that can provide science education for children with special needs. Indonesian Journal of Community and Special Needs Education 2022; 2(2): 149-154.

Maryanti R, Nandiyanto ABD, Hufad A, Sunardi S. Science education for students with special needs in Indonesia: From definition, systematic review, education system, to curriculum. Indonesian Journal of Community and Special Needs Education 2021; 1(1): 1-8.

Maryanti R, Nandiyanto ABD. Curriculum development in science education in vocational school. ASEAN Journal of Science and Engineering Education 2021; 2(1): 151-156.

Maryanti R, Nandiyanto ABD. Curriculum development in science education in vocational school. ASEAN Journal of Science and Engineering Education 2021; 2(1): 151-156.

Massadah E, Widaningsih L. Measurement of the level of digital competence of vocational teachers in learning development. Indonesian Journal of Multidiciplinary Research 2024; 4(1): 189-196.

Maulana I, Asran MA, Ash-Habi RM. Implementation of sustainable development goals (SDGs) no. 12: Responsible production and consumption by optimizing lemon commodities and community empowerment to reduce household waste. ASEAN Journal of Community Service and Education 2023; 2(2): 141-146.

Musayaroh S, Asmiati N, Utami YT, Mulia D, Sidik SA, Abadi RF, Pratama TY, Maslahah S, Pramudyo AS. A digital accessibility and inclusive design-based e-module in higher education: Does it work in a classroom with a deaf student? ASEAN Journal of Community and Special Needs Education 2023; 2(1): 55-60.

Namasivayam S, Al-Obaidi ASM, Fouladi MH. A conceptual curriculum design approach for educating engineers of and for the future. Indonesian Journal of Science and Technology 2023; 8(3): 381-396.

Nobre GC, Tavares E. Scientific literature analysis on big data internet of things applications on circular economy: A bibliometric study. Scientometrics 2017; 111: 463-492.

Nurnabila AT, Basnur J, Rismayani R, Ramadhani S, Zulhilmi Z. Analysis of the application of Mediterranean diet patterns on sustainability to support the achievement of sustainable development goals (SDGs): Zero hunger, good health and well-beings, responsible consumption, and production. ASEAN Journal of Agricultural and Food Engineering 2023; 2(2): 105-112.

Nurramadhani A, Riandi R, Permanasari A, Suwarma IR. Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs). Indonesian Journal of Science and Technology 2024; 9(2): 261-286.

Nursaniah SSJ. Analysis of science education curriculum for students with special needs in special schools: the curriculum of 2013. Indonesian Journal of Community and Special Needs Education 2023; 3(2): 113-130.

Ocak MA. Where does Arduino's power come from?: An extended literature review. Journal of Learning Teaching in Digital Age 2018; 3(1): 21-34.

Oda T, Matsuo K, Barolli L, Yamada M, Liu Y. Design implementation of an IoT-based e-learning testbed. International Journal of Web Grid Services 2017; 13(2): 228-241.

Placidi P, Morbidelli R, Fortunati D, Papini N, Gobbi F, Scorzoni A. Monitoring soil ambient parameters in the iot precision agriculture scenario: An original modeling approach dedicated to low-cost soil water content sensors. Sensors 2021; 21(15): 5110.

Pogge T, Sengupta M. The sustainable development goals: A plan for building a better world?. Journal of Global Ethics 2015; 11(1): 56-64.

Rahmah FA, Nurlaela N, Anugrah R, Putri YAR. Safe food treatment technology: The key to realizing the sustainable development goals (SDGs) zero hunger and optimal health. ASEAN Journal of Agricultural and Food Engineering 2024; 3(1): 57-66.

Rizqita AJ, Sunardi S, Bela MRWAT Development of traluli program of family-resourced early intervention for multiple disability and visual impairment (MDVI) children with fine motor impairment in inclusive school. Indonesian Journal of Community and Special Needs Education 2024; 4(1): 65-74.

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

Rousseau JJ. Social justice equity. People, Planet, Progress Beyond 2016; 2: 251-263.

Rozak RWA, Kembara MD, Praja WN, Warsihna J. Analysis of teachers' understanding of implementing the merdeka curriculum in primary schools. Indonesian Journal of Multidiciplinary Research 2024; 4(1): 237-250.

Rubagiza J, Umutoni J, Kaleeba A. Teachers as agents of change: Promoting peacebuilding social cohesion in schools in Rwa. Education as Change 2016; 20(3): 202-224.

Saadu UT, Obafemi KE, Oluwakemi AC. Primary school teachers' competence level in the early identification of gifted children. Indonesian Journal of Community and Special Needs Education 2024; 4(1): 1-10.

Saavedra AR, Opfer VD. Teaching learning 21st century skills: Lessons from the learning sciences. A Global Cities Education Network Report. New York, Asia Society 2012; 10: 2012.

Salvadó Z, Garcia-Yeste C, Gairal-Casado R, Novo M. Scientific workshop program to improve science identity, science capital educational aspirations of children at risk of social exclusion. Children Youth Services Review 2021; 129: 106189.

Shahroni N, Minghat AD, Mustakim SSB. Competency index of technical vocational education and training (TVET) instructors for 4.0 industrial revolution. ASEAN Journal of Educational Research and Technology 2022; 1(2): 155-162.

Shahroni N, Minghat AD, Mustakim SSB. Methodology for investigating competency index of technical vocational education and training (TVET) instructors for 4.0 industrial revolution. ASEAN Journal for Science Education 2022; 1(1): 49-62.

Shi Q, Yang Y, Sun Z, Lee C. Progress of advanced devices Internet of things systems as enabling technologies for smart homes health care. ACS Materials Au 2022; 2(4): 394-435.

Smith HD, Light G, Pinto L, Swarat S. The gateway science workshop program: Enhancing student performance retention in the sciences through peer-facilitated discussion. Journal of Science Education Technology 2005; 14: 337-352.

Stephenson NS, Miller IR, Sadler-McKnight NP. Impact of peer-led team learning the science writing workshop template on the critical thinking skills of first-year chemistry students. Journal of Chemical Education 2019; 96(5): 841-849.

Stuckey M, Hofstein A, Mamlok-Naaman R, Eilks I. The meaning of ‘relevance’in science education its implications for the science curriculum. Studies in Science Education 2013; 49(1): 1-34.

Sulthani DA, Thoifah I. Urgency of stakeholders in improving the quality of education. Riwayat: Educational Journal of History Humanities 2022; 5(2): 443-451.

Susilawati A, Kustiawan I, Rochintaniawati D, Hasanah L, Lim Y. Light intensity distribution in the room using light dependent resistor: Through the engineering design process. Indonesian Journal of Science Technology 2024; 9(3): 679-708.

Susilawati A, Kustiawan I, Rochintaniawati D, Hasanah L. Things for science teachers: A bibliometric analysis. Journal of Engineering Science Technology 2023; 18(6): 41-50.

Susilawati A, Rochintaniawati D, Permanasari A, Kustiawan I. Research trends about internet of things in science education: A bibliometric analysis. Journal of Engineering Science Technology 2022; Special Issue (June 2022): 17-24.

Thapwiroch K, Kumlue A, Saoyong N, Taprasan P, Puengsungewan S. Easy-mushroom mobile application using the internet of things (IoT). Indonesian Journal of Educational Research and Technology 2021; 1(2): 1-6.

Tipmontiane K, Williams PJ. The integration of the engineering design process in biology-related STEM activity: A review of Thai secondary education. ASEAN Journal of Science and Engineering Education 2022; 2(1): 1-10.

Tungtawee C, Chano J. Bibliometric analysis using VOSviewer with Publish or Perish of curriculum evaluation using the CIPP model. Indonesian Journal of Multidiciplinary Research 2024; 4(1): 163-170.

Vasconcelos C, Silva J, Calheiros CS, Mikusiński G, Iwińska K, Skaltsa IG, Krakowska K. Teaching sustainable development goals to university students: A cross-country case-based study. Sustainability 2022; 14(3): 1593.

Wilshin S, Amos S, Bomphrey RJ. Seeing with sound; Surface detection avoidance by sensing self-generated noise. International Journal of Micro Air Vehicles 2023; 15: 17568293221148377.

Yeung A, Pyke SM, Sharma MD, Barrie SC, Buntine MA, DaSilva KB, Lim KF. The advancing science by enhancing learning in the laboratory (ASELL) project: The first Australian multidisciplinary workshop. International Journal of Innovation in Science Mathematics Education 2011; 19(2): 51-72.

Zou W, Sastry M, Gooding JJ, Ramanathan R, Bansal V. Recent advances a roadmap to wearable UV sensor technologies. Advanced Materials Technologies 2020; 5(4): 1901036.