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How to do research methodology: From Literature Review, Bibliometric, Step-by-step Research Stages, to Practical Examples in Science and Engineering Education

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ABSTRACT

This paper explains how to do research in science and engineering education. To support the explanation, the paper was supported by a literature review for research design and computational bibliometric analysis. We mapped several types of research methodologies, supported by several examples from researchers and practitioners who were involved in these research topics. We also developed 9 steps in research methodology, namely PHMEEDERID, an abbreviation of Identify Problems; Develop Hypothesis; Choose Research Methodology; Conduct Experiments and Create Equipment; Refine Design and Develop; Evaluate and Test; Do Revision and Retest; Implement; and Disseminate. The step-by-step method was also added to make readers and users easily understand. This study has the potential to be used as standard information for scientists, teachers, educators, and practitioners in doing research in science education and engineering education.

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1. INTRODUCTION

Research methodology is crucial for guiding the research process, providing a clear framework for designing studies, selecting subjects, sampling, processing data, and analyzing results to meet research objectives. It also aids product design by identifying user needs, addressing challenges, optimizing resources, and reducing project timelines. In science, engineering, and education, methodology ensures systematic processes, reliable outcomes, and quality data, contributing to advancements in knowledge and technology. Careful consideration of research design is essential to ensure effective planning and implementation aligned with research goals [1-4].

The methodology provides the theoretical foundation for justifying research methods and design. Research methods are categorized into
(i) descriptive (describing population characteristics),
(ii) analytical (examining relationships or differences between variables),
(iii) exploratory (deepening knowledge and generating new ideas).

Methodology encompasses eight approaches: qualitative, quantitative, descriptive, experimental, phenomenology, surveys, grounded theory, and ethnography. It is widely applied in science, engineering, and education to guide research and analysis [5-8].

Science is a systematic discipline focused on building knowledge through testable hypotheses and observations, which can be quantitative or qualitative [9]. Engineering, derived from the Latin "ingenerate" (to create), applies scientific principles to solve real-world problems and improve daily life [10, 11]. While science focuses on knowledge, engineering emphasizes action and creation. In education, students engage in both science and engineering processes to achieve learning goals, with their distinctions (**Figure 1**).

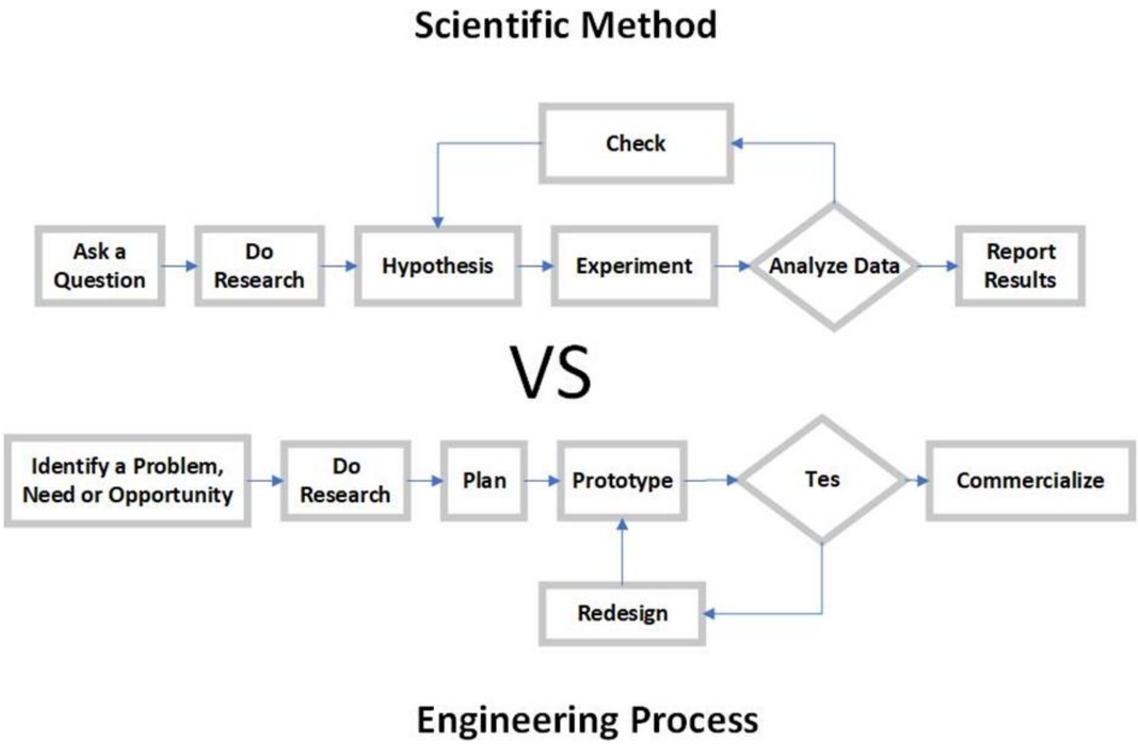

Figure 1. Difference of scientific method versus engineering process.

Modeling plays a key role in practical engineering and is valuable in engineering education research [12, 13]. Qualitative methodologies, like design science research, focus on the design

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process, generating insights into methods used for product creation. In education, this aligns with design thinking, where the design process is developed through learning [14, 15].

Educational products often include learning media, models, assessment tools, and curricula. Common IT-based learning media include augmented reality (AR), virtual reality (VR), interactive videos, 3D animation, internet of things (IoT), and games [16, 17]. **Table 1** provides examples of designed educational products and their development using methods such as Research and Development (R&D), Analysis, Design, Development, Implementation, Evaluation (ADDIE), Engineering Design Process (EDP), Design thinking, Design-Based Research (DBR), Design Research Methodology (DRM), Define, Design, Develop, dan Disseminate (4D).

The results obtained from bibliometric analysis were carried out through searching on the www.scopus.com page, a search was carried out using the keywords "research AND methods AND in AND designing AND processes" resulting in a total of 12,711 documents read from 1915 to 2025. This data was taken on 18 July 2024 at 07:31 am. The increase in publications is shown in **Figure 2**. There has been a continuous increase starting from 1995 until now. If the year is limited to the last 10 years where the analysis was carried out from 2015 to 2025, the total number of documents is 9,234 documents. Documents published from 2015-2023 are continuously increasing and the peak is in 2023 with 1,610 documents. Thus, documents published in Scopus data may increase again for data in the following years, showing that research on research methods in designing processes is one of the hottest research topics that is currently being carried out and many discussed by researchers.

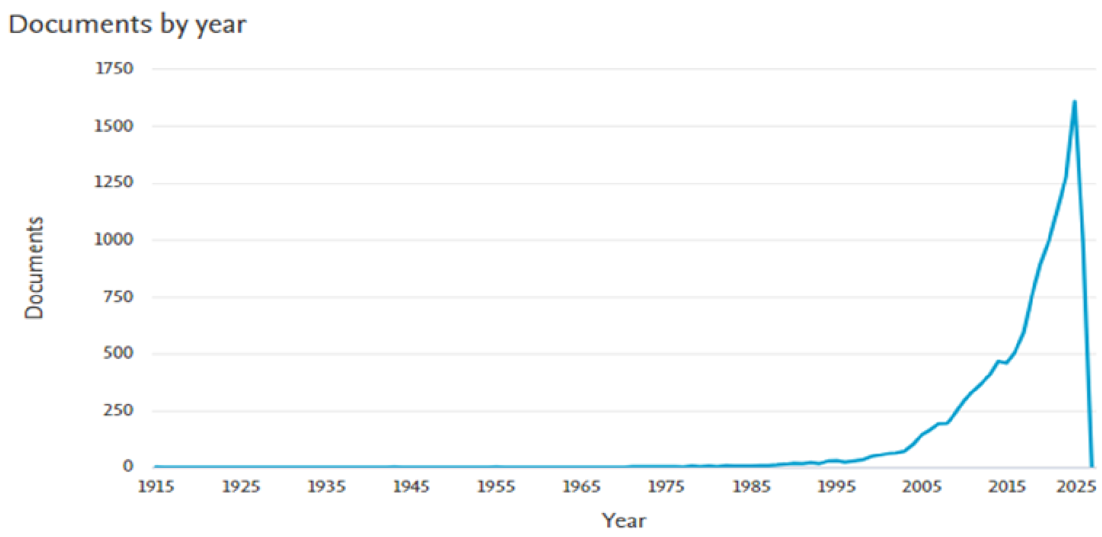

Figure 2. Research trends about research methods in designing processes from 1915-2025.

The purpose of this study is to explain how science and education design research, types, and step-by-step design methods, and to inform examples of the application of design methods in science education. Novelties in this study include: (i) informing several types of design methodologies, seeing the research trends, and providing an overview of information about the stages of each methodology introduced. We also developed 9 steps in research methodology, namely PHMEEDERID, an abbreviation of Identify Problems; Develop Hypothesis; Choose Research Methodology; Conduct Experiments and Create Equipment; Refine Design and Develop; Evaluate and Test; Do Revision and Retest; Implement; and Disseminate. In describing the research trend, a bibliometric explanation was carried out as previous studies reported, as shown in **Table 2**.

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Table 1. Educational products in science learning which is built using research methods in the form of product design.

Product	Science topic	Method	Ref
Ethnoscience-oriented multimedia learning process	Salt making on conductivity materials	R&D with ADDIE's development design	[18]
Prototypes to increase natural disaster mitigation for elementary schools.	Natural disaster mitigation	EDP	[19]
A robotic hand inspired by traditional Javanese puppets called Wayang.	Body movement system	EDP	[20]
A design thinking teaching method	Physics concept	Design thinking	[21]
STEM-Engineering design process in element, compound, and mixture topic	Element, compound, and mixture	EDP	[22]
Artefact design and development in design science research	Artefact	Design thinking	[23]
Produce a learning media in the form of science learning educational games.	Blood circulation, Health problems in the circulatory organs, how to maintain human circulatory organs,	R&D with 4D's development design.	[24]
Arabic learning media innovation from a neuroscience perspective for Santri	Neuroscience	R&D with Borg & Gall's development design.	[25]
Interactive media based on Flash.	Bloodstream system	R&D with Borg & Gall's development design	[26]
online learning video based on the science technology society (STS)	Biology	R&D with Sadiman's development design.	[27]
Media food card berbasis AR (FCAR)	Nutrition food	R&D with ADDIE's development design.	[28]
Light intensity distribution in the room using light dependent resistor	Light intensity	EDP	[29]
AR based on Android in the problem-solving laboratory (PSlab-AR application)	Electricity	R&D with 4D's development design.	[30]
Game-AR application of trigonometry integrating numeration in daily life	Trigonometry	R&D with 4D's development design.	[31]
Mobile-based interactive e-module	Earthquake swarms disaster mitigation	R&D with ADDIE's development design.	[32]
A guidebook-AR for green technology in plastic waste management	Green technology in plastic waste management	R&D with ADDIE	[33]
A virtual museum in the form of interactive mobile media applications based on mobile using VR technology	Materials of Keris	AVR Method	[34]

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Table 2. Previous studies on bibliometrics.

Title	Ref.
The use of simple spectrophotometer in STEM education: A bibliometric analysis	[35]
Correlation between process engineering and special needs from bibliometric analysis perspectives.	[36]
Bibliometric analysis for understanding the correlation between chemistry and special needs education using VOSviewer indexed by Google.	[37]
Implementation of Biotechnology in Education Towards Green Chemistry Teaching: A Bibliometrics Study and Research Trends	[38]
Research Trends about internet of things in Science Education: A bibliometric analysis	[39]
Bibliometric analysis of briquette research trends during the Covid-19 pandemic.	[40]
Bibliometric computational mapping analysis of publications on mechanical engineering education using VOSviewer	[41]
Particulate matter emission from combustion and non-combustion automotive engine process: review and computational bibliometric analysis on its source, sizes, and health and lung impact	[42]
Involving Particle Technology in Computational Fluid Dynamics Research: A Bibliometric Analysis	[43]
How Language and Technology Can Improve Student Learning Quality in Engineering? Definition, Factors for Enhancing Students Comprehension, and Computational Bibliometric Analysis	[44]
Bibliometric data analysis of research on resin-based brakepads from 2012 to 2021 using VOSviewer mapping analysis computations	[45]
Past, current and future trends of salicylic acid and its derivatives: A bibliometric review of papers from the Scopus database published from 2000 to 2021	[46]
Research trends about STEM of Internet of things for science teachers: A bibliometric analysis	[47]

2. LITERATURE REVIEW

2.1. Engineering Design Process (EDP)

The EDP is a cycle of thinking, working, and sharing that is used by engineers, inventors, and anyone looking to solve a problem [48]. EDP has different steps involved in various versions of the engineering process. Most include 5-8 steps, including thinking, planning, building, testing, and sharing to some degree as part of this cycle. The idea is for students to engage in thinking and communicating about a problem and potential solutions, then generate different designs to determine if the solution is likely to work. The student engineer then builds or creates some object, process, or experience as a solution [49, 50]. The process is ongoing, with repeated back-and-forth movements between various steps (see **Figure 3**).

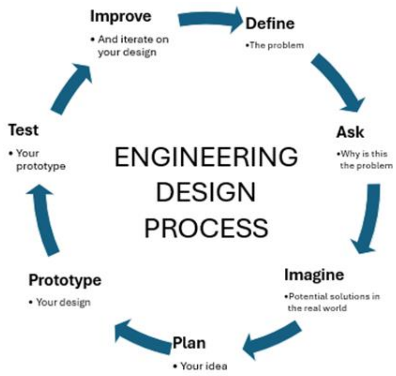

Figure 3. Procedure EDP.

2.2. Design thinking

Design thinking is a human-centered innovation approach that integrates three key elements: the needs of people, the possibilities of technology, and business benefits [51-53].

Initially popular in design, it has expanded to other fields, including education, where it helps develop learning outcomes, media, curriculum, and models [54-57]. The process fosters innovation and problem-solving by encouraging out-of-the-box thinking, considering user experiences, and accommodating diverse team perspectives [58]. Design thinking involves five iterative stages: empathize, define, ideate, prototype, and test (see **Figure 4**) [59]. These stages are flexible and can be revisited as needed. The approach combines design and data to solve problems analytically.

Figure 4. Procedure design thinking.

2.3. Design-based Research (DBR)

Design-Based Research (DBR) is a research methodology in the learning sciences, aimed at developing solutions (interventions) to educational problems and testing their effectiveness through iterative cycles [60, 61]. The goal is to generate new theories and frameworks for learning, teaching, and educational reform. Critics argue that DBR focuses more on product development than traditional scientific research, and question its ability to test established theories. DBR is essential in science instruction, with a focus on refining instructional designs and learning theories through iterative analysis [62, 63]. Traditionally using qualitative data, recent studies also employ "big data" [64]. Design-Based Implementation Research (DBIR) scales DBR to larger systems like school districts. DBR supports interdisciplinary collaboration and helps uncover the mechanisms behind student learning [65, 66]. DBR typically involves four phases: analysis, development, iteration, and reflection (see **Figure 5**). Variations include stages such as design, development, and evaluation, with an iterative cycle of improvement based on reflection or evaluation (see **Figures 6 and 7**, respectively).

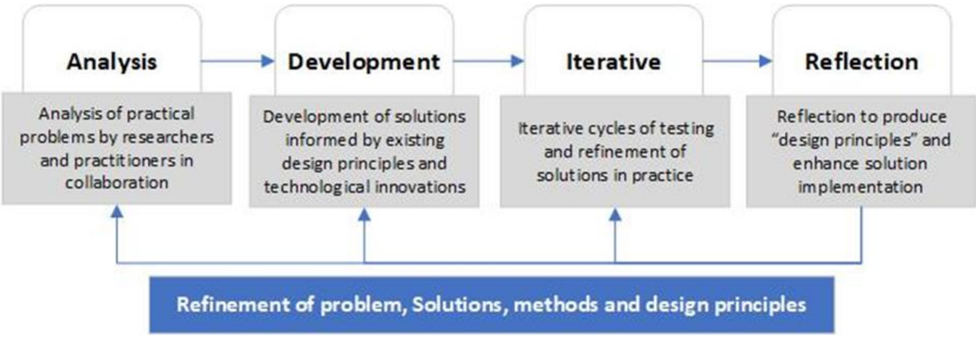

Figure 5. The four phases of DBR.

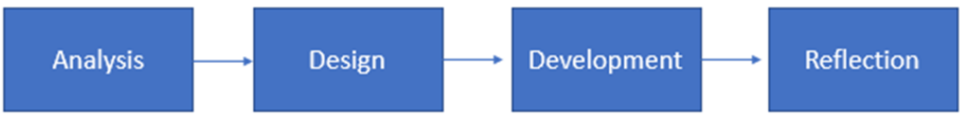

Figure 6. The four phases of DBR with reflection.

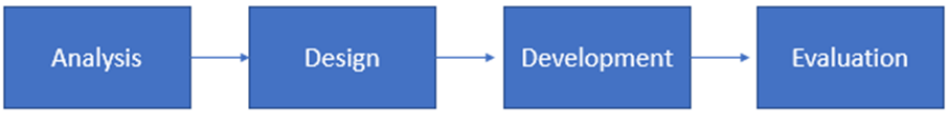

Figure 7. The four phases of DBR with evaluation.

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2.4. DRM Framework

DRM is a methodology developed to assist in conducting design research systematically [67]. DRM provides a structured framework for each stage of design research, from literature review to research plan development and research implementation [68]. **Figure 8** is the procedure for DRM framework [69]. They have 4 steps they are: (i) Research clarification involves reviewing the literature to identify factors influencing task clarification and product success [70]. Based on the literature, the current and expected situations are described, and criteria for evaluating task clarification support are established; (ii) Descriptive Study 1 reviews literature to identify key factors affecting task clarification [71, 72]. Findings indicate that poor problem definition during task clarification leads to high time usage and delays due to modifications at later stages; (iii) Prescriptive studies aim to improve the existing situation by creating a vision of the desired state, which should reduce modifications, shorten design time, accelerate time to market, and enhance product success [73, 74]; and (iv) Descriptive Study II examines the effectiveness of support in achieving the desired situation [75]. Two empirical studies were conducted: the first assessed the support's ability to improve problem definition, and the second evaluated software usability based on predefined criteria.

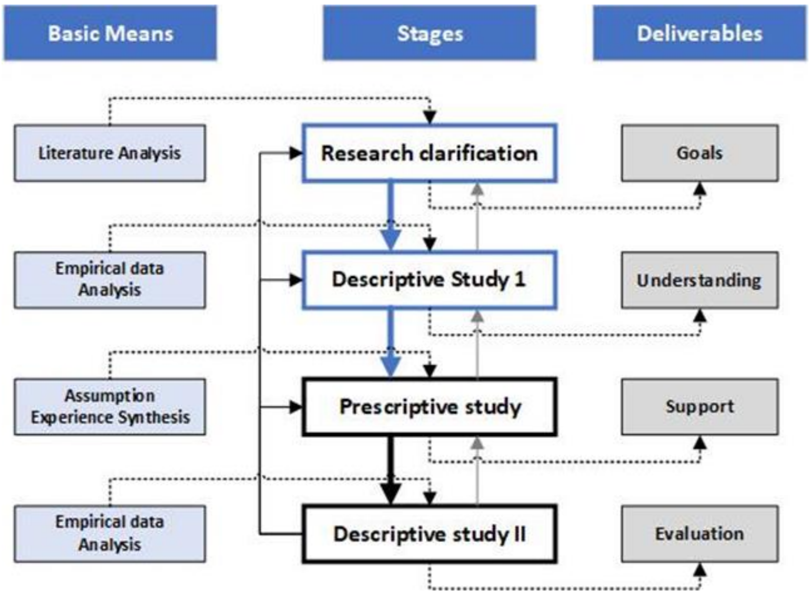

Figure 8. The DRM framework.

2.5. Research and Development (R&D)

The R&D method, first popularized in Europe in the 1960s, was adapted for education in the 1980s by Borg and Gall to improve educational products [76]. Today, R&D is widely used to design and test products in academia. R&D involves identifying problems, designing solutions, and developing products. In education, it can be applied to develop models for leadership, teacher training, and curricula. The method combines research, which follows scientific norms, and development, which focuses on improving quality and effectiveness [77, 78]. It is a systematic process of design, development, and evaluation to create products that enhance learning [79]. R&D is a problem-solving process starting with needs analysis, product development, evaluation, and dissemination [80]. It aims to test and validate products, whether for technology, methods, or tools [81]. Borg and Gall outlined four key stages of R&D: (i) initial research, (ii) development based on problem analysis, (iii) field testing in real environments, and (iv) revisions based on feedback [82]. Key R&D models include Borg and Gall, Sadiman, ADDIE, Dick and Carey, and 4D.

(i) The Borg and Gall Development Model follows a waterfall approach, with detailed stages from needs analysis to dissemination (see **Figure 9**) [76, 80, 83]. Revisions are made after individual, small group, and field trials.
(ii) The Sadiman development model follows these steps: needs identification, objective formulation, material development, evaluation tool creation, production, validation, revision, and media preparation for use (see **Figure 10**) [80, 84].
(iii) The ADDIE model (**Figure 11**) is a versatile learning design framework for developing materials for both traditional and online learning [85]. Its general structure makes it adaptable to various settings [86, 87]. The model comprises five stages: Needs Analysis, Design, Development, Implementation, and Evaluation.
(iv) The Dick and Carey model, comprising 10 clear, sequential steps (**Figure 12**), is ideal for novice designers as a foundation for learning other design models. Its concise yet detailed structure ensures clarity and coherence between steps [88].
(v) The 4D model: Define, Design, Develop, Disseminate (**Figure 13**). Emerged in the early 1970s as an evolution of existing development: analysis, design, and evaluation [89].

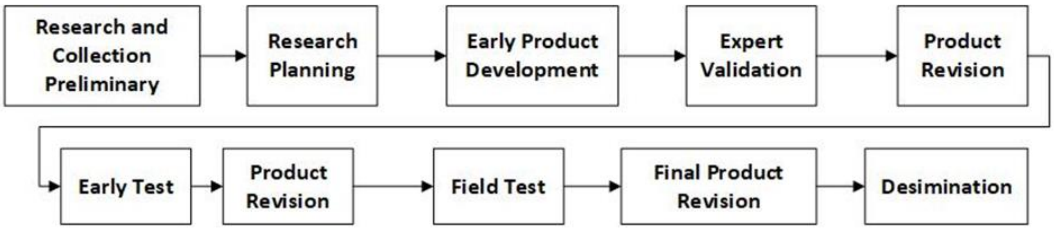

Figure 9. Procedure R&D with Borg & Gall's development model.

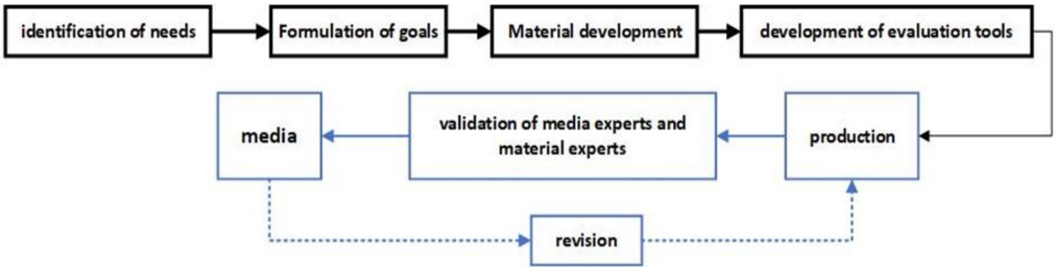

Figure 10. Procedure R&D with Sadiman's development model.

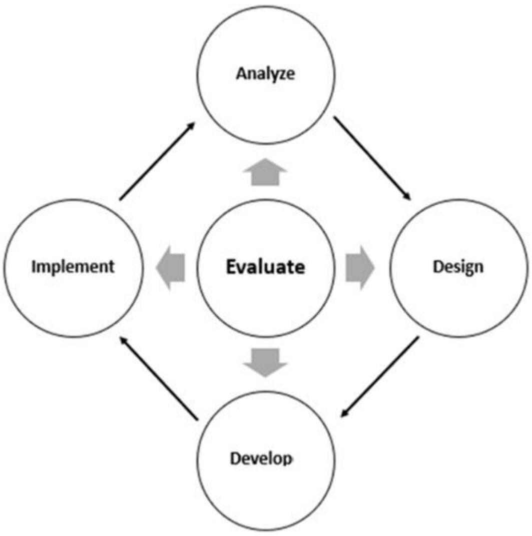

Figure 11. Procedure R&D with ADDIE's development model.

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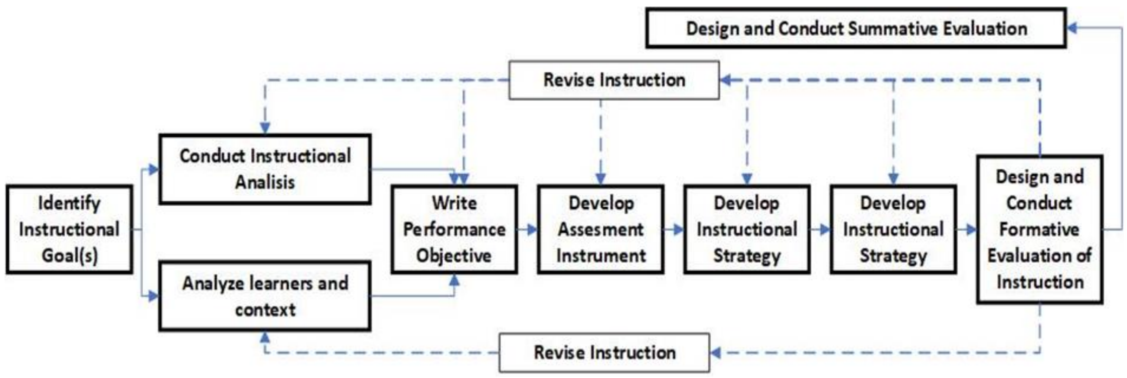

Figure 12. Procedure R&D with Dick and Carey's development model.

3. METHODS

This paper discussed research methods in science and engineering education, particularly focusing on creating media designs for the teaching and learning process. We highlighted the use of appropriate research methods tailored to specific design objectives. The discussion included an explanation of methodological stages, examples of designs, and applications of media design in science education, as demonstrated by various researchers. To support the explanation, a literature review for research design and computational bibliometric analysis was added. We mapped several types of research methodologies, supported by several examples from researchers and practitioners who were involved in these research topics. The step-by-step method was also added to make readers and users easily understand.

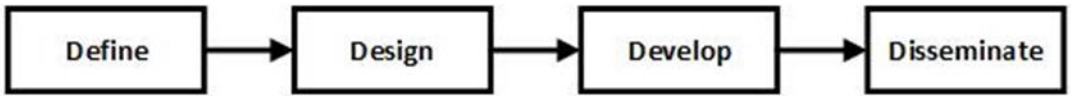

Figure 13. Procedure R&D with 4D's development model.

4. RESULTS AND DISCUSSION

4.1. Step-by-Step Analysis of Research Stages from Practical Examples in Science and Engineering Education

Figure 14 shows a step-by-step analysis of educational research steps carried out on science and engineering concepts. If we carry out research relating to science and engineering, we must understand how step by step must be carried out properly to be able to choose the right research method and find a solution to the problem. The step-by-step is known as 9 steps **PHMEEDERID**, an abbreviation of Identify **Problems**, Develop **Hypothesis**, Choose Research **Methodology**, Conduct **Experiments** and Create **Equipment**, Refine Design and **Develop**, **Evaluate** and Test, Do **Revision** and Retest, **Implement**, and **Disseminate**. It can be explained as follows:

(i) **Step 1:** Identify **Problems**: Analyze the issue from various perspectives, including user needs, urgency, unmet needs, potential impacts, and existing solutions. Evaluate gaps using scientific and technological concepts.

(ii) **Step 2:** Develop **Hypothesis**: Propose potential solutions as products, media, or strategies to address the problem.

(iii) **Step 3:** Choose Research **Methodology**: Choose appropriate methods in science, technology, and engineering based on their characteristics, such as ease of use, timeline, participants, and outcomes.

(iv) **Step 4:** Conduct **Experiments** and Create **Equipment**: Follow the chosen method to develop the product or strategy that addresses the hypothesis.
(v) **Step 5:** Refine Design and **Develop**: Use technology to create a flowchart, storyboard, and assets (e.g., images, software, tools). Build the product and test its functionality.
(vi) **Step 6: Evaluate** and Test: Validate the product with experts and assess its effectiveness through practical testing.
(vii) **Step 7:** Do **Revision** and Retest: Refine the product based on evaluation results and repeat testing until it meets expectations.
(viii) **Step 8: Implement**: Deploy the product for broader use and assess its impact. We can implement products that have been created in one group pretest-posttest design or pretest-posttest control group design research.
(ix) **Step 9: Disseminate**: Share the product, its process, and benefits with a wider audience.

4.2. Comparative Step-by-step analysis of science and engineering education from several research methods.

Tables 3 and 4 compare educational research steps in science and engineering with widely developed research methods. **Table 3** highlights that EDP and design thinking are simpler methods, focusing only on product design and limited testing without requiring field implementation or dissemination. DBR extends to classroom implementation, testing the product's impact on student competence. DRM involves a longer process with four stages, reaching dissemination, making it the most time-intensive method among the four. **Table 4** analyzes R&D methods, showing that Borg & Gall and 4D include dissemination, while ADDIE, Dick & Carey, and Sadiman method is stopped at evaluation. **Figure 15** outlines the characteristics of these methods.

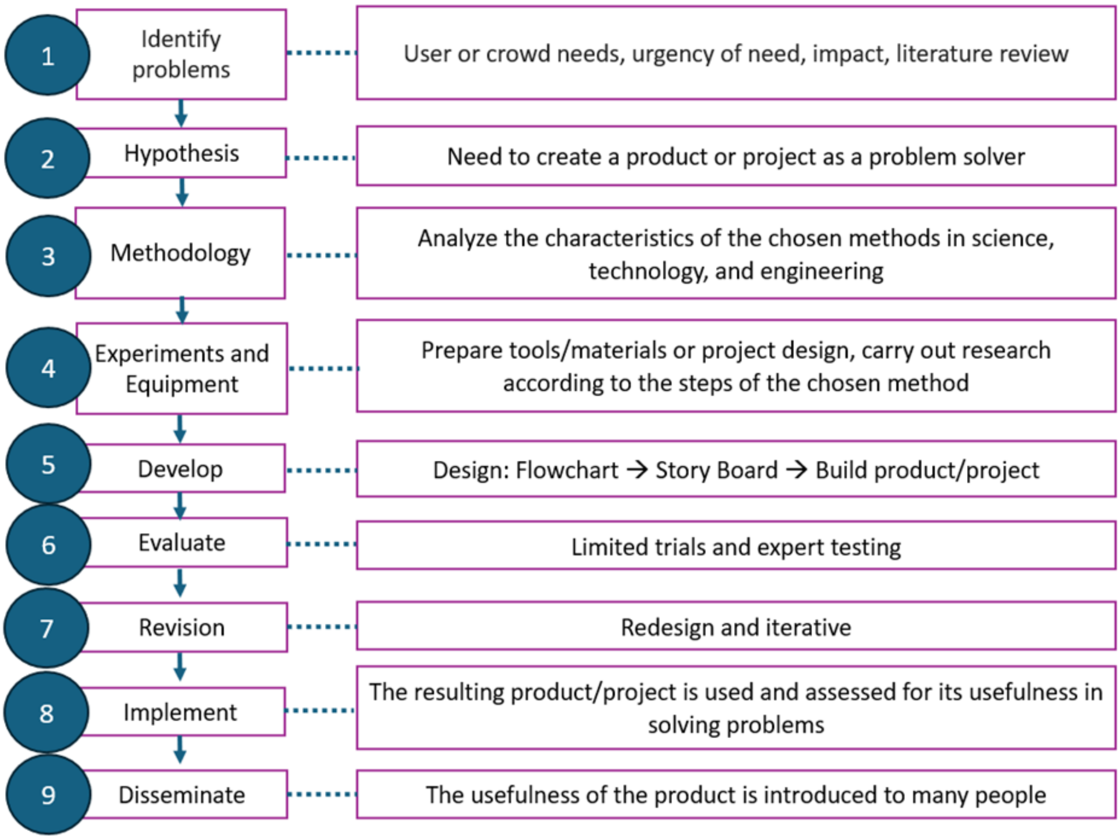

Figure 14. Step-by-step analysis of research stages in science and engineering education.

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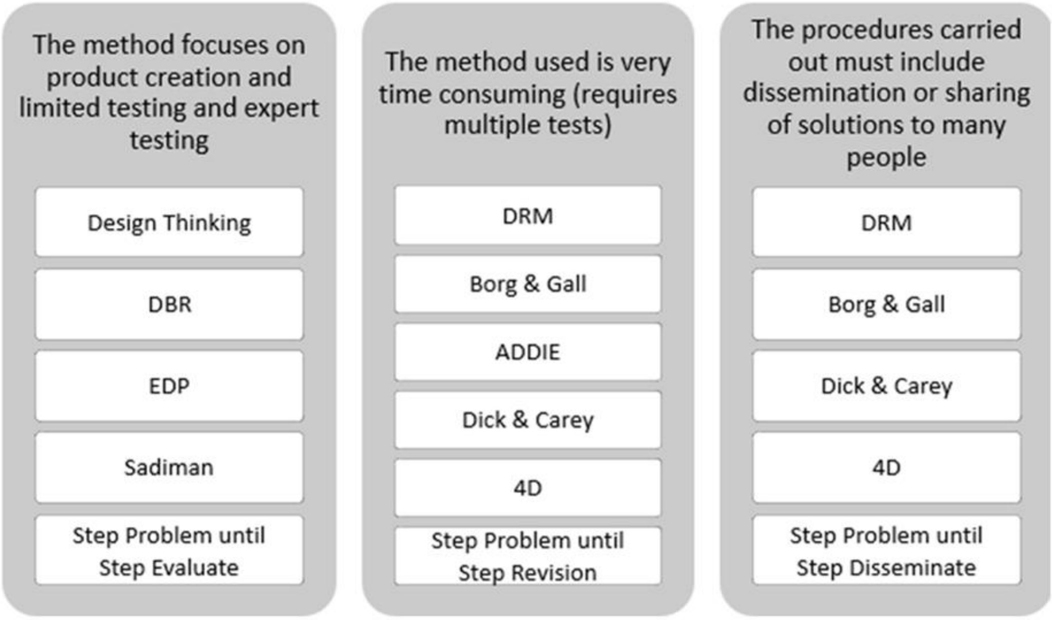

Figure 15. The characteristic of several types of engineering methods.

Table 3. Step-by-step analysis of science and engineering education from several research methods other than R&D.

Step by Step	EDP	Design Thinking	Design based - Research	DRM
Identify **Problems**	Define Ask	Empathize	Analysis	Research clarification
Develop **Hypothesis**	Define	Define		
Choose Research **Methodology**	Plan			Descriptive study 1; Prescriptive study
Conduct **Experiments** and Create **Equipment**	Prototype	Idea	Development/ design	
Refine Design and **Develop**		Idea; Prototype		
Evaluate and Test	Test	Prototype; Test	Iterative/evaluation	Descriptive study 1
Do **Revision** and Retest	Improve	Test		
Implement Disseminate			Reflection	

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Table 4. Step-by-step analysis of science and engineering education from R&D.

Step by Step	R&D						
	Borg & Gall			Sadiman	ADDIE	Dick & Carey	4D
Identify **problems**	Research & Collection preliminary			Identification of needs	Analyze	Identify instruction goal	Define
Develop **Hypothesis**	Research planning			Formulation of goals		Write performance objective	
Choose Research **Methodology**				Material development		Develop assessment instrument; Develop instructional strategy	Design
Conduct **Experiments** and Create **Equipment**	Early product development			Development of evaluation tools	Design		
Refine Design and **Develop**				Production		Design and conduct a formative evaluation of the construction	
Evaluate and Test	Expert validation	Early Test	Field	Validation of media experts and material experts	Develop		
Do **Revision** and Retest	Product Revision	Product Revision	Final Revision	Media			Develop
Implement					Implement	Design and conduct a summative evaluation	
Disseminate			Disseminat				Disseminat e

4.3. Practical Examples in Science and Engineering Education

4.3.1. Example 1. Making AR about Electricity in Damaged Batteries.

An example of a science learning design involves using AR to create learning media for electrical material on accumulators (**Figure 16**). The steps taken include:

Step 1: Identify **Problems**: Address motorbike battery issues and aid students' understanding of accumulator electrical processes through media, including battery fluid refilling videos.

Step 2: Develop **Hypothesis**: AR accumulators can improve students' understanding of battery electricity and repair processes.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering based on timeline, 32 vocational school students as participants, and learning outcomes using AR.

Step 4: Conduct **Experiments** and Create **Equipment**: Collect information on battery types, uses, and repair processes. Design flowcharts and storyboards based on curriculum needs and student learning characteristics. Create a performance assessment rubric instrument for repairing damaged batteries.

Step 5: Refine Design and **Develop**: Develop AR media with detailed specifications, focusing on explaining electricity in accumulators and repair procedures.

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Step 6: **Evaluate** and Test: build a prototype based on the storyboard and flowchart. Conduct limited testing, identify issues, and refine the media.

Step 7: Do **Revision** and Retest: test the media with users, gather feedback, and conduct wider trials. Evaluate its effectiveness in solving problems and improving understanding.

Step 8: **Implement**: Use the media in classrooms, collect output data, and share the results. In trials with 32 vocational school students, 85% successfully repaired batteries and refilled fluids safely, demonstrating the effectiveness of the AR media as a learning tool.

Step 9: **Disseminate**: Share the results and benefits of the AR media with a broader audience, showcasing its impact and usability as a solution for accumulator-related learning challenges.

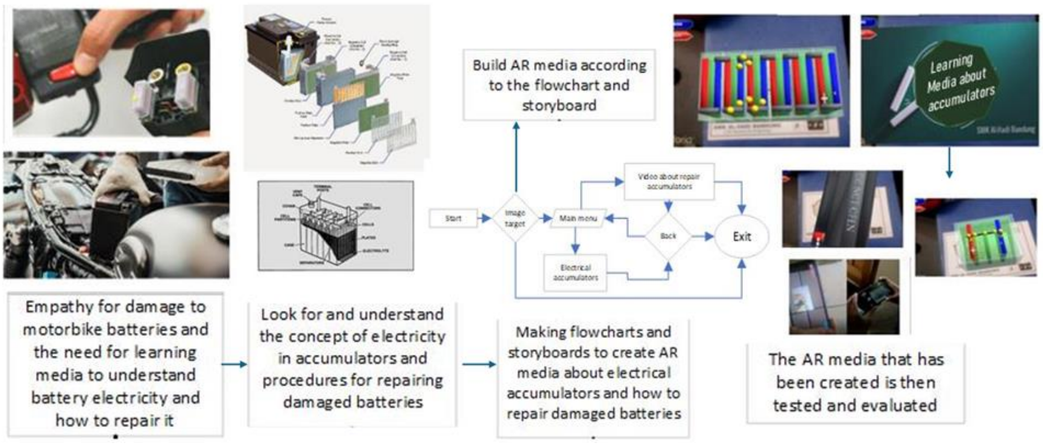

Figure 16. Steps method for making learning media based on AR accumulators.

4.3.2. Example 2. Designing a Learning Model.

Figure 17 shows the process of designing the create, collect, answer, path, and evaluation (CCAPE) learning model with steps to create, collect, answer, path, and evaluate in mathematics subjects. In this example, the stages of the Design based research method start from:

Step 1: Identify **Problems**: Analysis by **identifying problems** in mathematics learning, especially in the assessment process.

Step 2: Develop **Hypothesis**: A hypothesis is carried out that shows the need for innovative learning models for implementing assessments in mathematics subjects

Step 3: Choose Research **Methodology**: Select the right method in science, technology, and engineering based on the timeline, and prepare 2 classes for class control experiment, and learning outcomes.

Step 4: Conduct **Experiments** and Create **Equipment**: we began with making the lesson plan and gathering tools and materials to be used, creating an assessment rubric and checklist for successful implementation of learning.

Step 5: Refine Design and **Develop**: a CCAPE model design is created by determining the steps or designs that will be carried out in the CCAPE learning process

Step 6: **Evaluate** and Test: In the iterative stage, continuous testing.

Step 7: Do **Revision** and Retest: the learning process is created following needs and expectations.

Step 8: **Implement**: reflection is carried out in the form of **implementation** in the classroom, and the results show that the experimental class using the CCAPE learning model is

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more effective in improving students' mathematics learning outcomes compared to not using the CCAPE learning model.

Step 9: **Disseminate**: Share the results and benefits CCAPE learning model with several mathematics and other subject teachers.

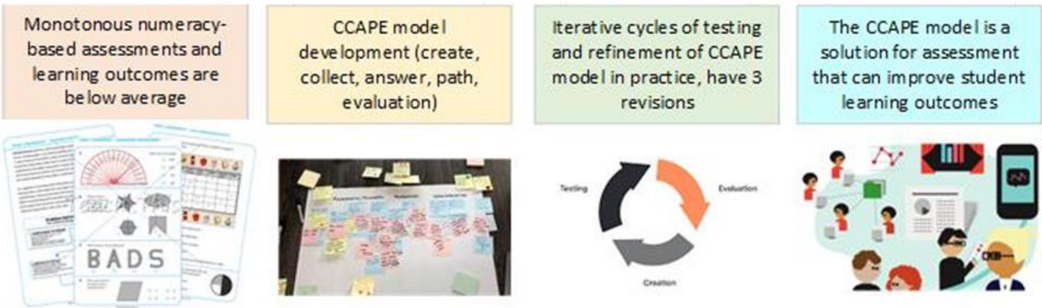

Figure 17. Steps for making CCAPE learning model.

4.3.3. Example 3. Designing IoT-based LED Product

Figure 18 analyzes and develops sustainable solutions like IoT-based smart lamps, designed by students in STEM-IoT learning. Steps include:

Step 1: Identify **Problems**: The need for lighting automation to reduce excessive use of electrical energy.

Step 2: Develop **Hypothesis**: The use of IoT-based smart lamps as media or products for STEM learning design.

Step 3: Choose Research **Methodology**: collecting data and information is an important step that forms the basis of research.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare the tools/materials used and the software to be used. Tool design, coding, and testing.

Step 5: Refine Design and **Develop**: IoT-based smart lamps as media or products that will be designed by students in STEM learning.

Step 6: **Evaluate** and Test: After testing, the product is evaluated for success.

Step 7: Do **Revision** and Retest: Errors are identified and corrected through redesign until they function as expected.

Step 8: **Implement**: Hardware and software systems are tested to assess research success through practical use in STEM learning in class, with difficulties in design evaluated based on usability, time, and learning hours. Additionally, the products can be tested in a project to demonstrate their real-life application.

Step 9: **Disseminate**: The product can be shared as a solution to reduce uncontrolled energy use and promote energy-saving habits based on IoT.

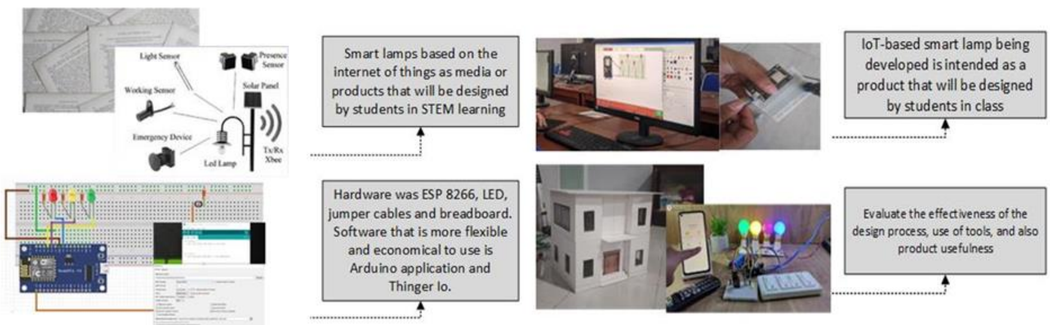

Figure 18. Create smart lamps based on the internet of things.

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4.3.4. Example 4. Designing an Arduino Project to Measure Light Intensity Automatically.

Designing a light intensity measurement product using a Light Dependent Resistor (LDR) [29]. Steps are carried out (**Figure 19**).

Step 1: Identify **Problems**: Arising from the common issue of uncontrolled electricity usage, despite its importance as a primary need.

Step 2: Develop **Hypothesis**: A product to automatically measure light intensity, enabling controlled and adjusted electrical energy use based on lighting needs.

Step 3: Choose Research **Methodology**: We can select the design process, research location, and validation instruments used.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare the tools/materials used and the software to be used. Tool design, coding, and testing.

Step 5: Refine Design and **Develop**: The product uses an LDR to measure light intensity, automatically controlling room lighting by turning lights on or off.

Step 6: **Evaluate** and Test: After testing, the product is evaluated for success.

Step 7: Do **Revision** and Retest: Errors are identified and corrected through redesign until they function as expected.

Step 8: **Implement**: Product testing involves placing the equipment in various rooms to optimize results based on the distance from the light source. The tool automatically controls electricity, turning lights on and off according to light intensity and room layout.

Step 9: **Disseminate**: Once successful, the product can be shared as a solution to reduce uncontrolled energy use and promote energy-saving habits.

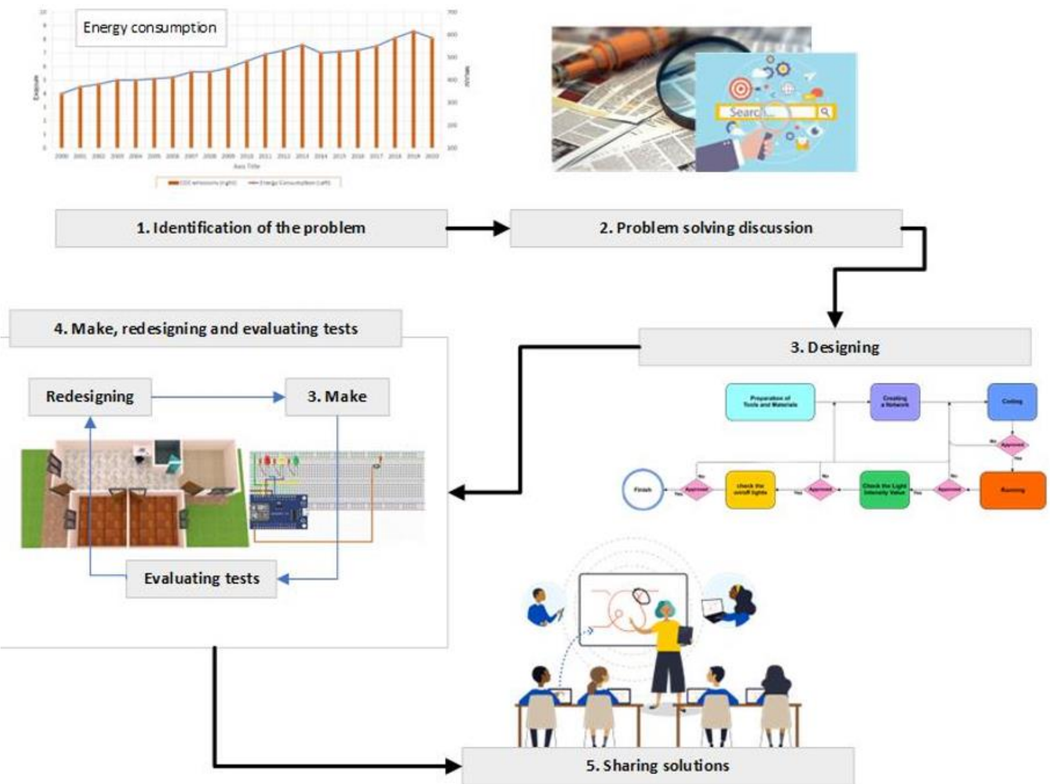

Figure 19. EDP about light intensity measurement product using an LDR.

4.3.5. Example 5, Creating AR Food Cards.

The AR Food cards are designed to motivate young children to consume nutritious food, and the design process is shown in **Figure 20.**

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Step 1: Identify **Problems**: Observation and analysis of young children's difficulty in consuming nutritious foods like chicken liver, tuna, eggs, anchovies, and spinach.

Step 2: Develop **Hypothesis**: Young children love using cards to play, and become fond of nutritious food.

Step 3: Choose Research **Methodology**: Create an AR food card product for children, test and implement it in 28 kindergartens and 28 parents.

Step 4: Conduct **Experiments** and Create **Equipment**: Select the types of food whose nutrition will be discussed in the AR food card.

Step 5: Refine Design and **Develop**: AR-integrated cards are being developed for young children, displaying 3D images and videos to explain the nutritional benefits of foods. The media follows a flowchart, offering diverse presentations of nutritious food compositions.

Step 6: **Evaluate** and Test: Tested for media success and validated by media, language, and child psychology experts

Step 7: Do **Revision** and Retest: Continuous re-testing is conducted to address deficiencies until the media functions properly.

Step 8: **Implement:** At this stage, parents evaluate the use of AR-based food cards by observing 28 children's interests in consuming nutritious food before and after using the cards.

Step 9: **Disseminate**: The use of FCAR has a good impact on the process of consuming nutritious food for early childhood, the results are shared with parents and the other.

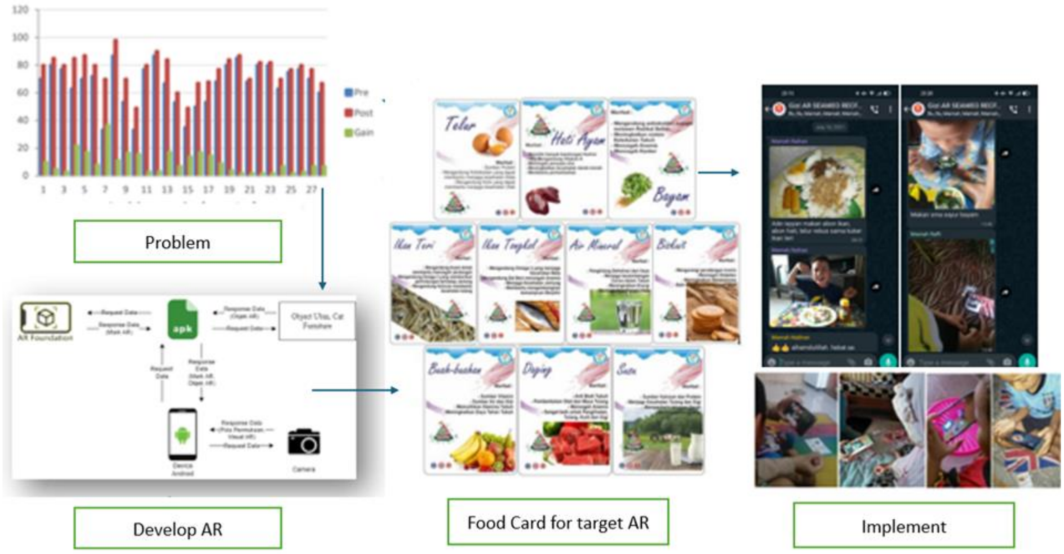

Figure 20. Steps for making AR food cards.

4.3.6. Example 6. Big Ball Games to Improve Understanding of Human Body Health.

Figure 21 is the design and development steps for creating a big ball game are outlined in several stages:

Step 1: Identify **Problems**: The analysis focuses on the impact of different ball sizes in sports and their varying health benefits.

Step 2: Develop **Hypothesis**: The big ball game helps users understand the health benefits of playing with a large ball.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

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Step 4: Conduct **Experiments** and Create **Equipment**: Prepare concepts on ball types and their health benefits in sports, and make flowcharts and storyboards for big ball games.

Step 5: Refine Design and **Develop**: Create and build the game based on the established flow.

Step 6: **Evaluate** and Test: limited trials and media expert validation tests are carried out

Step 7: Do **Revision** and Retest: evaluation, and improvement from the results of limited trials and validation tests. And tested how the use of this big ball game increases understanding of human health.

Step 8: **Implement:** This study did not include implementation, but if applied, the game can be used in learning to develop skills and raise awareness of the benefits of sports with a large ball created in one group pretest-posttest design or pretest-posttest control group design research.

Step 9: **Disseminate**: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

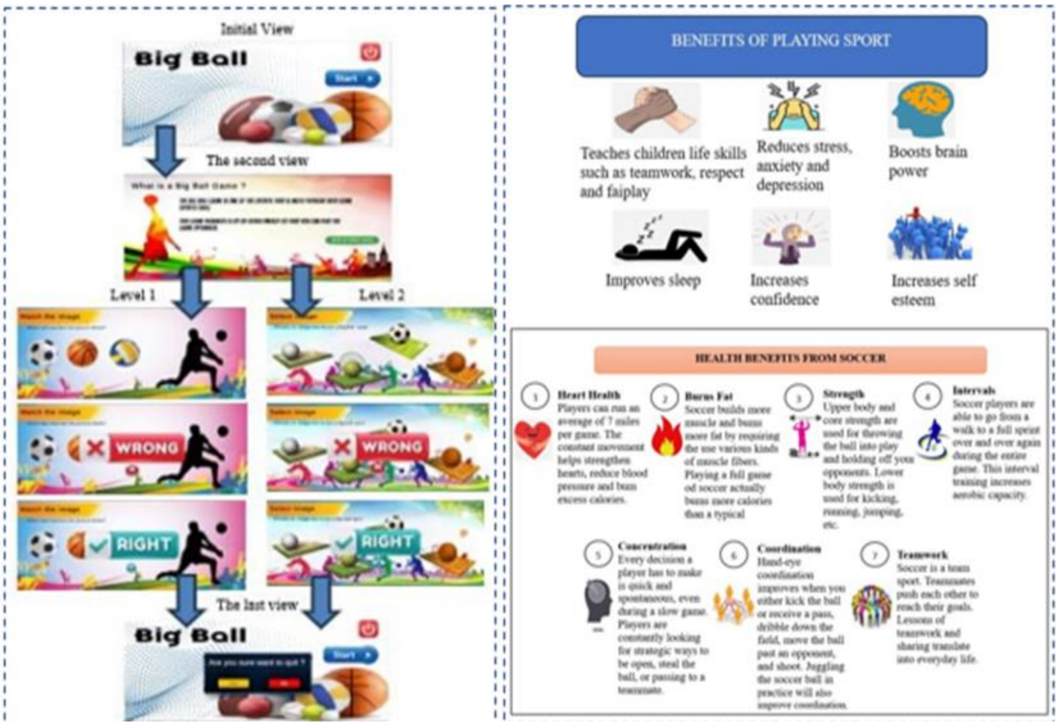

Figure 21. Step for making big ball games to the understanding of human body health [90].

4.3.7. Example 7. AR Design about Climate Change to Raise Awareness between Generations.

Figure 22 is the design and development steps for creating an AR on climate change are outlined in several stages:

Step 1: Identify **Problems**: The analysis focuses on the lack of intergenerational awareness of climate change and its impact on the future.

Step 2: Develop **Hypothesis**: AR on climate change can raise intergenerational awareness of its impacts.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes. 20 post-millennial and 20 millennial generations as participants.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare a concept on climate change and a video highlighting its impact on human life.

Step 5: Refine Design and **Develop**: create an AR flow that will be created, and build AR according to the flow that has been made

Step 6: **Evaluate** and Test: tested on a limited basis and conducted a media expert validation test

Step 7: Do **Revision** and Retest: evaluate, and improve from the results of limited trials and expert validation tests.

Step 8: **Implement**: AR was tested on 20 Generation X and 20 Generation Z participants.

Step 9: **Disseminate**: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

The results of the analysis include: 1) each generation needs to be given treatment. Thus, there is an increased awareness of climate change which needs to be addressed and handled for sustainable development for a better future life, 2) the treatment given to increase awareness across generations must be provided using media assistance that suits the characteristics of the generation itself. One

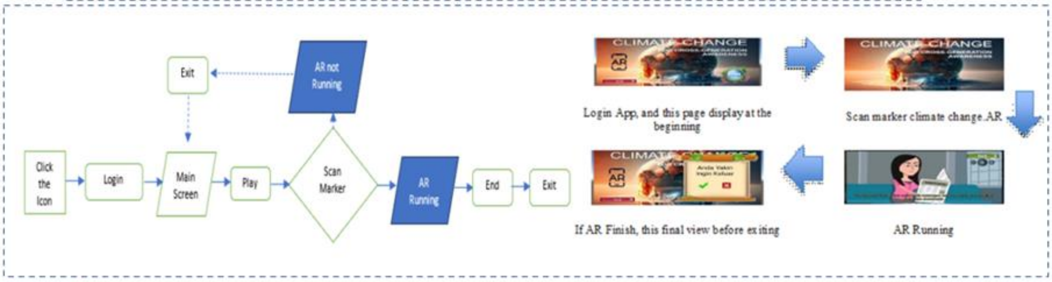

Table 1. Differences in knowledge, attitudes, climate-friendly behaviour, and multiplicative action before and after using AR.

Variable	Gen	Mean			Conclusion	
		Before	After	Difference	N-gain	Category
Knowledge	Z	4.18	8.24	4.06	0,70	High
	Y	3.45	7.35	3.90	0,60	Medium
Attitude	Z	42.85	49.91	7.06	0,41	Medium
	Y	45.35	50.24	4,89	0,33	Medium
Climate-friendly	Z	39.82	46.32	6.50	0,32	Medium
behaviour	Y	40,25	49.42	9,17	0,46	Medium
Multiplicative	Z	30.56	45.81	15.25	0,52	Medium
action	Y	41.36	50.21	8,85	0,47	Medium

Figure 22. Step for making AR about climate change [91].

4.3.8. Example 8. AR Game Application about Numeracy Trigonometry in Everyday Life.

Figure 23 is the design and development steps for creating an AR game on trigonometry in everyday life are outlined in several stages:

Step 1: Identify **Problems**: The analysis focused on students' lack of understanding of trigonometry, as seen in their numeracy scores related to its real-life applications.

Step 2: Develop **Hypothesis**: The AR Trigonometry game helps enhance students' numeracy in applying trigonometry.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare a concept on numeracy skills in trigonometry and its real-life applications.

Step 5: Refine Design and **Develop**: Create and build the AR game based on the established flow.

Step 6: **Evaluate** and Test: Tested on a limited basis with expert media validation.

Step 7: Do **Revision** and Retest: Evaluation and improvements based on limited trials and expert validation.

Step 8: Implement: This study did not include implementation, but if applied, the game can be used in learning to develop skills and raise numeracy trigonometry competencies created in one group pretest-posttest design or pretest-posttest control group design research.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

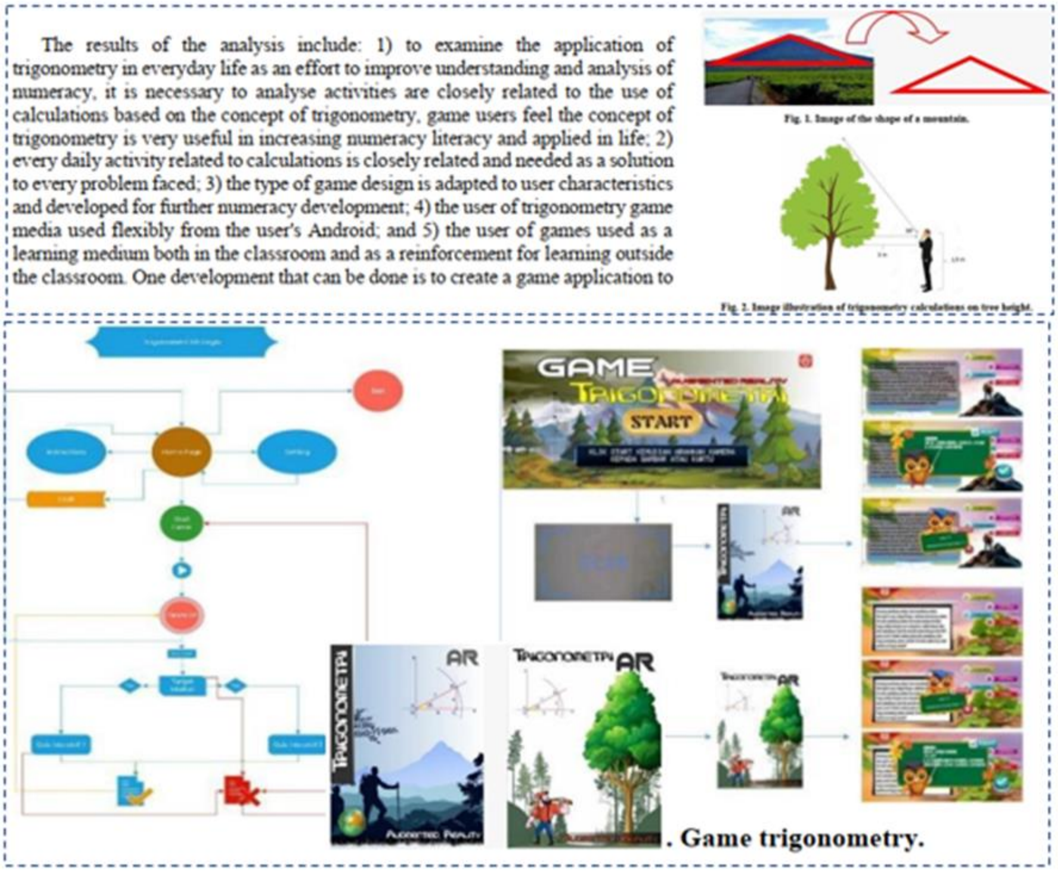

Figure 23. Step for making AR about trigonometry [31].

4.3.9. Example 9. AppSheet Development on Multigeneration Children's

Figure 24 is the design and development steps for creating an AppSheet for multigenerational children are outlined in several stages:

Step 1: Identify **Problems**: The analysis was based on past studies discussing the collective impacts of heredity and environment on children's entrepreneurship development.

Step 2: Develop **Hypothesis**: The AppSheet collected data on multigenerational children.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes. Three generations differ in business ownership as participants.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare the concept of multigenerational children and the instruments for the AppSheet.

Step 5: Refine Design and **Develop**: Create and build the AppSheet based on the established flow.

Step 6: **Evaluate** and Test: Tested on a limited basis with media expert validation.

Step 7: Do **Revision** and Retest: Evaluation and improvements based on limited trials and expert validation.

Step 8: Implement: Assessment across three generations differing in business ownership.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

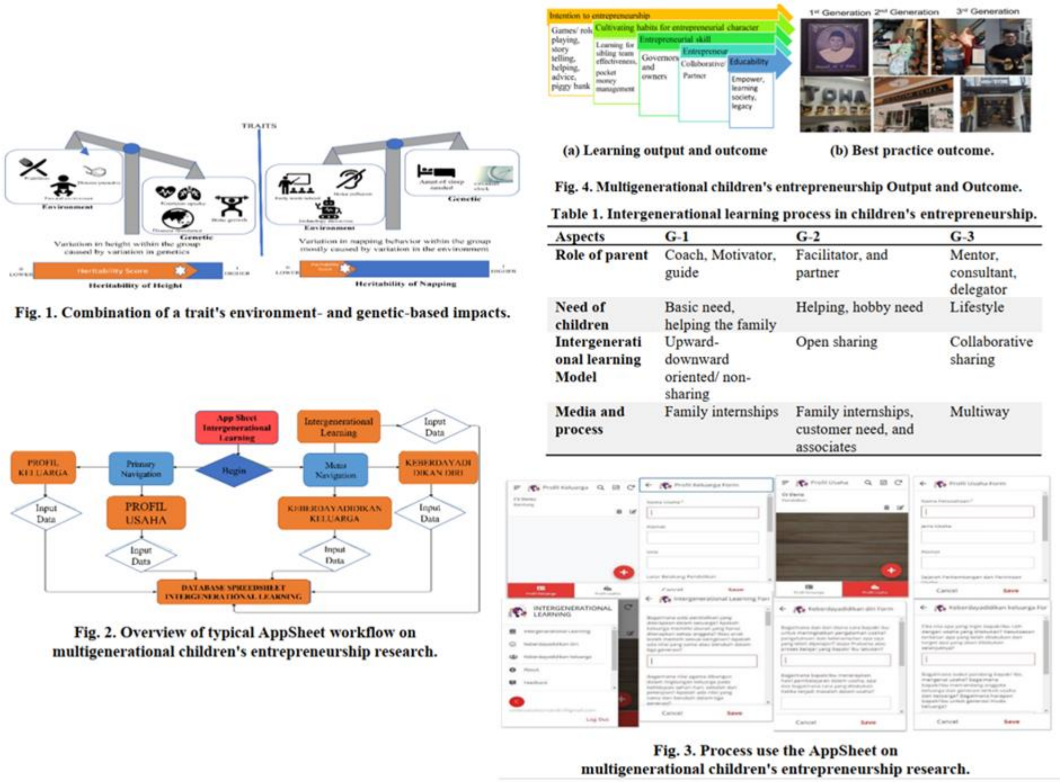

Figure 24. Step for making AppSheet about multigeneration children [92].

4.3.10. Example 10. LMS as Supporting Technology for School Management.

Figure 25 is the design and development steps for creating an LMS to support school management are outlined in several stages:

Step 1: Identify **Problems**: Problem identification and analysis focus on the need for LMS development to manage school operations.

Step 2: Develop **Hypothesis**: LMS allows the management team to monitor all school activities.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare the LMS concept, instruments, and information sections.

Step 5: Refine Design and **Develop**: Create and build the LMS based on the established flow.

Step 6: **Evaluate** and Test: Tested on a limited basis with expert media validation.

Step 7: Do **Revision** and Retest: Evaluation and improvements based on limited trials and expert validation.

Step 8: Implement: This study did not include implementation, but if applied, LMS can be used to support technology for school management created in one group pretest-posttest design or pretest-posttest control group design research.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

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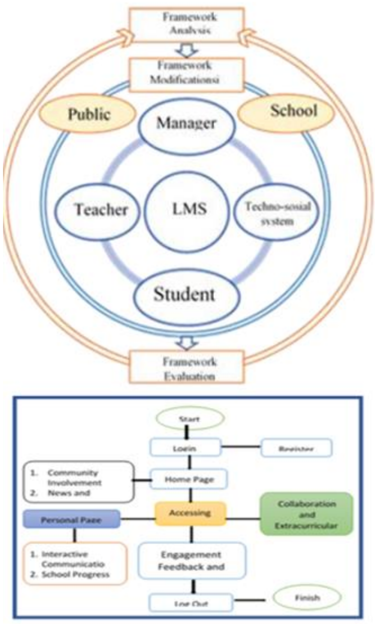

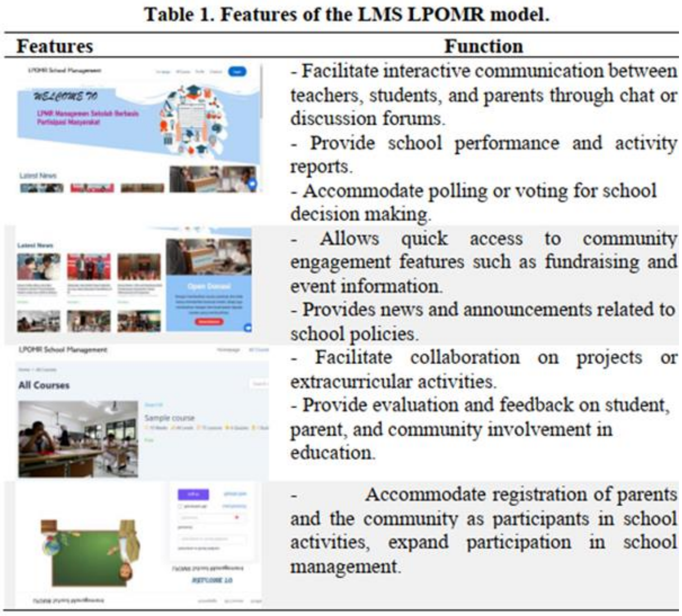

Table 1. Features of the LMS LPOMR model.

Features	Function
	- Facilitate interactive communication between teachers, students, and parents through chat or discussion forums. - Provide school performance and activity reports. - Accommodate polling or voting for school decision making.
	- Allows quick access to community engagement features such as fundraising and event information. - Provides news and announcements related to school policies.
	- Facilitate collaboration on projects or extracurricular activities. - Provide evaluation and feedback on student, parent, and community involvement in education.
	- Accommodate registration of parents and the community as participants in school activities, expand participation in school management.

Figure 25. Step for making LMS a supporting technology for school management [93].

4.3.11. Example 11. AppSheet about Wetlands for SDGs

Figure 26 is the design and development steps for creating an AppSheet about wetlands are outlined in several stages:

Step 1: Identify **Problems**: The analysis focuses on the importance of preserving wetlands for human life.

Step 2: Develop **Hypothesis**: Use AppSheet to collect data on wetland conditions in an area.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare the concept of wetlands and the instruments to be included in the AppSheet.

Step 5: Refine Design and **Develop**: Create and build the AppSheet based on the established flow.

Step 6: **Evaluate** and Test: Tested on a limited basis with expert media validation.

Step 7: Do **Revision** and Retest: Evaluation and improvements based on limited trials and expert validation. The validator recommended adding a GPS feature to detect the wetland's location.

Step 8: Implement: This study did not include implementation, but if applied, AppSheet can be used to collect data about wetland conditions created in one group pretest-posttest design or pretest-posttest control group design research.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

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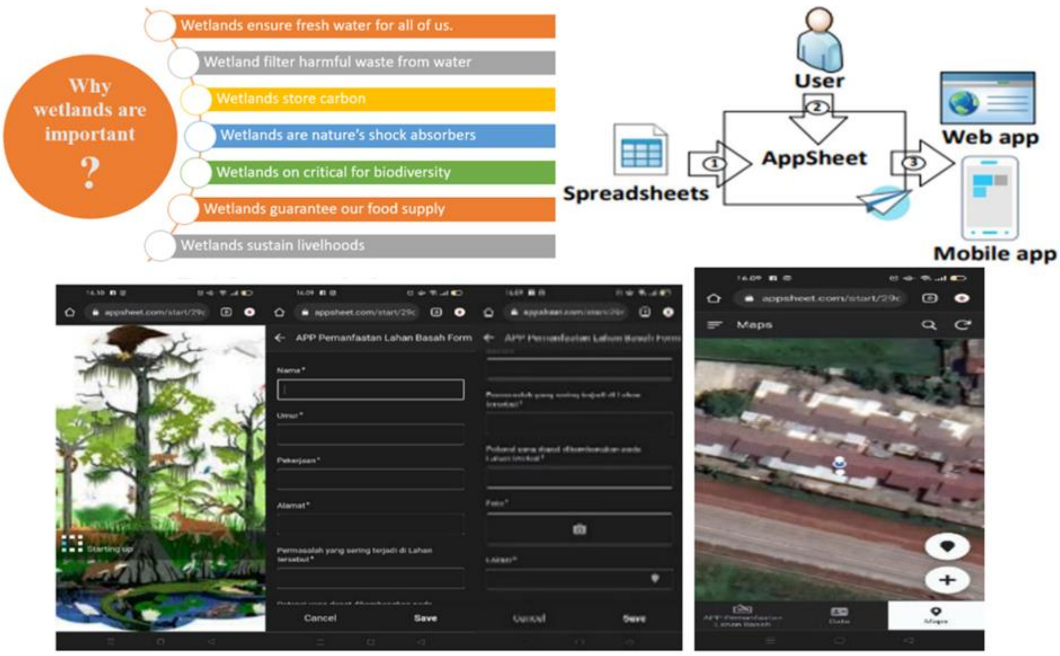

Figure 26. Step for making AppSheet about wetland [94].

4.3.12. Example 12. AR about Gender Quality

Figure 27 shows the design and development steps in making AR gender quality. In making it, several steps are taken:

Step 1: Identify **Problems**: The analysis focuses on gender differences, highlighting female heroes for gender equality, and discussing factors that differentiate gender and their respective qualities.

Step 2: Develop **Hypothesis**: Through AR games, the gender equality advocated by female heroes in Indonesia can be explained.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

Step 4: Conduct **Experiments** and Create **Equipment**: prepare the concept of gender quality.

Step 5: Refine Design and **Develop**: create a flow for making the AR game to be made, and build the AR game according to the flow that has been made

Step 6: **Evaluate** and Test: tested on a limited basis and carried out expert media validation tests.

Step 7: Do **Revision** and Retest: evaluation, and improvement from the results of limited trials and expert validation tests.

Step 8: Implement: This study did not include implementation, but if applied, Game AR can be used to collect data about gender equality knowledge created in one group pretest-posttest design or pretest-posttest control group design research.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

4.3.13. Example 13. Game-based Learning Media on a System of Unit Material.

Figure 28 shows the design and development steps in making game-based learning media on a system of units. In making it, several steps are taken:

Step 1: Identify **Problems**: Problem identification and analysis focus on the need for game-based learning media for the system of unit material.

Step 2: Develop **Hypothesis**: This media aims to improve students' understanding.

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Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes. One class the third elementary school a participant.

Step 4: Conduct **Experiments** and Create **Equipment**: The concept of the system of unit material is prepared.

Step 5: Refine Design and **Develop**: The AR game flow is created and built accordingly.

Step 6: **Evaluate** and Test: It undergoes limited testing and expert media validation.

Step 7: Do **Revision** and Retest: Evaluation and improvements are made based on these results, leading to an assessment of student competency in the system of unit materials.

Step 8: Implement: This study did not include implementation, but if applied, Game AR can be used to collect data about the system of unit material. Created in one group pretest-posttest design or pretest-posttest control group design research.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

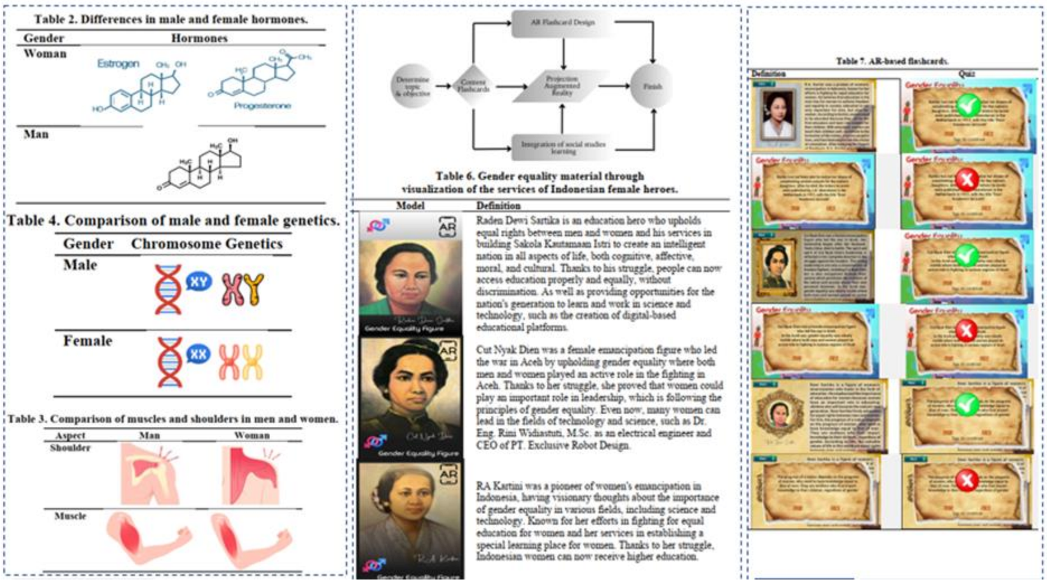

Figure 27. Step for making AR about gender quality [95].

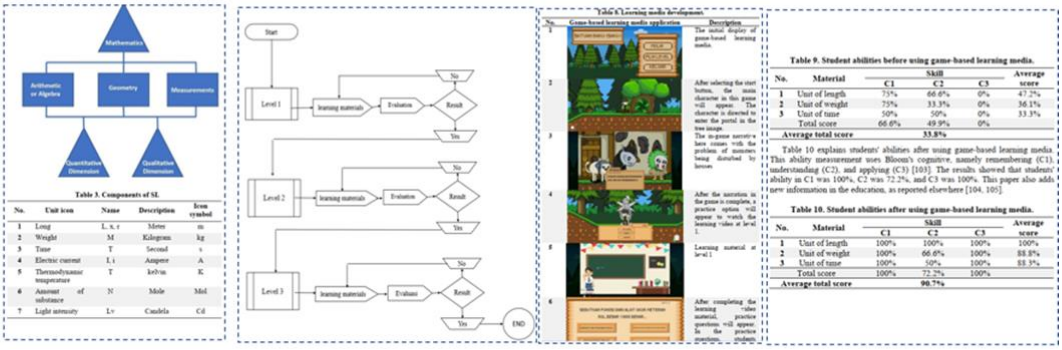

Figure 28. Making game-based learning media about the system of unit material [96].

4.3.14. Example 14. E-module Local Wisdom Ethnoastronomy in the Digital Era to Strengthen the Pedagogical Competence of Social Studies Teachers

Figure 29 shows the design and development steps in making an e-module on local wisdom ethnoastronomy. Several steps were taken to make it:

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Step 1: Identify **Problems**: Problem identification and analysis are carried out based on the need to make an e-module on local wisdom ethnoastronomy.

Step 2: Develop **Hypothesis**: through an e-module on local wisdom ethnoastronomy, it can improve the pedagogical competence of social studies teachers.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes. Participants are teachers in 7 schools in Bandung.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare a concept on local wisdom ethnoastronomy, and make an e-module.

Step 5: Refine Design and **Develop**: create a flow for making an e-module to be made, and build an e-module according to the flow that has been made

Step 6: **Evaluate** and Test: tested on a limited basis and conducted a media expert validation test

Step 7: Do **Revision** and Retest: Evaluation and improvements were made based on limited trials and expert validation.

Step 8: **Implement:** Implementation to teachers in 7 schools in Bandung Regency and West Bandung Regency was obtained, with results showing that teachers appreciate the e-module model offered. The e-module has met the criteria of ideal components in a full, systematic structure, easy-to-understand material mapping, and contains learner activities, quizzes, and reflections.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

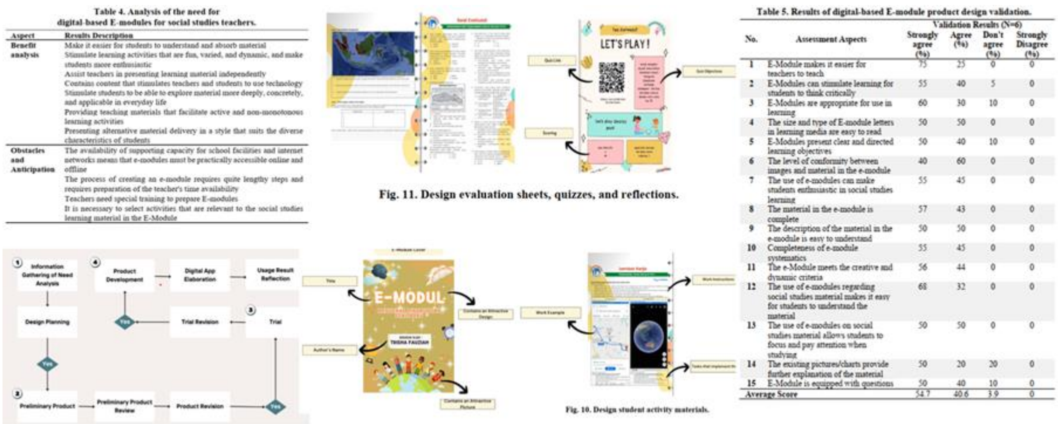

Figure 29. Step for making an E-module about local wisdom ethnography [97].

4.3.15. Example 15. The Natuna Game about the Natural Wealth of the Natuna Marine on National Awareness of the Post-Millennial Generation

Figure 30 is the design and development steps for creating the Natuna game, which highlights the natural wealth of Natuna's marine resources and promotes national awareness among the post-millennial generation, are outlined in several stages:

Step 1: Identify **Problems**: Problem identification and analysis focus on the need to create the Natuna game.

Step 2: Develop **Hypothesis**: The Natuna game, highlighting the natural wealth of Natuna's marine resources, can enhance national awareness among the post-millennial generation.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes. 80 Gen Z's are participants.

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Step 4: Conduct **Experiments** and Create **Equipment**: Prepare a concept natural wealth of Natuna's marine resources, and national awareness post-millennial generation.

Step 5: Refine Design and **Develop**: create a flow for making the Natuna game.

Step 6: **Evaluate** and Test: tested on a limited basis and conducted a media expert validation test

Step 7: Do **Revision** and Retest: evaluation, and improvement from the results of limited trials and expert validation tests.

Step 8: **Implement:** Implementation with pretest-posttest control group design with 40 students used the Natuna game, and 40 students did not use the Natuna game, the result is the game Natuna Media developed is very suitable for use and is expected to increase awareness across generations in maintaining national resilience.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

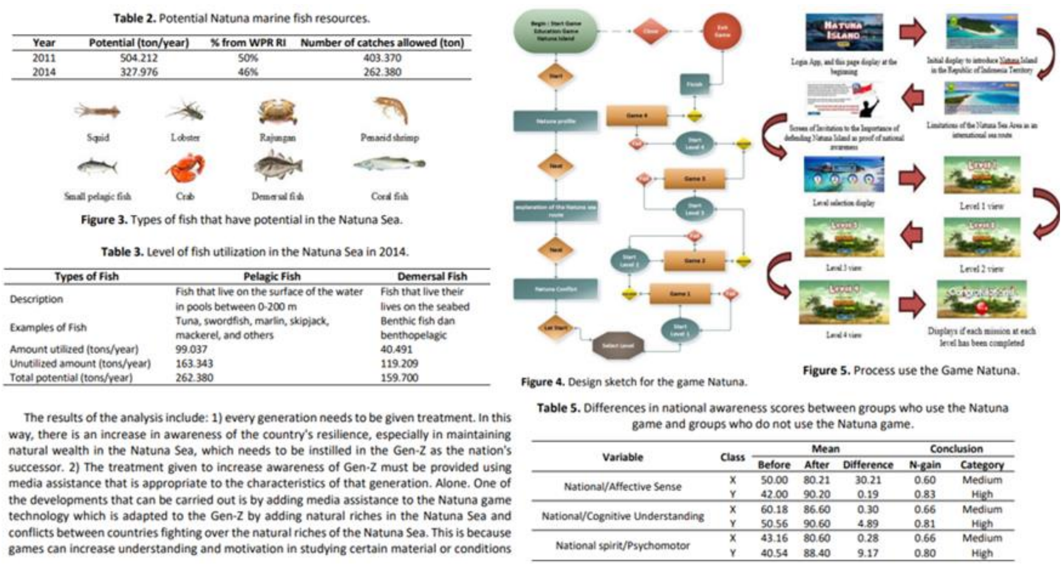

Figure 30. Step for making the Natuna game [98].

4.3.16. Example 16. Make Applications on Environmental Management in River

Figure 31 shows the design and development steps in making an application for environmental management in the river. Several steps were taken to make it:

Step 1: Identify **Problems**: Problem identification of river environmental conditions that require improved conservation management.

Step 2: Develop **Hypothesis**: Application used for environmental management in River.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare a concept of management environment for River.

Step 5: Refine Design and **Develop**: The application flow is created and built accordingly.

Step 6: **Evaluate** and Test: It undergoes limited testing and expert media validation.

Step 7: Do **Revision** and Retest: Evaluation and improvements are made based on these results.

Step 8: Implement: This study did not include implementation, but if applied, this application can be used to collect data about the management environment in the river created in one group pretest-posttest design or pretest-posttest control group design research.

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Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

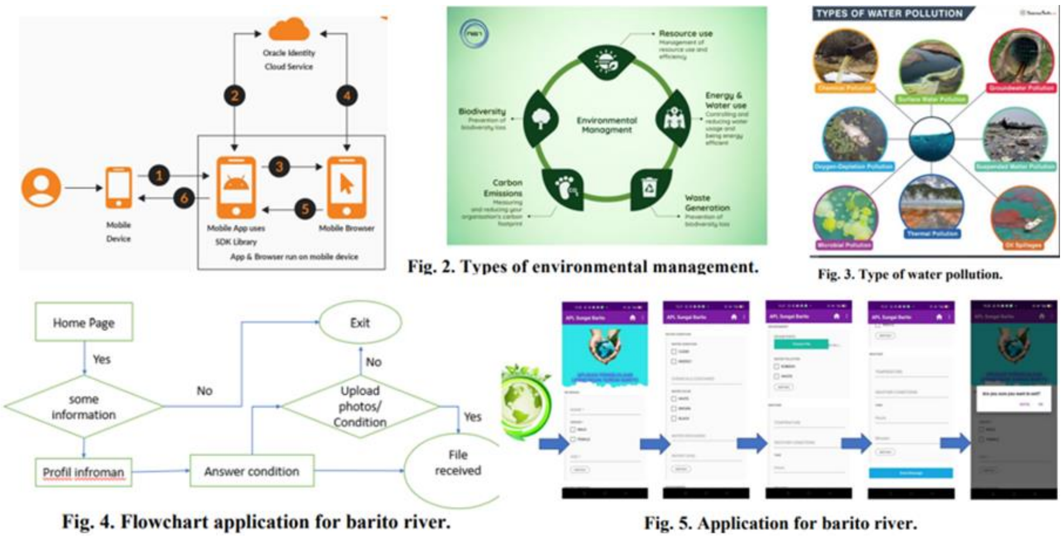

Figure 31. Step for making an application for Barito River [99].

4.3.17. Example 17. Android Application for Smart Diagnosis of Children with Disabilities and Its Correlation to Neuroscience

Figure 32 is the design and development steps for creating an Android application for the smart diagnosis of children with disabilities and its correlation to neuroscience are outlined in several stages:

Step 1: Identify **Problems**: the needs of students with disabilities in using applications in learning are adjusted in relation to neuroscience.

Step 2: Develop **Hypothesis**: Android application used for disabilities.

Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare a concept on an algorithm for smart diagnostic applications.

Step 5: Refine Design and **Develop**: The application flow is created and built accordingly.

Step 6: **Evaluate** and Test: It undergoes limited testing and expert media validation.

Step 7: Do **Revision** and Retest: Evaluation and improvements are made based on these results.

Step 8: Implement: This study did not include implementation, but if applied, this application can be used to collect data about using this application in learning, it can created in one group pretest-posttest design or pretest-posttest control group design research.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

4.3.18. Example 18. AR for Cultivating Computational Thinking Skills in Mathematics

Figure 33 shows the design and development steps in making an AR for cultivating computational thinking skills in mathematics. Several steps were taken to make it:

Step 1: Identify **Problems**: Problem the computational thinking skill in Mathematics is very low.

Step 2: Develop **Hypothesis**: AR cultivating computational thinking skills in mathematics.

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Step 3: Choose Research **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes. The study involved 160 students from four junior high schools.

Step 4: Conduct **Experiments** and Create **Equipment**: Prepare a concept on CT skills in mathematics, and make an AR. Instrument CT ability test.

Step 5: Refine Design and **Develop**: create a flow for making an AR.

Step 6: **Evaluate** and Test: tested on a limited basis and conducted a media expert validation test.

Step 7: Do **Revision** and Retest: evaluation, and improvement from the results of limited trials and expert validation tests.

Step 8: Implement: This study was created in pretest-posttest control group design research. The result is AR effective for enhanced the CT Skills.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

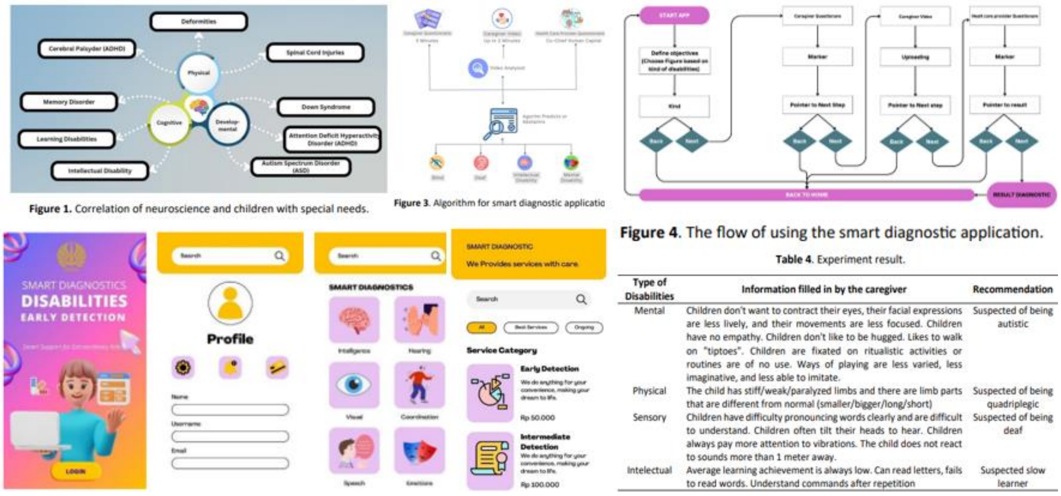

Figure 32. Step for making a smart diagnostic application [100].

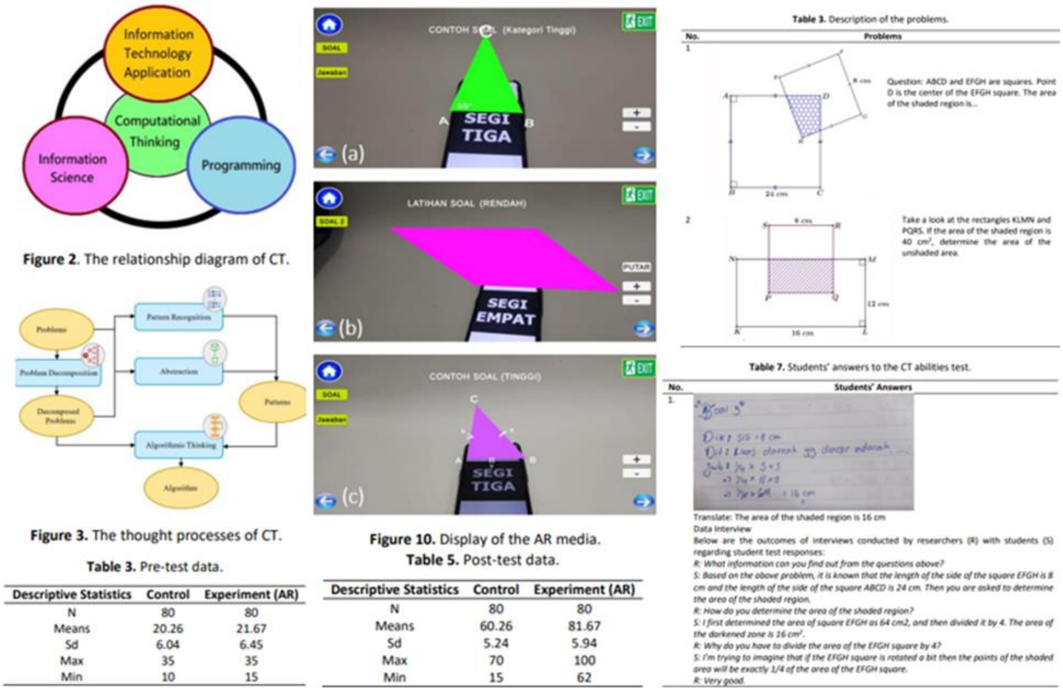

Figure 33. Step for making AR for computational thinking skills [101].

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4.3.19. Example 19. Blockchain System Design for Post-Disaster Management.

Figure 34 shows the design and development steps in making a blockchain system design. Several steps were taken to make it:

Step 1: Identify **Problems**: Problem identification and analysis are carried out based on the need for made blockchain system for disaster management in Indonesia.

Step 2: Develop **Hypothesis**: Blockchain system used for post-disaster management in Indonesia.

Step 3: Choose **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

Step 4: Conduct **Experiments** and **Create Equipment:** prepare tools and materials to be used.

Step 5: Refine Design and **Develop:** create a flow for making a Blockchain system.

Step 6: Evaluate and Test: tested on a limited basis and conducted a media expert validation test.

Step 7: Do **Revision** and Retest: evaluation, and improvement from the results of limited trials and expert validation tests.

Step 8: Implement: This study did not include implementation, but if applied, this application can be used to collect data about this application in learning for simulation disasters.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

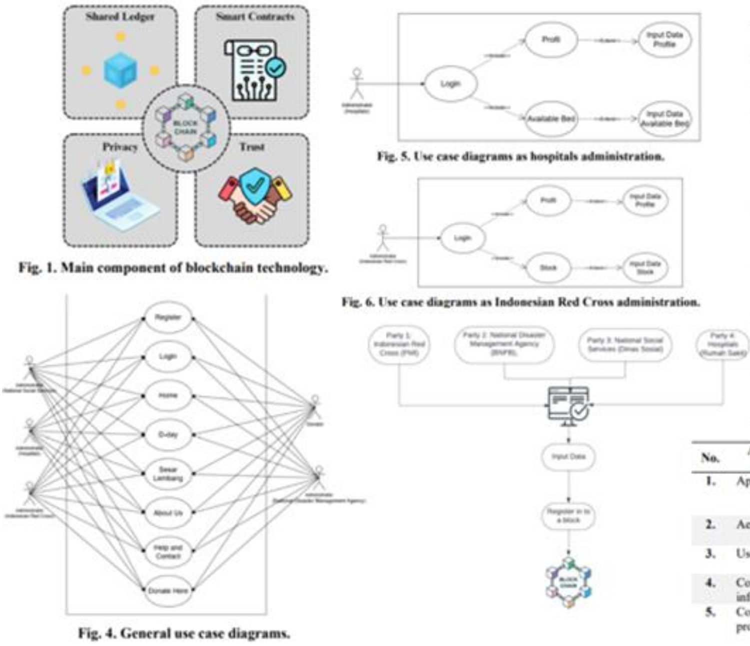

Table 3. The functionality testing result.

Test Case Types	Description	Expected	Status
Functionality	The area must accommodate up to 20 characters	All 20 characters in the request must be in accordance	Pass
	Home Must display news	Entire feature news can be accessed with the appropriate and capable return to home page	Pass
	Lembang Fault Must display information around the Lembang Fault	Users can access the Lembang Fault page and go back to home page	Pass
	About Us Must display information around the team from developer system information	Users can access the page About Us and back to home page	Pass
	Help and Contact Must display possible contacts _ contacted and a list of questions and answers (FAQ)	Users can access the page Help and Contact and go back to home page	Pass
	D-Day Must display map interactive, data around disasters, and related data need logistics	Users can access page D-Day and back to home page	Pass
	Profile Must display information or personal data from the user	Users can access the page profile and go back to home page	Pass
Security	Verification password rules work	Password users will accept if followed by the rule	Pass
Utility	Ensure all link works with Good	The link will bring the user to the page other websites are suitable with the URL on the page	Pass

Table 4. The usability testing result.

No.	Aspect Testing Usability	Results
1.	Appropriateness	100% respondents agreed that this innovation is suitable for post-disaster management, highlighting its informativeness due to the clarity and real-time updates of logistics needs.
2.	Aesthetics	90% of respondents agreed that this innovation has good aesthetic value, with notes that the design is too simple and lacks graphics.
3.	Usefulness	100% of respondents agreed that this innovation is useful in handling post-disaster recovery.
4.	Convenience get information	93% of respondents stated that they would use this innovation because it makes easier for them to obtain information about post-disaster.
5.	Convenience use prototype	93% of respondents stated that they do not find it difficult to use. However, they noted the need for improvements in the mobile phone interface.

Figure 34. Blockchain system design for post-disaster management [102].

4.3.20. Example 20. A Guidebook for Green Technology with AR

Figure 35 shows the design and development steps in making a guidebook a green technology with AR, including:

Step 1: Identify **Problems**: There is a need for more digital development of green technology books.

Step 2: Develop **Hypothesis**: A guidebook for a green technology developed with AR.

Step 3: Choose **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes.

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Step 4: Conduct **Experiments** and **Create Equipment:** prepare tools and materials to be used.

Step 5: Refine Design and **Develop:** create a flow for making an AR in a guidebook.

Step 6: Evaluate and Test: tested on a limited basis and conducted a media expert validation test.

Step 7: Do **Revision** and Retest: evaluation, and improvement from the results of limited trials and expert validation tests.

Step 8: Implement: This study did not include implementation, but if applied, this application can be used to collect data about using this application in learning.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

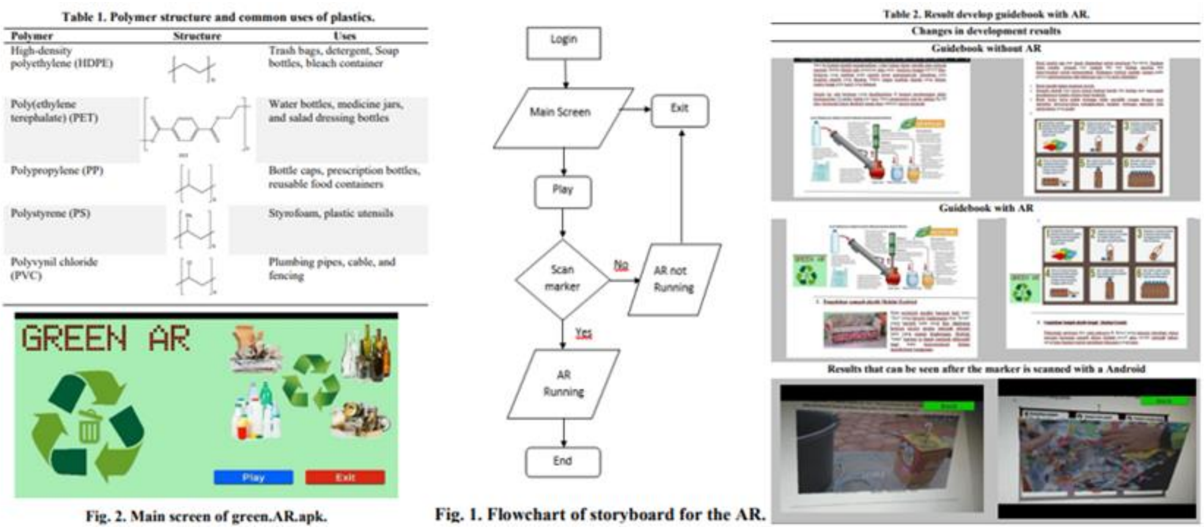

Figure 35. Step for making game AR about green technology [33].

4.3.21. Example 22. Design Mobile-based Interactive E-Module (MIeM) Fostering Earthquake Swarms Disaster Mitigation

Figure 36 shows the design and development steps in making a mobile-based interactive e-module (MIeM) fostering earthquake swarms disaster mitigation, including:

Step 1: Identify **Problems**: There are media interactive for fostering earthquake swarm disaster mitigation.

Step 2: Develop **Hypothesis**: a mobile-based interactive e-module (MIeM) fostering earthquake swarms disaster mitigation.

Step 3: Choose **Methodology**: Selecting the right method in science, technology, and engineering and learning outcomes. Pretest posttest control group design involving 22 students at a Junior High School in Halmahera.

Step 4: Conduct **Experiments** and **Create Equipment:** prepare concepts about earthquake swarm disaster mitigation, tools, and materials to be used.

Step 5: Refine Design and **Develop**: create a flow for making a Mobile-based Interactive E-Module (MIeM)

Step 6: Evaluate and Test: tested on a limited basis and conducted a media expert validation test.

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Step 7: Do **Revision** and Retest: evaluation, and improvement from the results of limited trials and expert validation tests.

Step 8: Implement: The implementation was carried out using a pretest-posttest control group design. The analysis results show that the product MIeM is declared valid for use in science learning. The implementation of the developed MIeM was found to be significantly more effective in fostering students' ESDMA compared to conventional modules.

Step 9: Disseminate: Dissemination was not conducted in this study, but if applied, the results can be shared with researchers in the relevant field.

Figure 36. Step for making mobile-based interactive e-module (MIeM) [32].

Based on the results of the step-by-step analysis of design methods in science learning, it shows that the design method can be used to develop products, media, and learning models. Products that are created or developed usually start from an analysis of problems and needs [103, 104]. Therefore, preliminary studies regarding needs analysis and problem identification are very necessary and adapted to conditions [105-107]. The process carried out at each stage of the DBR method always includes an itinerary or redesign section, meaning that the product, model, or media being designed must be tested and then redesigned if an error occurs or does not meet expectations [108-119]. This is what differentiates the process or stages of DBR methods from other research methods. Based on the results of implementing DBR, of the five methods that have been discussed, the processes that are still said to be simple are the DbR, Design Thinking, and EDP methods. Meanwhile, DRM and R&D are classified as methods that require a very long process and take a long time.

Fig. 2. Display of the MIeM product:
(a) cover, (b) literacy space, (c) disaster tourism space.

Table 4. Analysis results of the ESDMA pretest and posttest data.

Description	Experiment Class		Control Class	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Average	16.00	54.67	17.10	40.70
Standard Deviation	7.50	13.09	6.64	10.03
Normality Test *One-Sample Kolmogorov-Smirnov Test (Sig.)*	0.532	0.540	0.539	0.901
	Pretest		*Posttest*	
Homogeneity Test *Test of Homogeneity of Variances (Sig.)*	0.461		0.967	
T-test (*Independent Samples Test*)	[illegible] = - 0.339		[illegible] = 2.627	
Effect Size	1.2 (large)			

Table 5. Statistical analysis result of <g>.

Description	Class	
	Experiment	*Control*
Average 〈*g*〉	0.46	0.28
Normality Test *One-Sample Kolmogorov-Smirnov Test (Sig.)*	0.790	0.957
Homogeneity Test *Test of Homogeneity of Variances (Sig.)*	0.867	
T-test (*Independent Samples Test*)	2.668	

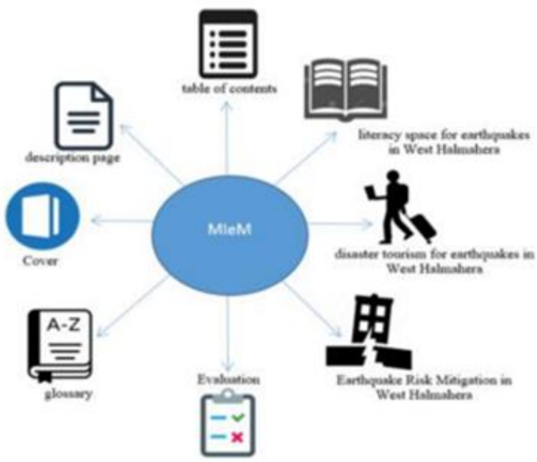

Fig. 3. The MIeM product characteristics.

Figure 36. Step for making mobile-based interactive e-module (MIeM) [32].

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4. CONCLUSION

The conclusion of this research is to describe the methodology used in scientific research and design in education, complete with an explanation of the procedures for each step and accompanied by examples of designs that can be carried out using the design method. The methods discussed are EDP, design thinking, DBR, DRM, and R&D. We also developed 9 steps in research methodology, namely PHMEEDERID, an abbreviation of Identify Problems; Develop Hypothesis; Choose Research Methodology; Conduct Experiments and Create Equipment; Refine Design and Develop; Evaluate and Test; Do Revision and Retest; Implement; and Disseminate. This methodology regarding design in science and engineering is research that is currently being carried out due to the many innovations being carried out in the world of education. This research can become a reference as an illustration of the use of research methods in designing products because it has been explained in detail step by step and also examples of developments carried out.

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