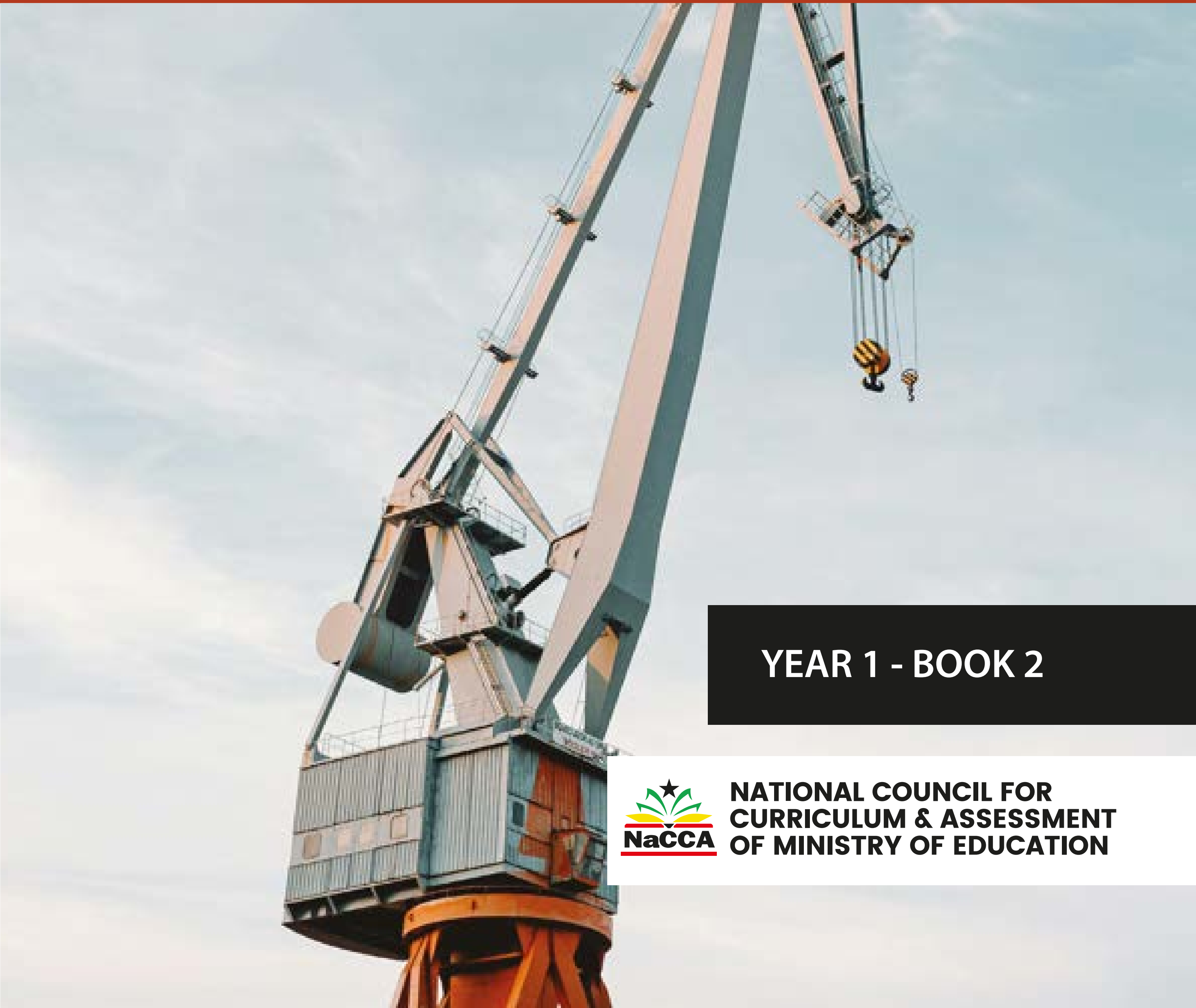
MINISTRY OF EDUCATION

ENGINEERING

For Senior High Schools

TEACHER MANUAL



YEAR 1 - BOOK 2

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Engineering

For Senior High Schools

Teacher Manual

Year One - Book Two

NaCCA
NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION

ENGINEERING TEACHER MANUAL

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CONTENTS

INTRODUCTION

The National Council for Curriculum and Assessment (NaCCA) has developed a new Senior High School (SHS), Senior High Technical School (SHTS) and Science, Technology, Engineering and Mathematics (STEM) Curriculum. It aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, competencies, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, further their education and enter the world of work.

This is the first time that Ghana has developed an SHS Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

This Book Two of the Teacher Manual for Engineering covers all aspects of the content, pedagogy, teaching and learning resources and assessment required to effectively teach Year One of the new curriculum. It contains information for the second 11 weeks of Year One. Teachers are therefore to use this Teacher Manual to develop their weekly Learning Plans as required by Ghana Education Service.

Some of the key features of the new curriculum are set out below.

Learner-Centred Curriculum

The SHS, SHTS, and STEM curriculum places the learner at the center of teaching and learning by building on their existing life experiences, knowledge and understanding. Learners are actively involved in the knowledge-creation process, with the teacher acting as a facilitator. This involves using interactive and practical teaching and learning methods, as well as the learner's environment to make learning exciting and relatable. As an example, the new curriculum focuses on Ghanaian culture, Ghanaian history, and Ghanaian geography so that learners first understand their home and surroundings before extending their knowledge globally.

Promoting Ghanaian Values

Shared Ghanaian values have been integrated into the curriculum to ensure that all young people understand what it means to be a responsible Ghanaian citizen. These values include truth, integrity, diversity, equity, self-directed learning, self-confidence, adaptability and resourcefulness, leadership and responsible citizenship.

Integrating 21st Century Skills and Competencies

The SHS, SHTS, and STEM curriculum integrates 21st Century skills and competencies. These are:

- **Foundational Knowledge:** Literacy, Numeracy, Scientific Literacy, Information Communication and Digital Literacy, Financial Literacy and Entrepreneurship, Cultural Identity, Civic Literacy and Global Citizenship
- **Competencies:** Critical Thinking and Problem Solving, Innovation and Creativity, Collaboration and Communication
- **Character Qualities:** Discipline and Integrity, Self-Directed Learning, Self-Confidence, Adaptability and Resourcefulness, Leadership and Responsible Citizenship

Balanced Approach to Assessment - not just Final External Examinations

The SHS, SHTS, and STEM curriculum promotes a balanced approach to assessment. It encourages varied and differentiated assessments such as project work, practical demonstration, performance assessment, skills-based assessment, class exercises, portfolios as well as end-of-term examinations and final external assessment examinations. Two levels of assessment are used. These are:

- Internal Assessment (30%) – Comprises formative (portfolios, performance and project work) and summative (end-of-term examinations) which will be recorded in a school-based transcript.

- External Assessment (70%) – Comprehensive summative assessment will be conducted by the West African Examinations Council (WAEC) through the WASSCE. The questions posed by WAEC will test critical thinking, communication and problem solving as well as knowledge, understanding and factual recall.

The split of external and internal assessment will remain at 70/30 as is currently the case. However, there will be far greater transparency and quality assurance of the 30% of marks which are school-based. This will be achieved through the introduction of a school-based transcript, setting out all marks which learners achieve from SHS 1 to SHS 3. This transcript will be presented to universities alongside the WASSCE certificate for tertiary admissions.

An Inclusive and Responsive Curriculum

The SHS, SHTS, and STEM curriculum ensures no learner is left behind, and this is achieved through the following:

- Addressing the needs of all learners, including those requiring additional support or with special needs. The SHS, SHTS, and STEM curriculum includes learners with disabilities by adapting teaching and learning materials into accessible formats through technology and other measures to meet the needs of learners with disabilities.
- Incorporating strategies and measures, such as differentiation and adaptative pedagogies ensuring equitable access to resources and opportunities for all learners.
- Challenging traditional gender, cultural, or social stereotypes and encouraging all learners to achieve their true potential.
- Making provision for the needs of gifted and talented learners in schools.

Social and Emotional Learning

Social and emotional learning skills have also been integrated into the curriculum to help learners to develop and acquire skills, attitudes, and knowledge essential for understanding and managing their emotions, building healthy relationships and making responsible decisions.

Philosophy and vision for each subject

Each subject now has its own philosophy and vision, which sets out why the subject is being taught and how it will contribute to national development. The Philosophy and Vision for Engineering is:

Philosophy: The next generation of creators and technology developers can be empowered through observation, curiosity, exposure to related engineering concepts and opportunities that leverage practical activities in a learner-centred environment, leading to global and local (“glocal”) relevance.

Vision: A skilled learner armed with 21st-century skills and competencies in critical thinking, designing, and development of engineering-based solutions for increasingly complex societal problems

SUMMARY SCOPE AND SEQUENCE

S/N	STRAND	SUB-STRAND	YEAR 1			YEAR 2			YEAR 3		
			CS	LO	LI	CS	LO	LI	CS	LO	LI
1.	Engineering Practice	Engineering In Society	1	2	5	1	1	2	1	2	4
		Health And Safety In Engineering Practice	1	2	4	1	2	6	1	2	4
		Ethics And Professional Practice	1	2	4	1	2	6	1	1	3
2.	Energy System	Circuit And Machines	1	2	7	1	2	5	1	2	4
		Renewable Energy System	1	2	4	1	2	4	1	2	4
		Energy Efficiency And Conservation	1	2	4	1	2	4	1	2	4
3.	Systems Design And Prototyping	Engineering Design	1	2	4	2	2	2	2	2	2
		Rapid Prototyping	1	1	1	2	2	2	2	2	2
4.	Automation And Embedded System	Automation Technologies	1	2	2	1	1	1	1	2	2
		Embedded System	2	4	6	2	2	2	1	1	1
Total			**11**	**21**	**41**	**13**	**18**	**34**	**12**	**18**	**30**

Overall Totals (SHS 1 – 3)

Content Standards	**36**
Learning Outcomes	**57**
Learning Indicators	**105**

SECTION 7: ENGINEERING DESIGN AND PROTOTYPING

Strand: **Systems Design and Prototyping**

Sub-strand: Engineering Design

Learning Outcome: *Outline the various stages in the Engineering Design Process and their roles in providing sustainable solutions to problems*

Content Standard: Demonstrate an understanding of Engineering Design Process

INTRODUCTION AND SECTION SUMMARY

Engineering Design Process is a proven systematic method for solving real-life problems and creating innovative solutions to real-world challenges. It provides a structured framework for engineers to follow when developing new products, systems, or technologies. It helps to prevent errors, reduce costs and save time by avoiding unnecessary trial and error. Using engineering design process to solve real-world problems and improve existing systems is at the core of technological advancement. Documenting solution requirements is a crucial step in the problem-solving lifecycle. It helps ensure that all stakeholders have a clear understanding of what the solution needs to accomplish. Engineers, in applying the Engineering Design Process, begin by clearly defining the problem they wish to solve. Hence, encourage learners to break down a given problem into specific components and to analyse and understand its (the problem) context, scope, and underlying causes. Encourage learners to gather relevant information, conduct literature reviews, and engage in discussions with experts or stakeholders to gain a comprehensive understanding of the issue. Manufacturing process, which lends itself to the Engineering Design Process, is the backbone of industries such as automotive, electronics, aerospace, healthcare and consumer goods.

The weeks covered by the section are:

- **Week 14.** Engineering Design
- **Week 15.** Engineering Research Methods
- **Week 16.** Manufacturing Processes I
- **Week 17.** Manufacturing Processes II

SUMMARY OF PEDAGOGICAL EXEMPLARS

The Teacher can initiate a discussion by introducing the engineering design process and its role in providing sustainable solutions to problems and the development of innovative products. Learners can discuss how the engineering design process was used in the development of some common products around them like cell phones and television sets and the solution of societal problems like sanitation and food security. Learners can also use a flowchart to illustrate the design process. In mixed grouping, learners work on a case study to develop solution requirements and objectives. They can present what has been developed to the whole class for comments. Where these facilities are lacking, learners can watch videos on 3D printing, casting, PCB production, laser cutting technology and other Rapid Prototyping (RP) Techniques employed in manufacturing or developing a product. Encourage learners to observe the operating principles, use cases, strengths and weaknesses of the respective RPs. Learners can also visit RP workshops to have first-hand experience of 3D printing machines producing models as an example of an RP technology. In groups, learners can make presentations on their observations, critique and add to others' presentations.

ASSESSMENT SUMMARY

Provide learners with application questions focusing on this section's focal areas. For instance; imagine you are designing a new smartphone. Outline the key steps in each stage of the engineering design process to bring the product from concept to reality. Discuss the ethical considerations that engineers should consider when designing a solution. Request Learners to Identify and define a problem clearly, considering stakeholders and local context. Ask learners to prioritise constraints and criteria based on stakeholder needs and preferences. Ask learners to generate multiple solutions, considering feasibility, creativity, and effectiveness and evaluate and select the most promising solution. Learners can be made to choose a real-world problem that interests them; such as reducing plastic waste or improving access to clean water. Assist learners to outline a comprehensive set of solution requirements that would contribute to solving this problem. They can further justify their choices by considering various stakeholders, potential challenges and the overall impact of each requirement.

Week 14

Learning Indicators:

1. *State the various elements within the engineering design process*
2. *List and document solution requirements for a given problem*

Theme or Focal Area: Engineering Design process

The Engineering Design process consists of problem identification, research and information gathering, ideas generation, evaluation and selection of solutions, development of design, building and testing prototypes, analysing and interpreting results, communication and presentation, reflection and iteration, ethical consideration, collaboration and teamwork.

The purpose of the engineering design process is to systematically solve problems and create innovative solutions to real-world challenges. It provides a structured framework for engineers to follow when developing new products, systems or technologies. The engineering design process is vital because it ensures that the engineer's approach to problem-solving is in a logical and efficient manner, leading to successful outcomes. It helps to prevent errors, reduces costs and saves time by avoiding unnecessary trial and error.

Whether it's designing a more fuel-efficient engine, improving medical devices, or creating sustainable infrastructure, engineering plays a crucial role in driving progress and innovation. The brief description of the engineering design process is:

1. **Identify the Problem:**
   Understanding the problem's scope and constraints is essential before jumping into the solution phase. Learners should know how to ask questions, conduct interviews, and conduct observations to gain a comprehensive understanding of the problem. Emphasising this step ensures that learners tackle the right challenges and do not waste time on irrelevant issues.

2. **Research and Gather Information:**
   Conducting research and gathering information is crucial in engineering design. Learners should learn to use various resources such as books, articles, scientific papers, and online sources to gain knowledge about the problem at hand. Encourage them to analyse existing solutions and technologies to build upon and avoid reinventing the wheel. This phase helps learners make informed decisions and develop a well-informed perspective.

3. **Generate Ideas:**
   Brainstorming and generating multiple ideas are vital steps to foster creativity in learners. Techniques like mind mapping, sketching, and group discussions can stimulate innovative thinking. Encourage an open-minded approach, where no idea is initially judged, allowing for a wide range of potential solutions.

4. **Evaluate and Select Solutions:**
   Teaching learners how to evaluate and select the most viable solutions is critical in the design process. Help them develop criteria based on factors such as functionality, cost, sustainability, and ease of implementation. Analysing the pros and cons of each option will lead to an informed decision.

5. **Develop a Design:**
   Transforming the selected solution into a detailed design involves considering various factors; such as materials, dimensions and specifications. This step helps in visualising the final product or system and prepares learners for the prototyping phase.

6. **Build and Test Prototypes:**
   Building physical or virtual prototypes allows learners to test their designs in a controlled environment. Iterative testing and making improvements based on feedback are crucial for refining the design and addressing any unforeseen issues.

7. **Analyse and Interpret Results:**
   Teaching learners how to analyse and interpret prototype testing data will help them draw meaningful conclusions. This analysis informs further iterations and improvements to the design.

8. **Communicate and Present:**
   Developing communication skills is essential in the engineering profession. Learners should learn how to effectively present their design process and findings to peers, clients or stakeholders. Using visual aids, diagrams and oral presentations can help convey complex ideas clearly.

9. **Reflect and Iterate:**
   Encourage learners to reflect on their designs, identify areas for improvement, and iterate on their solutions. Iteration is a key aspect of engineering design as it allows for continuous improvement.

10. **Ethical Considerations:**
    Discussing ethical responsibilities in the design process ensures that learners understand the implications of their work on society and the environment, emphasise safety, sustainability, and the social impact of their designs.

11. **Collaboration and Teamwork:**
    Simulating real-world engineering projects by working in teams helps learners develop essential teamwork and communication skills. Engineering often involves collaborative efforts and teamwork is crucial for successful project completion.

Learning Tasks

1. Introduce learners to the engineering design process and its role in creating sustainable solutions and innovative products.
2. Guide learners to discuss why it is important to consider the needs and preferences of potential users during design.
3. Lead learners to dive deeper into the concept of testing and refining a design to improve its functionality.
4. Guide learners to discuss what it means to iterate on a design and why it is beneficial.
5. Engage learners to compare the engineering design process and the scientific method.
6. Introduce learners to the concept of prototyping in the development of products of technology.

Theme or Focal Area 2: Documenting solution requirements

Documenting solution requirements is a crucial step in the software development lifecycle. It helps ensure that all stakeholders have a clear understanding of what the solution needs to accomplish. Here's a structured way to list and document solution requirements for a given problem:

1. **Problem Identification:**

   Explain the significance of clearly understanding the problem before attempting to solve it. Discuss techniques like root cause analysis, brainstorming and gap analysis.

   Teach learners to identify the broader context of the problem, its scope (what's included and excluded) and any limitations or constraints they need to consider.

2. **Stakeholder Analysis:**

   Help learners identify all relevant stakeholders, both direct and indirect, who might be affected by the problem and its solution.

   Discuss the importance of understanding each stakeholder's needs, expectations, and viewpoints. This can involve conducting surveys, interviews or focus groups.

3. **Functional Requirements:**

   Guide learners in breaking down the problem into specific functionalities or features that the solution should possess. Encourage them to create a list or diagram of these requirements.

4. **Performance Requirements:**

   Teach learners how to set measurable criteria for performance such as speed, accuracy, efficiency, capacity, and reliability. Emphasise the importance of quantifiable benchmarks.

5. **Safety and Security Requirements:**

   Explain the need to consider potential risks to users and how to mitigate them. Discuss securing sensitive data and ensuring the solution's overall safety.

6. **Technical and Design Requirements:**

   Introduce learners to technical aspects like selecting appropriate materials, sizes and dimensions based on the problem's characteristics.

7. **Regulatory and Compliance Requirements:**

   Help learners identify relevant regulations, standards and certifications that their solution must adhere to, depending on the problem domain.

8. **Cost and Resource Requirements:**

   Discuss the importance of estimating the budget, time, manpower and materials required for the solution. Encourage learners to consider potential trade-offs.

9. **Documentation and Reporting:**

   Teach learners how to create structured requirement specification documents, including clear descriptions, diagrams, and examples for better understanding.

10. **Prioritisation and Trade-offs:**

    Guide learners in evaluating requirements based on their importance and feasibility. Discuss scenarios where trade-offs might be necessary.

11. **Review and Validation:**

    Explain the iterative nature of requirement review and validation. Encourage learners to seek feedback from stakeholders and refine requirements accordingly.

12. **Communication and Collaboration:**

    Provide guidance on how to present and communicate requirements clearly to different stakeholders, fostering collaboration and understanding.

Learning Tasks

1. Discuss with learners how to break down a given design problem into specific functionalities or features that the product should possess. Guide learners to come up with the requirements for these functionalities.
2. Discuss with learners how to draw up a list of performance requirements for products such as mobile phones, projects, laptops etc.
3. Discuss with learners the steps in documenting the solution requirements for a given product such as a mobile phone.

Pedagogical Exemplars

1. **Initiating talk-for-learning:**

   The teacher initiates a discussion by introducing the engineering design process and its role in providing sustainable solutions to problems and developing innovative products.

   In a moderated discussion, guide learners to break down a given design problem into specific functionalities or features the product should possess. Guide learners to come up with the requirements for these functionalities.

   For a selected product such as a television, lead learners in a class discussion to come up with the technical design requirements such as material selection and specifications such as size and weight.

2. **Collaborative Learning**:

   Group learners in mixed ability and mixed gender groups to discuss how the engineering design process was used in the development of some common products around them such as a cell phone, or the solution of societal problems like sanitation and food security. Use a flowchart to illustrate the design process.

   Learners in think-pair-share can also be guided to discuss the full spectrum of solution requirements for the design of selected products.

   Have learners in mixed-ability and mixed-gender groupings think of a product that will address societal needs and present how they will go about documenting the solution requirements of the products.

3. **Experiential learning**:

   Group learners and task them to research what specific requirements will be needed for a product yet to be introduced onto the market, by asking other learners in the school relevant questions related to the product.

   Have learners, working in mixed ability and gender groups, identify a real-world problem and propose their solutions using the engineering design process.

Key Assessment

Level 1 Recall:

1. Outline the engineering design process.
2. Give one main reason why the engineering design process is important.
3. How many steps are there in the engineering design process?
4. Define the term "problem statement" in the context of engineering design.
5. Why is brainstorming an essential part of the engineering design process?
6. What is the purpose of creating prototypes during the design process?
7. Explain what it means to "evaluate" a design solution.
8. Why is communication important in the engineering design process?
9. What role does research play in the engineering design process?
10. Name two examples of real-world products that have gone through the engineering design process.

Level 2 Skills of conceptual understanding:

1. Describe the steps involved in the engineering design process.
2. How do defining criteria and constraints help guide the design process?
3. Compare and contrast the concepts of "iteration" and "optimisation" in the context of design.
4. Give an example of a situation where ethical considerations would impact the engineering design process.
5. Explain how the engineering design process might differ when designing a physical product as opposed to a software application.
6. Explain the importance of user testing during the engineering design process.
7. Analyse the role of teamwork and collaboration in successfully executing the engineering design process.
8. Describe how risk assessment is integrated into the engineering design process.
9. Provide an example of how sustainability principles could influence decisions at different stages of the design process.
10. Imagine you're designing a new smartphone. Outline the key steps to be taken in each stage of the engineering design process to bring the product from concept to reality.
11. How might cultural factors influence the elements within the engineering design process?

Level 3 Strategic reasoning:

Select a minimum of three (3) of the following questions:

1. You are tasked with creating a mobile app to solve a transportation problem in your city.
   i. Define the problem to be solved.
   ii. How would you determine the specific features and functions that the app needs to have to address the problem effectively?
   iii. Provide a detailed list of at least five solution requirements and explain why each one is important.
2. Choose a real-world problem that interests you such as reducing plastic waste or improving access to clean water. Outline a comprehensive set of solution requirements that would contribute to solving this problem. Justify your choices by considering various stakeholders, potential challenges and the overall impact of each solution.
3. Imagine a scenario where a company is struggling with employee communication and collaboration. Develop a unique list of solution requirements that could enhance communication

and collaboration within the organisation. Think outside the box and consider both technological and non-technological aspects.

4. Reflect on a recent problem-solving experience, either personal or observed. Describe the process you went through to identify and document the solution requirements for that problem. What challenges did you encounter? How did you prioritise the requirements? Looking back, would you make any changes to your approach?
5. Choose a problem that can be addressed through a combination of disciplines such as environmental conservation. Create a list of solution requirements that highlights the collaboration between these disciplines. Explain how each requirement contributes to a holistic solution.
6. Think about a problem related to social justice, privacy, or fairness. Generate a set of solution requirements that not only address the technical aspects of the problem but also consider ethical considerations. How would your proposed solution uphold ethical standards?
7. Consider a challenge that affects communities on a global scale, such as access to education or healthcare. List and document solution requirements that could be implemented in various parts of the world. Discuss the adaptability and cultural sensitivity of your requirements.
8. Research the energy sector and document the requirements for an energy-efficient home automation system. Discuss how factors like energy conservation, user customisation and remote control contribute to the overall effectiveness and appeal of the system.
9. Choose a social issue such as homelessness and outline the solution requirements for a community outreach programme aimed at providing support and resources to those in need. How can a detailed understanding of both functional and non-functional requirements contribute to the programme's successful implementation?

Week 15

Learning Indicator: *Outline relevant research questions for a given problem.*

Theme or Focal Area: Research

Research is an important endeavour in finding solutions to real-world problems. Research tries to find answers to unknown questions or create a technique for designing and innovating a new solution or product. The first step in a research process is identifying and formulating the problem. Begin by clearly defining a problem to be solved. Encourage learners to break down the problem into specific components and understand its context and scope.

1. **Ask critical questions:**

   Teach learners to ask thought-provoking questions about the problem. These questions should challenge assumptions, explore underlying causes and consider potential implications.

2. **Conduct background research using various sources:**

   Familiarise learners with different research methods, including literature reviews, surveys, experiments and case studies.

   Guide learners on how to identify credible and reliable sources of information. Teach them to evaluate the authority, credibility and relevance of the sources they use.

3. **Problem analysis and identifying key variables and factors:**

   Help learners to evaluate existing information related to the problem critically. Identify gaps in knowledge and areas where further investigation is required.

   Guide learners in identifying the main variables and factors that contribute to the problem. Discuss how these variables can be studied and manipulated to find potential solutions.

4. **Formulating clear and specific research questions:**

   Teach learners to formulate research questions that are clear, focused and directly address the problem statement.

   Encourage learners to develop research questions that can be measured and evaluated to provide meaningful answers.

5. **Exploratory and descriptive research questions:**

   Help learners understand the distinction between exploratory questions which seek to gain insights and descriptive questions which aim to gather specific information.

   Encourage learners to formulate a mix of exploratory and descriptive research questions to thoroughly investigate the problem.

6. **Causal and correlational research questions:**

   Introduce the concepts of causal and correlational relationships between variables.

   Teach learners to design research questions that explore potential cause-and-effect relationships.

7. **Testable and feasible research questions:**

   Guide learners to develop research questions that are feasible within the given resources, time frame, and ethical considerations.

   Discuss the importance of considering practicality and ethical implications when formulating research questions.

8. **Collaboration and feedback:**

   Encourage learners to collaborate with peers to refine their research questions and gain diverse perspectives.

   Teach learners to seek constructive feedback from peers, mentors or experts to improve the quality of their research questions.

9. **Ethical considerations:**

   Discuss the importance of conducting research with integrity, ensuring informed consent and protecting confidentiality.

   Teach learners to handle data responsibly, ensuring its security and avoiding any potential misuse.

10. **Communication and presentation:**

    Help learners refine their communication skills to effectively convey their research questions and findings.

    Introduce appropriate formats for presenting research questions such as written reports, presentations or visual aids.

Learning Tasks

1. Imagine you are investigating the impact of technology on communication. What strategies would you employ to generate research questions that encompass various dimensions of this topic?
2. Consider a health-related problem like obesity. Develop a set of research questions that explore not only its causes and effects but also potential solutions. Explain the rationale behind each question.
3. Choose an environmental issue such as deforestation. How could you structure research questions that investigate the ecological, economic and social implications of this problem?
4. Select a historical event and create research questions that delve into its causes, consequences and lessons learned. How would your questions encourage a comprehensive understanding of the event?
5. Discuss a cultural phenomenon you find intriguing. Generate research questions that delve into both the origins and the contemporary influences of this phenomenon on society.

Pedagogical Exemplars

1. **Collaborative Learning:** Learners work in mixed ability and mixed gender groups on a given case study to document research questions for the given problem. Learners will make a presentation on their solution to the class.
2. **Problem-Based Learning:** Learners should work on a case study to develop a methodology for the research and make presentations to the whole class.
3. **Experiential Learning:** Invite researchers as guest speakers to present to learners their experiences on researching to solve societal problems.
4. **Enquiry-based Learning:** Give learners a topic of national interest to research and present their findings to the class.

Key Assessment

Level 1 Recall

1. List the various types of research you know about.
2. Identify key steps in conducting research.
3. What is meant by open-ended research?

Level 2 Skills and Conceptual Understanding

1. Identify the key characteristics of a well-formulated research question.
2. Differentiate between open-ended and closed-ended research questions.
3. Evaluate the relevance and feasibility of a given research question.

Level 3 Strategic reasoning:

Select a minimum of three (3) of the following questions:

1. Analyse a real-world issue that interests you. What criteria would you consider when formulating research questions that effectively address this problem's various aspects?
2. Given a societal challenge, how can you critically assess its underlying factors to generate research questions that capture the complexity of the issue?
3. Imagine you're tasked with designing a research project to investigate a local environmental problem. How would you go about identifying interconnected research questions that provide a comprehensive understanding of the issue's causes, impacts, and potential solutions?
4. Choose a historical event and explain how your process of brainstorming and refining research questions would differ if you were aiming to uncover different perspectives or hidden aspects of the event.
5. Consider a health-related concern in your community. How would you leverage prior research and expert opinions to formulate research questions that contribute to the existing knowledge while addressing current gaps?
6. Think about a technological advancement that has transformed communication. Develop a set of research questions that delve into both the positive and negative consequences of this advancement on society, culture and interpersonal relationships.
7. Select a global economic issue such as income inequality. How would you structure research questions that not only explore its immediate effects but also delve into the broader implications for various social and economic systems?
8. Investigate a controversial topic that has ethical implications. How could you design research questions that consider different ethical frameworks and cultural perspectives, fostering a comprehensive examination of the subject?
9. Reflect on a scientific discovery that revolutionised an industry. How might you formulate research questions that investigate both the scientific breakthrough itself and the subsequent practical applications and challenges?
10. Consider a work of literature or a piece of art that addresses a societal problem. Develop research questions that delve into the artist's intentions, the historical context, and how the work has influenced public discourse

Week 16

Learning Indicator: *Formulate research objectives for a given problem*.

Theme or Focal Area: Research Objectives

Before embarking on any research endeavour, it is crucial for learners to thoroughly understand the problem they are addressing. This involves analysing the problem's context, scope and underlying causes. Encourage learners to gather relevant information, conduct literature reviews and engage experts or stakeholders to gain a comprehensive understanding of the issue and thus be able to formulate research objectives.

1. **Research Gap Identification:**
   Research gaps refer to areas where the existing knowledge is insufficient or where further investigation is needed. Teach learners to identify these gaps through their literature review and analysis of existing studies. Understanding the research gaps is vital because it helps learners position their research in the broader context and demonstrate the significance of their work.

2. **Alignment with Problem Statement:**
   Learners should formulate research objectives that align with the problem statement they are trying to address. The objectives should be specific to the aspects of the problem they aim to investigate. Emphasise the importance of staying focused and not straying from the core problem.

3. **Specificity and Measurability:**
   Research objectives must be specific and measurable to guide the research process effectively. Help learners articulate their objectives clearly, avoiding vague language and ensuring that the outcomes can be measured or observed.

4. **SMART Objectives:**
   Introduce learners to the concept of SMART objectives which are Specific, Measurable, Achievable, Relevant and Time-bound. Guide them in formulating objectives that meet these criteria as it helps in creating realistic and manageable research plans.

5. **Multiple Objectives:**
   In some cases, addressing a complex problem may require multiple research objectives. Help learners prioritise and sequence these objectives to ensure coherence and a logical flow in their research. Each objective should complement the other and contribute to a comprehensive understanding of the issue.

6. **Exploratory and Confirmatory Objectives:**
   Different types of research objectives serve various purposes. Explain the concepts of exploratory and confirmatory objectives. Exploratory objectives are typically used when there is limited existing knowledge, while confirmatory objectives aim to validate or test specific hypotheses based on existing theories or findings.

7. **Feasibility and Resources:**
   While setting research objectives, learners should consider the feasibility of achieving them within the available resources and constraints. Encourage realistic planning and allocation of time, budget, data and other resources.

8. **Ethical Considerations:**

   Discuss the ethical considerations associated with research objectives. Learners should be mindful of obtaining informed consent from participants, ensuring confidentiality of data and following ethical guidelines in their research.

9. **Collaboration and Feedback:**

   Encourage learners to collaborate with peers, mentors or advisors and seek feedback on their research objectives. Engaging in discussions and receiving constructive criticism can help refine and improve the objectives.

10. **Communication and Presentation:**

    Effective communication is vital in research. Teach learners to present their research objectives clearly and concisely using appropriate formats, whether in written documents or oral presentations. Emphasise the importance of conveying their ideas to diverse audiences.

Learning Tasks

1. Analyse a real-world problem of your choice. How would you break down this problem into specific research objectives? Justify your choices.
2. Given a complex issue, explain how research objectives can help focus your study and guide your research process. Provide specific examples to illustrate your point.
3. Learners develop three (3) research objectives and ten (10) research questions and discuss how the two differ.
4. Learners evaluate a set of research objectives provided for a hypothetical study. Are they clear, specific, and achievable? If not, let learners revise them to improve their quality.

Pedagogical Exemplars

1. **Collaborative Learning:**

   Learners work in groups on a given case study to document research objectives for a given problem. Learners will make a presentation on the developed research objectives to the class.

   Guide learners working in groups to develop three (3) research objectives and ten (10) research questions on the topic "the effects of social media on teenagers' mental health".

2. **Problem-Based Learning:**

   Learners work on a case study to develop research objectives and make presentations to the whole class. Other groups critique and make suggestions. Encourage learners to tolerate the views of others.

   Give learners a sample research objective and have learners working in groups critique the given research objectives.

3. **Experiential Learning:** Invite researchers as guest speakers to present to learners their experiences in conducting research, and formulating research objectives to solve societal problems.
4. **Enquiry-based Learning:** Give learners a topic of national interest to research and present their research objectives to the class.

Key Assessment

Level 2 Skills and Conceptual Understanding

1. Give learners samples of research objectives and ask them to evaluate the appropriateness of the given objectives.
2. Ask learners to formulate research objectives for a problem identified in school.
3. Ask learners to state research objectives for improving the performance of a given product on the market.

Level 3 Strategic reasoning:

Consider selecting at least three (3) of the following questions.

1. Imagine you are tasked with investigating the impact of social media on teenagers' mental health. Develop two research objectives that clearly state what you intend to achieve in your study.
2. You are interested in exploring the factors influencing learners' academic performance in your school. Develop research objectives that specify how you would investigate the relationships between these factors and learners' grades.
3. A company wants to improve its employee satisfaction and retention rates. Formulate research objectives that outline the steps needed to identify key areas of dissatisfaction and propose strategies for improvement.
4. Your town has been experiencing frequent power outages. Create research objectives for a study that aims to determine the causes of these outages, assess their impact on residents and businesses and suggest potential solutions.
5. In the context of climate change, propose two research objectives that would guide a study on the effects of rising temperatures on a specific plant species and its surrounding ecosystem.
6. A medical clinic wants to enhance patient engagement and adherence to treatment plans. Develop research objectives that outline how you would investigate the factors influencing patient engagement and design effective interventions.
7. You're interested in exploring the relationship between screen time and sleep quality among adolescents. Formulate research objectives that would help you understand the potential link between these variables and how they might affect each other.
8. A non-profit organisation is concerned about the decrease in volunteer participation. Create research objectives to guide a study aimed at identifying the reasons behind this decline and proposing strategies to attract more volunteers.
9. A government agency aims to reduce traffic congestion in a major city. Develop research objectives that outline how you would study the underlying causes of the congestion and recommend feasible traffic management solutions.

Week 17

Learning Indicator: *Describe the fundamental principles behind 3D printing, casting, PCB production and laser cutters and the specific use cases and applications*

Theme or Focal Area: Manufacturing processes

Manufacturing processes are essential for transforming raw materials into finished products. They play a crucial role in creating a wide range of items that we use in our daily lives. These processes are the backbone of industries such as automotive, electronics, aerospace, healthcare, and consumer goods.

1. **3D Printing:** 3D printing, also known as additive manufacturing, is a process that builds objects layer - by -layer using digital design data. It offers unparalleled design freedom, enabling complex geometries that traditional manufacturing methods struggle to achieve. Different types of 3D printers exist including Fused Deposition Modelling (FDM), Stereo lithography (SLA) and Selective Laser Sintering (SLS). Various materials such as plastics, metals, ceramics and even food can be used in 3D printing. The process starts with creating a digital design file (CAD), which is then sliced into thin cross-sectional layers. The printer adds material layer – by-layer, creating a physical object.

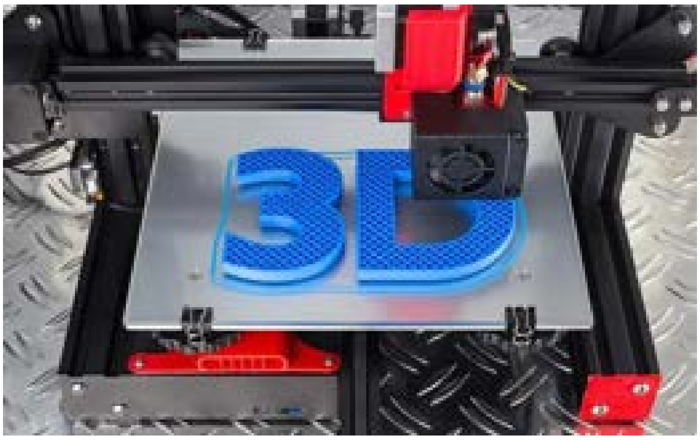

Figure 88: *A picture of 3D printing*

2. **Casting:** Casting involves pouring molten material into a mould and allowing it to solidify, creating a final product with the desired shape. Sand casting, investment casting and die casting are common casting processes. Sand casting is versatile and suitable for complex shapes, while investment casting is used for precision parts. Die casting is efficient for the mass production of metal components. Casting finds applications in creating intricate components like engine parts, jewellery and sculptures.

Figure 89: *A picture of Casting*

3. **PCB Production:** Printed Circuit Boards (PCBs) are crucial for electronic devices. PCB production starts with designing the circuit layout using specialised software. The design is then transferred onto the board through etching, which removes excess copper to create the circuit pattern. Drilling creates holes for component mounting, and soldering attaches components to the board. PCBs are used in a wide range of electronics, from simple toys to advanced medical devices.

Figure 90: *A picture of the production of Printed Circuit Boards*

4. **Laser Cutters:** Laser cutting employs a focused laser beam to cut or engrave materials with high precision. The laser's energy is absorbed by the material, causing it to vaporise or melt, resulting in clean cuts or etched patterns. Laser cutters are used in industries such as architecture, fashion, and manufacturing for creating prototypes, intricate designs and functional parts.

Figure 91: *A picture of Laser Cutter*

Safety and Best Practices: Safety is paramount in manufacturing processes. Adequate ventilation is crucial to dissipate fumes and prevent exposure to harmful chemicals. Proper Personal Protective Equipment (PPEs) such as gloves, eye protection and masks should be worn. Handling of equipment and materials should follow guidelines to prevent accidents and injuries.

Hands-on Projects and Demonstrations: Hands-on projects allow learners to experience these processes first-hand. They can design and print simple 3D objects, cast moulds using safe materials, create basic PCBs and work with laser cutters to fabricate intricate designs.

Environmental and Sustainable Considerations: Manufacturing processes can impact the environment through energy consumption and waste generation. Sustainable materials, recycling, and energy-efficient practices are being explored to reduce these impacts.

The specific use case applications

Showcase how these processes are used across industries. For instance, 3D printing is revolutionising prototyping and custom prosthetics. Casting is vital in the automotive and jewellery sectors. PCBs power everything from smartphones to medical equipment and laser cutters contribute to innovative architecture and fashion designs.

Future Trends and Emerging Technologies

Advancements in materials, automation and process integration are shaping the future of manufacturing. 3D printing is evolving towards larger scales and multi-material capabilities. Casting is adopting digital technologies for precise moulds. PCBs are becoming smaller and more intricate and laser cutting is benefiting from improved optics and control systems. Nanotechnology and biomanufacturing are emerging trends with promising impacts.

Learning Tasks

1. Describe the steps involved in the casting process. How does the choice of mould material impact the final product?
2. Discuss the significance of printed circuit boards (PCBs) in modern electronics. How do they facilitate the building of electronic devices?
3. Explain the importance of material selection in laser cutting. How does the interaction between the laser and the material influence the cutting process?
4. Analyse the potential applications of 3D printing in various industries such as aerospace, healthcare and automotive. How does the customisation aspect of 3D printing contribute to its versatility?
5. Evaluate the environmental impact of casting as a manufacturing method. Compare the sustainability of casting with alternative production techniques.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** The teacher initiates a discussion by introducing the concept of rapid prototyping, its role in product design, the various rapid prototyping (RP) technologies and their use cases. The objective is to ignite and sustain the interest of learners to participate in open discussion.
2. **Experiential learning:**

   Watch videos on 3D printing, casting, PCB production and laser cutting technology employed in RP. The videos will indicate the operating principles, use cases and strengths and weaknesses of the respective RPs.

   Guide learners to design and produce simple 3-D objects in an RP workshops to have firsthand experience of 3D printing machines producing models as an example of an RP technology.

   Using the Proteus Software, guide learners to design their own PCB for the simple circuits they covered in Section 4.
3. **Collaborative Learning:** Have learners work in groups and discuss learner observations on the RP technologies. Groups should make presentations on their observations, critique and add to others' presentations.

Key Assessment

Level 1 Recall

1. Explain in simple terms what 3D printing is and how it works.
2. Describe the basic process involved in creating a 3D-printed object.
3. What is casting?
4. Describe the key steps involved in the casting process.
5. What does PCB stand for and what is its main purpose?
6. What is a laser cutter and what types of materials can it cut?
7. Outline three specific industries where laser cutters are extensively used.

Level 2 Skills of conceptual understanding

1. How does casting differ from other manufacturing methods?
2. Describe the basic steps involved in producing a printed circuit board (PCB) for electronic devices.
3. Explain how a laser cutter works to create precise shapes and designs.
4. Discuss how the precision and speed of laser cutters contribute to efficient production processes and the creation of intricate designs.
5. Explain the importance of material selection in 3D printing.
6. Detail the quality control measures required in casting processes.

Level 3 Strategic reasoning:

1. 3D Printing Applications: Provide examples of real-world applications where 3D printing is used. Explain how 3D printing benefits these applications in terms of customisation, rapid prototyping, or cost-effectiveness.
2. Casting Variations: Compare and contrast sand casting and investment casting as two common casting techniques. Highlight their specific advantages and limitations in different manufacturing scenarios.
3. PCB Production Advancements: Describe how advancements in technology have influenced the production of PCBs over time. Discuss how smaller components and increased functionality have driven changes in PCB design and manufacturing.

Level 4 Extended critical thinking and reasoning:

1. Discuss the properties of different types of 3D printing materials and how these properties impact the final printed object's performance.
2. Discuss how defects can occur during casting and the methods used to identify and rectify such issues.
3. PCB Design Considerations: When designing a PCB for a complex electronic device, what factors should be considered? Discuss the balance between component placement, signal integrity, and thermal considerations.
4. Laser Cutters and Design Iteration: How do laser cutters facilitate the rapid prototyping process? Explain how designers can use laser cutters to quickly iterate through design variations and refine their ideas before final production.

Section 7 Review

1. Would learners be able to state the various elements within the engineering design process?
2. Can learners list and document solution requirements for a given problem?
3. Can learners outline relevant research questions for a given problem?
4. Can learners formulate research objectives for a given problem?
5. Can learners conduct simple research using a research questionnaire?
6. Can learners design and fabricate simple 3-D objects?
7. Can learners design simple circuits and assemble the components on a PCB?

Further Reading

1. CETE: Report Incorporating Engineering Design Challenges into STEM Courses, National Center for Engineering and Technology Education (2012)
2. Wesley L. Stone and Hugh Jack, "Project-Based Learning: Integrating Engineering Technology and Engineering," in American Society of Engineering Education Annual Conference, Columbus, Ohio, 2017.
3. *Engineering Design and Manufacturing Education through Research Experience for High School Teachers*. Available from: https://www.researchgate.net/publication/326822347_Engineering_Design_and_Manufacturing_Education_through_Research_Experience_for_High_School_Teachers [accessed Apr 16, 2024].

Teaching/Learning Resources

1. Video documentaries
2. Audio-visual equipment
3. Laptops with MS Office installed
4. Workshops and manufacturing facilities.

References

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3. Buchanan, R. (2019). Systems thinking and design thinking: The search for principles in the world we are making. *She Ji: The Journal of Design, Economics, and Innovation*, *5*(2), 85-104.

SECTION 8: AUTOMATION AND CONTROL ENGINEERING

Strand: **Automation and Embedded Systems**

Sub-strand: Automation Technologies

Learning Outcome: *Examine Fundamental Automation Components and Systems*

Content Standard: Demonstrate familiarity with general concepts, components and systems in the Automation Industry

INTRODUCTION AND SECTION SUMMARY

In this section, learners will be introduced to the use of technology to perform tasks with minimal human intervention, also known as automation. They will understand and appreciate that many industries, including manufacturing, healthcare, agriculture, transportation, energy and more rely heavily on automation. Learners will be able to describe the role of automation in increasing overall production, decreasing human error, boosting efficiency and streamlining procedures. Additionally, learners will be introduced to interpreting technical drawings and connecting system components accordingly, a fundamental skill in various technical fields such as engineering, manufacturing, construction and electronics. The ability to interpret drawings accurately is crucial for successful implementation of projects in fields such as engineering, construction, manufacturing and electronics. Learners will be encouraged to explore the potential integration of artificial intelligence and machine learning into automation systems, discussing the benefits and challenges associated with this advanced level of automation.

The weeks covered by the section are:

Week 18. Automation and Control

Week 19. Schematic Interpretation and Component Integration

SUMMARY OF PEDAGOGICAL EXEMPLARS

In this section, consider using initiating talk-for-learning, experiential learning, collaborative learning and self-directed learning. Self-directed learning will allow learners to explore available online resources that can help them learn more about automation systems. Allow learners to watch videos on different kinds of automated systems with a focus on the role of automation in industrialisation and the roles of system components or subsystems in realising the specific automation goal. Teachers can initiate a discussion by introducing the history of automation, its role in industrialisation, common components such as relays, motors, switches, sensors, PLCs and how they have been used in common automation systems around learners' community such as automated irrigation systems, automated streetlights, water level controllers, automated doors and gates at public places. Learners can be put into groups to discuss observations on the role of automation in industrialisation as well as system component functions.

ASSESSMENT SUMMARY

Written or power point presentations can be used to elicit learners' observations on the role of automation in industrialization, as well as system component functions. Let learners study a technical drawing of an automatic water level controller or automated irrigation system and then attempt the process of integrating individual components like Integrated Circuits (ICs), relays, sensors and motors into a functional system. Oral presentation is encouraged for this exercise. Let learners predict potential challenges that might arise if automation components are not properly utilised in an industrial setting. These should contribute to learners' formative assessment.

Week 18

Learning Indicator: *Learners should be able to identify basic automation components and materials and their respective functions or roles in the automation industry*

Theme or Focal Area: Basic Automation Components

Automation refers to the use of technology to perform tasks with minimal human intervention. It involves the design, development and implementation of systems that can operate autonomously, following predefined instructions and rules. Automation plays a crucial role in various industries, including manufacturing, healthcare, agriculture, transportation, energy and more. It aims to streamline processes, increase efficiency, reduce human error and improve overall productivity.

Basic Automation Components:

1. **Sensors:** Sensors are devices that detect changes in the environment or the state of a system. They convert physical parameters (such as temperature, pressure, light, motion etc.) into electrical signals that can be processed by the automation system.

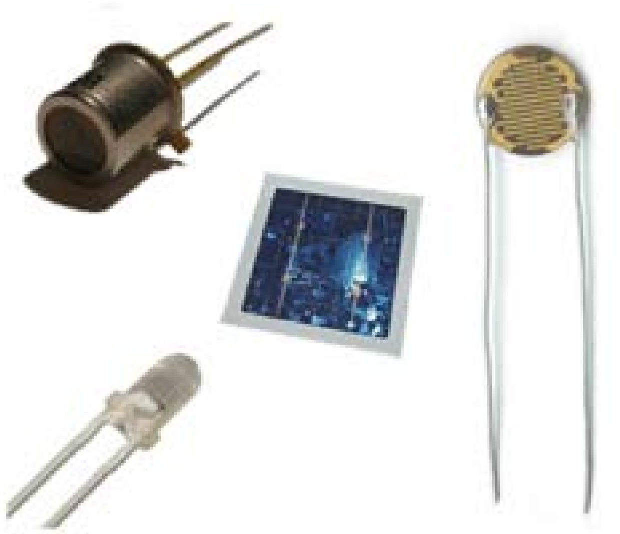

Figure 92: *A picture of Sensors*

2. **Actuators:** Actuators are devices responsible for carrying out actions based on the signals received from sensors or the control system. They can perform tasks like moving, positioning, opening/closing valves and more. Examples include motors, solenoids, hydraulic cylinders and pneumatic actuators.

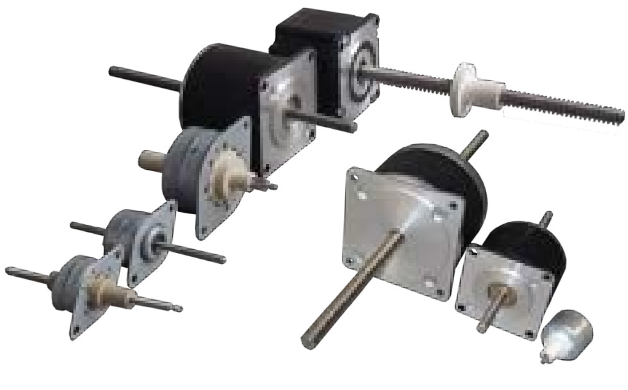

Figure 93: *A picture of an electric actuator*

3. **Controller:** The controller is the brain of the automation system. It receives input signals from sensors, processes the data and generates control signals for the actuators. Controllers can range from simple programmable logic controllers (PLCs), embedded systems to more complex programmable automation controllers (PACs) or computer-based control systems

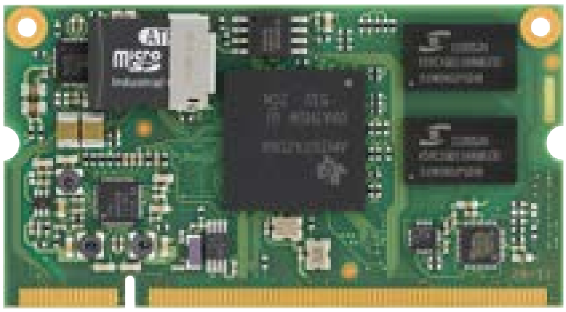

Figure 94: *A picture of a controller*

4. **Programmable Logic Controller (PLC):** A PLC is a specialised digital computer designed for industrial automation. It is programmed to perform control functions based on input from sensors and other devices. PLCs are commonly used in manufacturing and industrial processes.

Figure 95: *A picture of a PLC*

5. **Human-Machine Interface (HMI):** The HMI is the interface through which humans interact with the automation system. It typically includes displays, touchscreens and input devices like buttons and switches. HMIs allow operators to monitor the system's status, input commands and adjust.

Figure 96: *A picture of HMI*

6. **Control Software:** Control software, including SCADA (Supervisory Control and Data Acquisition) systems, PLC programming and industrial automation software is used to create the logic that governs automation processes and to communicate with hardware components.

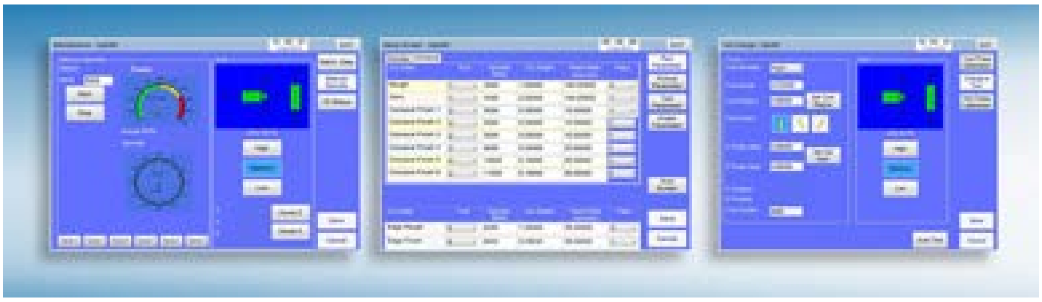

Figure 97: *A picture of Control Software*

7. **Conveyors and Transport Systems:** These are used to move materials or products from one location to another within a facility. They are common in manufacturing and logistics automation.

Figure 98: *A picture of Conveyor and Transport System*

8. **Robots and Manipulators:** Robots and manipulators are used for tasks such as pick-and-place, welding, painting and assembly. They provide precision and repeatability in manufacturing processes.

Figure 99: *A picture of an agricultural robot*

9. **Power Supply:** Automation systems require a stable and reliable power supply to operate. Power supplies provide the necessary electrical energy to power sensors, actuators, controllers and other components.

Figure 100: *A picture of Power Supply pack*

10. **Relays:** Relays are electromechanical devices that act as remote-controlled switches. They allow a low-power circuit (such as a control signal from a PLC) to control a high-power circuit (such as a motor or a large lamp) without direct electrical connection.

Figure 101: *A picture of Relays*

Relays are often used to control motors, lights, heaters and other high-power devices in industrial applications.

11. **Motors:** Motors are devices that convert electrical energy into mechanical motion. They are a key component in many automated systems, performing tasks such as moving conveyor belts, robotic arms and pumps.

Different types of motors are used depending on the application. Common types include DC motors, AC motors (such as induction motors and synchronous motors) and stepper motors.

Motors are controlled using signals from controllers, often through relays or motor drivers which adjust the power supplied to the motor to achieve the desired speed and direction.

Figure 102: *A Picture of Motors*

12. **Switches**: Switches are simple devices that open or close an electrical circuit to control the flow of current. They are used to manually or automatically control the operation of machines, devices or systems.

Figure 103: *A picture of Switches*

Learning Tasks

1. Compare and contrast the functions of motors and actuators in automation.
2. How do automation systems contribute to improving efficiency in manufacturing?
3. Design a simple automated process of turning on/off a switch to control water pumps, water levels etc.
4. Discuss potential challenges that might arise if automation components are not properly utilised in an industrial setting.
5. Investigate how advancements in automation components and systems have transformed a specific industry over the past decade

Pedagogical Exemplars

1. **Initiating talk-for-learning:** Teacher initiates a discussion by introducing the history of automation, its role in industrialisation, common components such as relays, motors, switches, sensors, PLCs and how they have been used in common automation systems around learners' community such as washing machine, automated irrigation systems, automated street lights, water level controllers, automated doors and gates at public places. Learners discuss the specific roles components or subsystems play in each of the cited automated systems.
2. **Experiential learning:** Watch videos on different kinds of automated systems with a focus on the role of automation in industrialisation and the roles of system components or subsystems in realising the specific automation systems. Learners should be given an experience of assembling a simple automated system such as a water level controller, automated irrigation system etc. They should also visit any local innovation hub or factory which builds or has automated system(s) installed to observe how the various components work together to achieve the design objective.
3. **Collaborative Learning:** Let Learners work in mixed-ability and mixed-gender groups to discuss learner observations on the role of automation in industrialisation as well as system component functions. Learners should be given a task to propose how some of the components could be put together to automate some activities within their communities. Groups should make presentations on their observations

4. **Self-Directed Learning:** Explore online resources: There are many online resources available that can help Learners learn more automation systems. Examples include *Make Academy, MOOC, Coursera,* etc.

Key Assessment

Level 1 Recall:

1. What is automation?
2. Name one basic component commonly used in automation.
3. What are the roles of sensors in the automation industry?
4. Define the term "actuator" in the context of automation.
5. List three examples of components used in building automation systems.

Level 2 Skills of conceptual understanding:

1. How does automation improve efficiency in industries?
2. Explain the function of a programmable logic controller (PLC) in an automated system.
3. Describe how a conveyor belt can be considered an essential automation component.
4. Discuss the role of feedback devices in maintaining precision within an automated process.
5. Describe the functions of sensors and actuators in an automation setup.

Level 3 Strategic reasoning:

1. Analyse the impact of automation on the job market, considering both positive and negative aspects.
2. Design a simple automated system for sorting objects using sensors and actuators and explain how each component contributes to the process.
3. Evaluate the importance of redundancy and fail-safe mechanisms in critical automated processes.
4. Predict the potential challenges that might arise from integrating different automation components from various manufacturers into a single system.
5. Formulate a step-by-step troubleshooting guide for identifying and rectifying common issues in an automated manufacturing line.

Level 4 Extended critical thinking and reasoning:

1. Investigate the ethical implications of widespread automation, considering societal factors such as job displacement, privacy concerns, and economic inequality.
2. Research and propose innovative materials that could revolutionise the automation industry in terms of efficiency, durability and sustainability.
3. Construct a detailed comparative analysis between traditional industrial processes and fully automated systems, highlighting factors like cost-effectiveness, environmental impact and product quality.
4. Explore the potential integration of artificial intelligence and machine learning into automation systems, discussing the benefits and challenges associated with this advanced level of automation.

Week 19

Learning Indicator: *Learners should be able to interpret and connect system components according to technical drawings and vice versa*

Theme or Focal Area: Interpreting and connecting system components

Interpreting and connecting system components according to technical drawings is a fundamental skill in various technical fields such as engineering, manufacturing, construction and electronics.

1. **Understand the Technical Drawing:** Start by thoroughly examining the technical drawing, which could be in the form of schematics, blueprints or circuit diagrams.

   Identify and familiarise yourself with symbols, labels, dimensions, and other notations used in the drawing.

2. **Identify Components and Features:** Identify the various components, parts or elements depicted in the drawing. This may include physical components (e.g., gears, ICs, switches, sensors) or connections (e.g., electrical connections, flow paths).

   Pay attention to key features such as sizes, shapes and any special characteristics.

3. **Read the Specifications:** Refer to any accompanying documentation or specifications that provide additional details about the components, materials, tolerances and other relevant information.
4. Establish Connections: Determine how the components are supposed to be connected or assembled based on the drawing. This might involve understanding how parts fit together, where fasteners should be used or how wires should be routed.
5. **Consider Tolerances and Clearances:** Be aware of any specified tolerances, clearances, or safety considerations mentioned in the drawing. These are critical for ensuring that components fit together correctly and function as intended.
6. **Material Selection***:* If the drawing doesn't specify materials, you may need to choose appropriate materials based on the application and any relevant standards.
7. **Verify Compatibility:** Check that the components you plan to use are compatible with each other. Ensure that the connections such as connectors or interfaces, match up correctly.
8. **Follow Industry Standards and Codes:** Comply with any industry-specific standards, codes or regulations that apply to your project.
9. **Use Tools and Equipment:** Depending on the nature of the system, you might need specific tools and equipment for assembly. Ensure you have the right tools for the job.
10. **Quality Control and Inspection:** As you assemble or connect components, periodically inspect your work to ensure accuracy and quality. Use measuring instruments, if necessary.
11. **Test and Troubleshoot:** After the components are connected, test the system to verify that it operates as intended. Be prepared to troubleshoot and correct any issues that arise.
12. **Documentation:** Maintain detailed records of your work, including any modifications or deviations from the original drawing. This documentation is valuable for future reference and quality assurance.
13. **Safety Precautions:** Always follow safety protocols to protect yourself and others while working with system components.

    Connecting system components based on technical drawings requires a combination of technical knowledge, attention to detail and practical skills. The ability to interpret drawings accurately is crucial for successful implementation in fields such as engineering, construction, manufacturing, and electronics.

Learning Tasks

1. Using a provided technical drawing, identify the key components of a complex system and explain how they work together to achieve a particular outcome.
2. Given a technical drawing with missing or incorrect connections between components, propose the necessary modifications to ensure the system functions as intended.
3. Based on a technical drawing of an electrical circuit, predict the potential consequences if a connection between two components were to be altered or removed.
4. Create a technical drawing of a mechanical system that achieves a unique function, incorporating various components and clearly illustrating their connections and interactions.
5. Design an architectural layout for a building's electrical system, justifying the placement and connections of key components based on safety, efficiency and functionality.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** Teacher initiates a discussion by introducing learners to the role of technical drawings in professional practice in general and automation in particular.
2. **Experiential Learning:** Introduce learners to Electrical, pneumatic, hydraulic, and piping schematics using samples for them to identify distinguishing features and characteristics. Learners are also guided through hands-on experience and how to identify signal flows in given schematics. Learners are also exposed to the creation and interpretation of functional block diagrams for automation systems.
3. **Project-based learning:** Learners to work on a project that involves interpreting and assembling components from a given electrical single line wiring diagram.
4. **Self-Directed Learning:** Explore online resources: There are many online resources available that can help learners learn more interpretation of Engineering Schematic and Technical Drawings. Learners should be tasked to look for more schematics and technical drawings from these sources, implement and report on outcomes
5. **Collaborative Learning:** Work in groups on a mini project which involves interpreting and assembling system components from a given schematic. Display project for the whole class to observe and comment on. Encourage learners to comment respectfully and tolerate others' views.

Key Assessment

Level 2 Skills and conceptual understanding

1. List and explain the functions of the components in a household electrical wiring.
2. Discuss the factors to consider when producing the schematics of an electrical system for example.

Level 3 Strategic reasoning:

1. Examine the technical drawing of a simple mechanical system. Identify and explain the purpose of each component shown in the drawing. How do these components work together to achieve a specific function?

2. Given a technical drawing of an electrical circuit, such as an arduino microcontroller, raspberry pi, describe the relationships between various components such as resistors, capacitors and switches. How does altering one component affect the behaviour of the entire circuit?
3. Analyse a technical drawing of a computer motherboard. Highlight the connections between different parts, including the processor, memory modules and various ports. Explain how these connections enable data transfer and communication within the system.
4. Compare and contrast two different technical drawings of similar systems, highlighting the variations in component connections and explaining the potential impact on system performance.

Level 4 Extended critical thinking and reasoning:

1. Examine a technical drawing of a modern smartphone. Explore the integration of components from diverse fields such as electronics, software and materials science. How do these components collectively enable features like touchscreens, wireless communication, and app functionality?
2. Choose a technical drawing of an intricate mechanical assembly. Discuss the challenges and steps involved in reverse engineering the system back into individual components. How might this understanding be applied to improve design or troubleshoot issues?
3. Given a technical drawing and a set of real-world constraints (e.g., limited space, specific materials), redesign the system's component connections to enhance performance while adhering to the constraints.
4. Research emerging technologies related to a specific system (e.g., renewable energy systems) and develop a technical drawing that integrates these advanced components, explaining how they push the boundaries of current capabilities.

Section 8 Review

1. Would learners be able to identify the basic automation components and their respective functions in the automation industry?
2. Would learners be able to interpret and connect system components according to technical drawings?

Further Reading

1. Yip, H. M., Liu, M. C., 2014, Developing Students' Ability to Interpret Engineering Drawings, International Journal of Engineering Education, IOP Conference Series Materials Science and Engineering, DOI: 10.1088/1757-899X/242/1/012070

Teaching/Learning Resources

1. Automation workshop
2. Video documentaries, audio-visual equipment, and laptops with MS Office installed
3. Audio-visual equipment, and laptops with MS Office installed

References

1. Gibson, I., Rosen, D. W., Stucker, B., 2014, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Springer, New York
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SECTION 9: EMBEDDED SYSTEM AND PROBLEM SOLVING

Strand: **Automation and Embedded Systems**

Sub-strand: Embedded Systems

Learning Outcome: *Appreciate the advantages and applications of embedded systems*

Content Standard: Demonstrate knowledge and understanding of features and application areas of embedded systems

INTRODUCTION AND SECTION SUMMARY

In this section, learners will be introduced to the use of specialised systems combining computer hardware and software to perform specific functions that enhance the lives of humans. These are called Embedded systems, and they work either as a standalone or as part of a larger system to perform dedicated functions or tasks. Learners will be able to identify some embedded systems in appliances found in their schools and communities. Learners will appreciate the deployment of embedded systems to improve efficiency, safety and convenience. This section explores embedded systems and fixed electronic circuits that serve different purposes. Learners will examine the advantages and limitations of some embedded systems.

The weeks covered by the section are:

Week 20. Embedded Systems I

Week 21. Embedded Systems II

SUMMARY OF PEDAGOGICAL EXEMPLARS

In this section, consider initiating talk-for-learning, case study, project-based learning, experiential learning, classroom discussions and debates as well as invited (guest) speakers. Initiate a discussion using questions and answers to introduce embedded systems, their evolution over time, features, application areas and some limitations. Guide Learners to study and examine real-world examples of computer systems that use Complex Instruction Set Computer (CISC) and Reduced Instruction Set Computer (RISC), Advanced Reduced Instruction Set Computer (ARISC) and learn about the trade-offs between performance, power consumption and cost. For example, they can compare how a modern smartphone using ARM RISC architecture uses less power than traditional x86 CISC-based laptops. Learners can be given a project on some embedded system to compare different architectures and memory types in terms of their features, advantages and disadvantages. Learners can engage in class discussions and debates about the pros and cons of each computer architecture and memory type. Inviting a local IT professional or engineer to come and speak to the class about their experiences working with CISC, RISC, ARISC and different types of memory can be a great way to make the material more relatable and engaging for learners.

ASSESSMENT SUMMARY

Assess learners based on their understanding of key concepts, participation in hands-on activities, and successful completion of project tasks. Written and Oral responses can be elicited in class discussions following a talk from a guest speaker. Learners can be encouraged to describe the embedded systems used in household appliances such as washing machines, blenders, microwave ovens etc. Allow learners to provide reasons why it is important to understand the role of embedded systems in appliances used within a learners' environment. Learners can give oral presentations which can be used for their formative assessment. Allow learners to explore the ethical implications of embedded systems that collect the personal data of users and discuss the potential benefits and risks.

Week 20

Learning Indicator: *Learners should list examples of embedded systems in their community*

Theme or Focal Area: Embedded systems

Embedded systems are specialised computer systems designed to perform dedicated functions or tasks. Embedded systems are used in a variety of applications to improve efficiency, safety and convenience. Here are some examples of embedded systems that you might find in a typical Ghanaian community:

1. **Traffic Lights Control Systems:** Traffic lights at intersections and pedestrian crossings often use embedded systems to manage traffic flow, improve road safety, and reduce congestion.

Figure 104: *A picture of a Traffic light*

2. **Automated Teller Machines (ATMs):** ATMs are embedded systems that allow people to withdraw money, check balances, and perform banking transactions.

Figure 105: *A picture of an ATM machine*

3. **Water Pump Control Systems:** Embedded systems are used to control the operation of water pumps, ensuring the efficient distribution of clean water to the community.

Figure 106: *A picture of a Water pump control system*

4. **Solar Power Inverters:** In areas with unreliable or no access to the electrical grid, embedded systems control solar power inverters, enabling the use of solar energy for electricity generation.

Figure 107: *A picture of a solar power inverter*

5. **Home Security Systems:**
   Many homes in Ghana use embedded systems for security, including burglar alarms, CCTV cameras, and access control systems.

Figure 108: *A picture of a Closed-Circuit Television (CCTV) camera*

6. **Electricity Metering Systems:** Embedded systems in smart meters are used to monitor and manage electricity consumption in households and businesses.

Figure 109: *A picture of an electricity meter*

7. **Telecommunication Infrastructure:** Cell towers and base stations rely on embedded systems to provide mobile phone and internet connectivity.

Figure 110: A picture of Telecommunication system

8. **Agricultural Equipment:** Embedded systems are used in agricultural machinery like tractors and irrigation systems to enhance farming practices.

Figure 111: *A picture of a Tractor*

9. **Healthcare Monitoring Devices:** In healthcare facilities and homes, you can find embedded systems in devices like blood pressure monitors, glucose meters and pulse oximeters.

Figure 112: *A picture of a blood pressure monitor*

10. **E-payment and Mobile Money Systems:** Ghana has a growing mobile money and electronic payment industry, with embedded systems facilitating transactions through mobile devices.

Figure 113: *A picture of an E-payment systems*

11. **Television Set-Top Boxes:** Embedded systems are found in digital television set-top boxes to decode and display television signals.

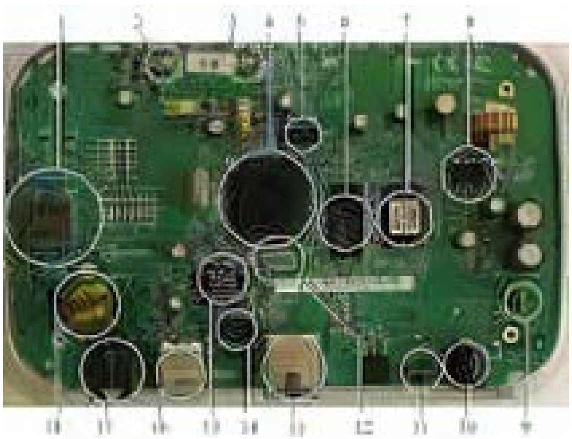

Figure 114: *A picture of an Embedded system*

12. **Traffic Surveillance Cameras:**
    Embedded systems are used in surveillance cameras to monitor and enforce traffic regulations.

Figure 115: *A picture of Traffic Surveillance cameras*

13. **Home Appliances:** Many household appliances such as refrigerators, washing machines and microwave ovens contain embedded systems to improve functionality and energy efficiency.

Figure 116: *Picture of Home Appliances with an embedded system*

14. **Biometric Access Control Systems:** These systems use embedded technology to manage access to secure facilities or offices.

Figure 117: *A picture of a Biometric control system*

13. **GPS Navigation Systems:** Embedded GPS systems are found in vehicles and smartphones to provide navigation and location services.

Figure 118: *A picture of GPS Navigation*

14. **Automatic Irrigation Systems:** In agriculture, automated irrigation systems use embedded systems to control water distribution to crops.

Figure 119: *A picture of an automated irrigation*

Learning Tasks

1. Discuss the basics of embedded systems, their components and their applications.
2. Reflect on the importance of embedded systems in modern technology and their impact on our daily lives.
3. Assist learners in block-diagram real-world embedded systems. Focus on consumer electronics products that learners encounter in their daily lives (e.g., smartphones, smartwatches, digital cameras etc.).
4. Discuss the components of these systems, including microcontrollers, integrated circuits (ICs), circuit boards and basic peripherals to the microcontroller.
5. Provide learners with a simple microcontroller board (e.g., Arduino) and basic components (LEDs, sensors, buttons) and help them identify the components and state their respective functions.
6. Guide Learners to discuss the design requirement for a new embedded system that could provide a simple functionality such as blinking an LED or reading sensor data.
7. Reflect on the advancements in embedded systems technology over the past decade. How have these advancements influenced various sectors?
8. Debate the ethical considerations surrounding the use of embedded systems in critical infrastructure, such as healthcare or transportation.

Pedagogical Exemplars

1. **Initiating talk-for-learning:**

   Initiates a discussion using question and answers to introduce embedded systems, their definition, components, their evolution over time, features, application areas and some limitations.

   Learners cite some electronic products within their environment and discuss the role of embedded systems within them and also propose how some existing products could be improved by embedded systems.

2. **Case studies:** learners can study real-world examples of computer systems that use CISC, RISC, ARISC and learn about the trade-offs between performance, power consumption and cost. For example, they can compare how a modern smartphone using ARM RISC architecture uses less power than traditional x86 CISC-based laptops.
3. **Enquiry-based learning**: learners research a specific computer architecture or type of memory and present their findings to the class. They can also compare and contrast different architectures and memory types in terms of their features, advantages and disadvantages.
4. **Classroom discussions and debates:** As learners learn about different computer architectures and memory types, they can engage in class discussions and debates about the pros and cons of each.
5. **Guest speakers:** Inviting a local IT professional or engineer to come and speak to the class about their experiences working with CISC, RISC, ARISC and different types of memory can be a great way to make the material more relatable and engaging for learners.
6. **Experiential Learning:** Provide learners with a simple microcontroller board (e.g., Arduino) and basic components (LEDs, sensors, buttons) and help them identify the components and state their respective functions.

Key Assessment

Level 1 Recall:

1. What is an embedded system?
2. List three examples of embedded systems.
3. Name five (5) household appliances using embedded systems.
4. What are some everyday devices that you interact with that might contain embedded systems?
5. List five (5) components of an embedded system.

Level 2 Skills of conceptual understanding:

1. Discuss the five main characteristics of embedded systems and explain the significance of these characteristics.
2. How do embedded systems differ from regular computers in terms of their functions and applications?
3. How do embedded systems make our lives easier? Provide specific instances from your immediate environment.
4. Compare embedded systems with general-purpose computers. Give examples to support your comparison.

Level 3 Strategic reasoning:

1. Compare and contrast two different embedded systems in terms of their complexity, resource requirement, power consumption and efficiency.
2. How would life suddenly change if all embedded systems suddenly stop working?
3. Imagine designing an embedded system for a given function. What factors would be considered in its development?

Level 4 Extended critical thinking and reasoning

1. Analyse the role of embedded systems in advancing technological progress in the world. Provide real-life examples.
2. Explore the ethical implications of embedded systems that collect personal data in your community. Discuss the potential benefits and risks.
3. Propose a futuristic embedded system concept that could revolutionise a specific aspect of your community. Justify its potential impact and challenges.

Week 21

Learning Indicator: *Discuss the advantages of embedded systems over fixed electronic circuits for solving similar problems and their limitations for specific scenarios.*

Theme or Focal Area: Advantages of embedded systems

Embedded systems and fixed electronic circuits serve different purposes and have their advantages and limitations. Let's discuss the advantages of embedded systems over fixed electronic circuits and the situations where embedded systems might have limitations:

Advantages of Embedded Systems

1. **Flexibility and Programmability:** Embedded systems are programmable, which means they can adapt to different tasks and functionalities without the need for physical circuit changes. This flexibility is valuable for applications that require updates, changes, or customisation.
2. **Reduced Component Count:** Embedded systems often require fewer components compared with fixed electronic circuits, which can lead to cost savings and a smaller physical footprint. They integrate various functions onto a single chip or board.
3. **Improved Cost Efficiency:** Mass production of embedded systems can result in cost savings, making them more economical for high-volume production compared with fixed electronic circuits, which may require custom manufacturing.
4. **Energy Efficiency:** Embedded systems can be optimised for low power consumption, making them suitable for battery-operated and energy-efficient applications such as IoT devices and mobile gadgets.
5. **Rapid Prototyping and Development:** Designing and developing embedded systems is typically faster and more iterative than creating fixed electronic circuits. This is advantageous for reducing time-to-market for new products.
6. **Integration with External Systems:** Embedded systems can easily interface with other systems, sensors, and communication protocols. This makes them ideal for applications that require data processing and communication with external devices or networks.
7. **Software Debugging and Updates:** Embedded systems can be debugged and updated through software, which simplifies maintenance and troubleshooting, and enables remote updates and improvements.

Limitations of Embedded Systems

1. **Complexity:** Embedded systems often involve software development in addition to hardware design, which can be complex and time-consuming. Managing software and hardware interactions can be challenging.
2. **Limited Analog Functionality:** While embedded systems excel at digital processing tasks, they may be less suitable for applications that require extensive analog signal processing or high-speed analog-to-digital conversions.
3. **Less Specialisation:** Fixed electronic circuits can be highly specialised and optimised for a single task, whereas embedded systems are more general-purpose and may not achieve the same level of efficiency for certain applications.
4. **Reliance on Power and Software:** Embedded systems are dependent on power sources and software. Power outages or software failures can render them inoperable, which is not always the case with passive fixed electronic circuits.

5. **Hardware Constraints:** Embedded systems are limited by the hardware they are built on. Upgrading hardware can be more challenging than modifying a fixed electronic circuit when performance improvements are needed.
6. **Licensing and Intellectual Property:** Embedded systems often rely on proprietary components or software, which can introduce licensing and intellectual property issues, potentially limiting customisation.

Learning Tasks

1. Guide Learners to make a list of embedded systems and fixed electronic circuits according to their functionality.
2. Support Learners to compare the features of embedded systems and fixed electronic circuits having similar functionality.
3. Guide learners to discuss the functionality and features of a smartphone and discuss the role of embedded systems in achieving such a level of functionality.
4. Have learners debate the topic of SmartPhones versus Feature Phones, which is better for our youth?
5. Have learners research and present papers on the evolution of mobile phones and draw lessons on the role of embedded systems in making mobile phones smarter and smarter.
6. Discuss the different characteristics of CISC, RISC and ARISC and demonstrate how these characteristics result in their functionality.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** Initiates a discussion using questions and answers to introduce embedded systems, their evolution over time, features, application areas and some limitations. Learners cite some electronic products within their environment and discuss the role of embedded systems within them and propose how some existing products could be improved by embedded systems.
2. **Case studies:** learners can study real-world examples of computer systems that use CISC, RISC, ARISC and learn about the trade-offs between performance, power consumption and cost. For example, they can compare how a modern smartphone using ARM RISC architecture uses less power than traditional x86 CISC-based laptops.
3. **Enquiry-based learning**: learners research a specific computer architecture or type of memory and present their findings to the class. They can also compare different architectures and memory types in terms of their features, advantages and disadvantages.
4. **Classroom discussions and debates:** Ask learners to debate to topic of Smart Phones vs. Feature Phones, which is better for our youth?
5. **Experiential Learning:** Learners can watch video documentaries on the development of key electronic circuits and embedded systems to appreciate the consideration involved in designing these circuits and systems.

Key Assessment

Level 2 Skills of conceptual understanding:

1. Compare the functionality of embedded systems and those of fixed electronic circuits. What are the key differences between the two in terms of their design and application?
2. List three advantages of using embedded systems over fixed electronic circuits. Explain why each advantage is significant in modern technology.
3. How do embedded systems contribute to increased efficiency in solving complex problems compared with fixed electronic circuits? Provide examples to support your explanation.
4. Describe two advantages of embedded systems over fixed electronic circuits for solving similar problems.

Level 3 Strategic reasoning:

Select at least three (3) of the following questions:

1. Identify a scenario where an embedded system would be more suitable than a fixed electronic circuit and explain why.
2. Consider a real-life scenario where an embedded system is used to control a home automation system and contrast it with a fixed electronic circuit approach. What benefits does the embedded system offer in this context?
3. Consider a hypothetical situation where both an embedded system and a fixed electronic circuit can be used to address a specific problem. Justify your choice and explain the limitations of each approach in that scenario.
4. Contrast the limitations of embedded systems and fixed electronic circuits in terms of scalability and complexity for solving specific problems.
5. Investigate a real-world scenario where an embedded system's flexibility provides a significant advantage over a fixed electronic circuit solution. Provide detailed reasoning and potential outcomes.

Level 4 Extended critical thinking and reasoning:

Select at least three (3) of the following questions:

1. Evaluate the impact of embedded systems on the evolution of consumer electronics. How have embedded systems revolutionised products like smartphones, washing machines or smart TVs? Discuss both positive changes and potential drawbacks.
2. Critically assess the sustainability aspect of embedded systems versus fixed electronic circuits. How do these technologies contribute to electronic waste and what strategies could be employed to mitigate their environmental impact?
3. Predict the future trends in the utilisation of embedded systems and fixed electronic circuits. Considering advancements in technology and emerging needs, speculate on potential changes in their advantages and limitations over the next decade.
4. Evaluate the ethical implications of choosing embedded systems over fixed electronic circuits, considering factors such as e-waste, resource consumption and societal impacts.
5. Design a case study that highlights a complex problem requiring an embedded system solution. Discuss the technical challenges, benefits, and trade-offs involved in implementing such a system and propose potential future enhancements.

Section 9 Review

1. Would learners be able to list examples of embedded systems and fixed electronic circuits found in their community?
2. Can learners explain the advantages of embedded systems over fixed electronic circuits for solving similar problems and their limitations?
3. Can learners compare embedded systems over fixed electronic circuits?
4. Can learners consider the broad characteristic differences between smartphones and feature phones.

Further Reading

1. *A Review of Embedded Systems Education in the Arduino Age: Lessons Learned and Future Directions*. Available from: https://shorturl.at/yABW0 [accessed: Apr 18, 2024].

Teaching/Learning Resources

1. Arduino Embedded System Kits
2. Video documentaries
3. audio-visual equipment and laptops with MS Office installed

References

1. Minaie A. and Sanati-Mehrizy R. (2208). Comparison of Embedded Systems Education in the United States, European, and Far Eastern Countries. In the American Society for Engi-neering Education Annual Conference, pp. 13.19.1-13.19.6.[2] Koopman P., Choset H., Gandhi R., Krogh B., Marculescu
2. *A Review of Embedded Systems Education in the Arduino Age: Lessons Learned and Future Directions*. Available from: https://shorturl.at/yABW0 [accessed: Apr 18, 2024].

SECTION 10: COMPUTER ARCHITECTURE

Strand: **Automation and Embedded Systems**

Sub-strand: Embedded Systems

Learning Outcome: *Appreciate the advantages and applications of Embedded Systems*

Content Standard: Demonstrate knowledge and understanding of features and application areas of embedded systems

INTRODUCTION AND SECTION SUMMARY

This section introduces learners to three different computer architectures used in the design of computer processors, which are: Complex Instruction Set Computer (CISC), Reduced Instruction Set Computer (RISC) and Advanced Reduced Instruction Set Computer (ARISC). Each of these architectures has distinct characteristics that affect how instructions are executed and how the processor operates. Additionally, learners will be introduced to Random Access Memory (RAM) and Read-Only Memory (ROM) which are two distinct types of computer memory with different use cases. Learners will understand and appreciate Arduino and its application. Arduino was created to provide an easy way for beginners and enthusiasts to build very practical projects and solve real-world problems. This section will introduce learners to an Integrated Development Environment (IDE) for writing, compiling and uploading code to these boards

The weeks covered by the section are:

Week 22. Computer Architecture and Microcontrollers I

Week 23. Computer Architecture and Microcontrollers II

Week 24. Introduction to Arduino

SUMMARY OF PEDAGOGICAL EXEMPLARS

Various pedagogies should be used to bring out the creativity in learners. Consider talk-for-learning, experiential learning, case study, project-based learning, classroom discussions and debates and guest speaker presentations. Initiate a discussion by revisiting embedded systems, their evolution over time, features, application areas and some limitations. Consider using video to help learners see computer architectures and memory types in an interactive way, making it easy to understand. Learners can study real-world examples of computer systems that use CISC, RISC and ARISC and learn about the trade-offs between performance, power consumption and cost. They can also compare different architectures and memory types in terms of their features, advantages, and disadvantages. As learners learn about different computer architectures and memory types, they can engage in class discussions and debates about the pros and cons of each. Inviting a local IT professional or engineer to speak to the class about their experiences working with CISC, RISC, ARISC and different types of memory can be a great way to make the material more relatable and engaging for learners**.**

ASSESSMENT SUMMARY

Assessment modes and strategies should be varied to suit all categories of learners for them to express their knowledge and understanding of the major themes in this section. Propose a research project investigating the impact of RAM specifications (size, speed) on the performance of machine learning algorithms. Let learners make an oral presentation to outline the potential methodologies and expected outcomes. This can be used as their formative assessment. Learners can explain the concept of “volatile memory” in the context of RAM after listening to a talk by a guest speaker. Learners can also be made to analyse the role of environmental variables in the Arduino IDE’s functionality. Consider tasking learners to explain how these variables streamline the process of interfacing with Arduino hardware and discuss their significance in cross-platform development.

Week 22

Learning Indicators:

1. *Learners should describe the CISC, RISC and ARISC architectures.*
2. *Specify use cases for RAM/ROM.*

Theme or Focal Area: CISC, RISC and ARISC architectures

CISC, RISC, and ARISC are three different computer architecture paradigms used in the design of computer processors. Each of these architectures has distinct characteristics that affect how instructions are executed and how the processor operates. Here's a brief description of each:

1. **CISC (Complex Instruction Set Computer):**

   CISC architecture is characterised by a large and diverse set of complex instructions. These instructions can perform multiple operations in a single instruction, often involving memory access, arithmetic operations and control flow changes.

   CISC architectures are typically more instruction-rich and can execute a wide variety of tasks with a single instruction.

   They are known for their flexibility and the ability to handle complex code efficiently.

   Common examples of CISC architectures include x86 and x86-64 (Intel and AMD processors).

2. **RISC (Reduced Instruction Set Computer):**

   RISC architecture, as the name implies, uses a smaller set of simpler and more uniform instructions.

   RISC processors typically execute instructions in a single clock cycle which makes them faster in terms of clock speed.

   RISC architectures rely on the principle of pipelining, breaking down instruction execution into stages which can lead to more efficient use of resources.

   They often use load-store architectures where arithmetic and logic operations only work on data stored in registers and memory access is explicitly done with load and store instructions.

   Examples of RISC architectures include ARM and MIPS.

3. **ARISC (Advanced Reduced Instruction Set Computer):**

   ARISC architecture is a more recent development that combines elements of both CISC and RISC.

   ARISC processors aim to strike a balance between the simplicity and speed of RISC and the flexibility of CISC.

   They often include a larger instruction set compared with traditional RISC architectures allowing for more complex instructions.

   Like RISC, ARISC architectures still maintain the concept of pipelining but they may also include features like out-of-order execution to optimise performance.

   ARISC processors are designed to be energy-efficient and suitable for a wide range of applications, including mobile devices and embedded systems.

Advancements and Future Trends:

Advancements include multi-core processors (multiple processing units on a single chip), heterogeneous architectures (combining different types of processing cores) and specialised accelerators for specific tasks (like GPUs and AI accelerators). The future might see more emphasis on energy-efficient designs, novel memory hierarchies and tighter integration with emerging technologies like quantum computing.

CISC: Intel Core series processors, which utilise complex instructions to optimise general-purpose computing tasks.

RISC: ARM Cortex processors, known for their power-efficient design, are commonly used in mobile devices and embedded systems.

ARISC: The Tensilica Xtensa processors provide configurable architectures for various application domains, allowing for tailored performance and efficiency trade-offs.

Learning Tasks

1. Discuss the concept of instruction pipelines in computer architectures. Discuss how pipelining improves execution efficiency and reduces latency. Explore how CISC and RISC architectures implement pipelines differently.
2. Discuss a scenario where an ARISC architecture could be advantageous over both CISC and RISC.
3. Discuss how ARISC architecture strikes a balance between CISC and RISC characteristics.
4. Learners to research the fundamental differences between CISC (Complex Instruction Set Computer) and RISC (Reduced Instruction Set Computer) architectures to understand their design principles, instruction sets and performance characteristics
5. Guide learners to analyse the instruction sets of both CISC and RISC architectures to identify common instructions, addressing modes, and data types. Compare the complexity of instructions in each architecture.
6. Practice with learners the writing of simple assembly language programs for both CISC and RISC architectures. Understand how instructions are represented in binary and how they map to machine code.
7. Explore performance metrics such as CPI (Cycles Per Instruction) and IPC (Instructions Per Cycle). Calculate these metrics for representative instructions in CISC and RISC architectures.
8. Study real-world processors that follow either CISC or RISC principles. Examples include Intel x86 (CISC) and ARM (RISC). Analyse their instruction sets, performance, and historical context.
9. Explore how instructions are encoded in machine code. Compare the length of instructions in CISC (often variable-length) and RISC (usually fixed-length) architectures.

Theme or Focal Area: Uses of CISC, RISC and ARISC architectures

Random Access Memory (RAM) and Read-Only Memory (ROM) are two distinct types of computer memory with different use cases. Here are some common use cases for both RAM and ROM:

Use Cases for RAM (Random Access Memory)

1. **Temporary Data Storage**: RAM is used to temporarily store data that the computer is actively using. This includes the data currently being processed by the CPU, open applications and the operating system.
2. **Running Applications:** RAM stores the executable code and data of running applications. The more RAM a computer has, the more applications it can run simultaneously without slowing down.
3. **Caching:** RAM is used to cache frequently accessed data from slower storage devices (like hard drives or SSDs) to improve system performance. This can include web page data, frequently used files and more.
4. **Virtual Memory:** When the RAM is insufficient for the tasks at hand, the operating system can use a portion of the hard drive or SSD as virtual memory. This allows the computer to continue running although at a slower pace.
5. **Gaming:** Many modern video games require substantial amounts of RAM to store textures, game assets, and other data for smooth gameplay.
6. **Video and Image Editing:** Applications like Adobe Photoshop and video editing software use RAM to store and manipulate large files and complex multimedia data.
7. **Multitasking:** RAM allows a computer to switch between tasks and applications quickly. More RAM means smoother multitasking.
8. **Database Management:** Database servers use RAM to cache frequently requested data, resulting in faster database query responses.

Use Cases for ROM (Read-Only Memory)

1. Firmware: ROM is used to store firmware, which contains low-level software that initialises hardware components at boot time. Examples include BIOS or UEFI firmware in computers and firmware in embedded systems like game consoles or smart appliances.
2. **Operating System Bootloader:** ROM may contain the bootloader that is responsible for loading the operating system from storage devices like hard drives or SSDs.
3. **Embedded Systems:** In many embedded systems (e.g., car navigation systems, digital cameras, and microwave ovens), ROM stores the software necessary for their operation, ensuring that it remains unaltered.
4. **Game Consoles:** ROM cartridges or game discs used in older game consoles store game data and the game console’s ROM contains essential software.
5. **Mobile Phones:** ROM in mobile devices often contains the phone’s operating system and system recovery software.
6. **Security:** Some ROM chips store cryptographic keys or security-related information that should not be altered or tampered with.
7. **Medical Devices:** ROM in medical equipment often stores the software needed for its functionality and regulatory compliance.

Learning Tasks

1. Provide an example of a use case where the read-only nature of ROM is essential for a computer system's functionality.
2. Compare and contrast the advantages and disadvantages of using volatile RAM versus non-volatile ROM in terms of data storage and accessibility.
3. Design a scenario in which a computer system would benefit from having both RAM and ROM and describe how each type of memory contributes to the system's functionality.
4. Evaluate the feasibility and potential challenges of creating a computer architecture that blurs the lines between RAM and ROM, aiming to combine the benefits of both types of memory. What implications could such an architecture have on data storage, data security and overall system performance?
5. Discuss memory access patterns in CISC and RISC architectures. Understand how memory hierarchy (cache, RAM, etc.) affects performance. Compare load/store instructions in both architectures.
6. Research emerging trends in processor design, such as ARISK (Adaptive Reduced Instruction Set Computer) architectures. Understand how ARISK combines features from both CISC and RISC to optimise performance1.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** Initiate a discussion by using questions and answers to introduce computer architecture and the various types such as CISC, RISC and ARISK.
2. **Case studies:** learners can study real-world examples of computer systems that use CISC, RISC and ARISC and learn about the trade-offs between performance, power consumption and cost. For example, they can compare how a modern smartphone using ARM RISC architecture uses less power than traditional x86 CISC-based laptops.
3. **Project-based learning**: learners research a specific computer architecture or type of memory and present their findings to the class. They can also compare different architectures and memory types in terms of their features, advantages, and disadvantages.
4. **Classroom discussions and debates:** As learners learn about different computer architectures and memory types, they can engage in class discussions and debates about the pros and cons of each.
5. **Guest speakers:** Inviting a local IT professional or engineer to come and speak to the class about their experiences working with CISC, RISC, ARISC and different types of memory can be a great way to make the material more relatable and engaging for learners.
6. **Experiential Learning:** Virtual reality has great potential in teaching computer architectures and memory types. It will help learners to see computer architectures and memory types in an interactive way, making it easy to understand.

Key Assessment

Level 2 Skills of conceptual understanding:

1. What is the primary purpose of RAM (Random Access Memory) in a computer system?
2. Explain the concept of "volatile memory" in the context of RAM.
3. Why is it important for a computer system to have sufficient RAM when running resource-intensive applications like video editing software?

Level 3 Strategic reasoning:

1. Compare and contrast the roles of RAM and ROM (Read-Only Memory) in a computer system. How do they contribute to overall system performance?
2. Describe a real-world scenario where a computer system's performance could be negatively impacted due to insufficient RAM. How might this affect the user experience?
3. Explain the concept of "virtual memory." How does it allow a computer to manage RAM usage more effectively?
4. Design a case study where a business requires a specialised computer system for 3D rendering. Specify the necessary amount of RAM and its role in ensuring efficient rendering processes.

Level 4 Extended critical thinking and reasoning:

1. Evaluate the trade-offs between using more RAM versus relying heavily on virtual memory. Discuss scenarios where one approach might be more suitable than the other.
2. Conduct a research project investigating the impact of RAM specifications (size, speed) on the performance of machine learning algorithms. Outline the potential methodologies and expected outcomes.

Week 23

Learning Indicator: *Learners should describe the memory architectures of RAM and ROM*

Theme or Focal Area: Memory architectures of RAM and ROM

RAM (Random Access Memory) and ROM (Read-Only Memory) are two essential types of computer memory with distinct architectures and functions. Here's a description of their memory architectures:

RAM (Random Access Memory)

1. **Volatility:** RAM is volatile memory, which means it loses its data when the power is turned off. It stores data temporarily and is used for tasks that require fast read and write operations.
2. **Architecture:** RAM is composed of integrated circuits that consist of memory cells. Each cell is typically a capacitor and a transistor, with the state of the transistor representing the binary value (0 or 1). The data in RAM is stored in a matrix-like structure of rows and columns, allowing random access to any memory location.
3. **Read/Write:** RAM is both readable and writable, which means data can be written to and read from it. This feature makes it ideal for storing data that needs to be frequently accessed and modified during a computer's operation.
4. **Speed:** RAM is extremely fast and provides quick access to data. It is crucial for temporarily holding data that the CPU actively uses while running applications and the operating system.
5. **Capacity:** RAM capacity can vary in computers, from a few gigabytes (GB) to multiple terabytes (TB) in high-end servers. The capacity and speed of RAM affect a computer's performance.

   Example Types: Common types of RAMs include Dynamic RAM (DRAM), Synchronous Dynamic RAM (SDRAM), Double Data Rate (DDR) RAM, and more.

ROM (Read-Only Memory)

1. **Volatility:** ROM is non-volatile memory, meaning it retains its data even when the power is turned off. It stores permanent data and is primarily used for firmware and software that should not be altered.
2. **Architecture:** ROM consists of memory cells that are typically implemented as fuse links, diode matrices, or mask-programmable ROM. The data in ROM is embedded during manufacturing and cannot be altered by normal computer operations.
3. **Read-Only:** ROM is read-only, meaning it can only be read from, and data cannot be written to or modified. This makes it suitable for storing firmware and software instructions that are essential for the computer's operation.
4. **Speed:** ROM is slower than RAM because it is not designed for rapid data access or modification. It is primarily used for booting up the computer, storing BIOS firmware, and firmware for various hardware components.
5. **Capacity:** The capacity of ROM varies depending on its purpose. It can range from a few kilobytes (KB) in older systems to several gigabytes (GB) in modern systems, especially when referring to forms of flash memory like EEPROM or NAND flash.

   Example Types: There are various types of ROM, including Mask ROM, PROM (Programmable ROM), EPROM (Erasable Programmable ROM), and EEPROM (Electrically Erasable Programmable ROM). Flash memory is a type of EEPROM that is commonly used for data storage in modern devices.

Learning Tasks

1. Discuss the purpose of "ROM" in a computer system and provide an example of when it is used.
2. Compare and contrast the primary differences between dynamic RAM (DRAM) and static RAM (SRAM) in terms of speed, construction, and usage scenarios.
3. Discuss the significance of "read-only" in Read-Only Memory (ROM). How does the non-volatile nature of ROM impact its role in storing essential system data?
4. Imagine you're designing a high-performance gaming computer. Discuss the justification for the choice between using more DRAM or more SRAM in the system's architecture, considering factors such as cost, speed and power consumption.

Pedagogical Exemplars

1. **Initiating talk-for-learning:** Initiate a discussion by reviewing computer architectures and introducing the different memory types.
2. **Case studies:** learners can study real-world examples of memory types and report their findings to the class.
3. **Enquiry-based learning**: Learners research the development of a specific type of memory and present their findings to the class. They can also compare different memory types in terms of their features, advantages and disadvantages.
4. **Classroom discussions and debates:** As learners learn about different memory types, they can engage in class discussions and debates about the pros and cons of each.
5. **Experiential Learning:** Use video to help learners see memory types in an interactive way, making it easy to understand.

Key Assessment

Level 1 Recall

1. What does RAM stand for, and what is its primary function in a computer system?
2. Explain the main difference between RAM and ROM in terms of data storage and accessibility.
3. How does RAM temporarily store data when a computer is running and why is this temporary storage important?

Level 2 Skills of Conceptual Understanding

1. Compare and contrast the read/write capabilities of RAM and ROM. How do these capabilities affect their usage in a computer system?
2. Describe the concept of volatile memory with respect to RAM. How does the volatile nature of RAM impact data retention and usage?
3. Discuss the advantages and disadvantages of using ROM for storing firmware and permanent software instructions compared with using RAM.

Level 3 Strategic reasoning:

1. Imagine designing a computer system for a mission-critical application. Explain the factors you would consider when choosing between volatile (RAM) and non-volatile (ROM) memory for storing critical data and instructions.

2. Analyse how advancements in memory technology have led to improvements in both RAM and ROM over the years. Provide examples of real-world applications that have benefited from these advancements.
3. Critically evaluate the potential security implications of using RAM for temporary data storage, particularly in scenarios involving sensitive information. How might these implications be addressed at the architectural level?

Week 24

Learning Indicator: *Install and configure the environmental variables of the Arduino IDE and interface with the Arduino hardware successfully*

Theme or Focal Area: Installing and configuring the environmental variables of the Arduino

Arduino is an open-source platform that consists of both hardware and software components. It was created to provide an easy way for beginners and enthusiasts to create interactive electronic projects. The platform includes a range of microcontroller boards that can be programmed to perform various tasks, along with an integrated development environment (IDE) for writing, compiling, and uploading code to these boards.

Microcontrollers and Their Applications:

Microcontrollers are small, integrated circuits that contain a processor, memory and input/output pins. They are designed to perform specific tasks and are commonly used in various applications such as robotics, automation, home electronics, wearable devices and more. Microcontrollers provide a cost-effective and efficient way to control electronic components and devices.

Installing Arduino IDE:

Go to the official Arduino website (arduino.cc) and download the Arduino IDE suitable for your operating system.

Run the downloaded installer and follow the on-screen instructions to install the Arduino IDE.

Configuring Environmental Variables:

Environmental variables are settings that the operating system uses to locate necessary files and resources. To set up the necessary environmental variables for Arduino IDE,

1. Find the location where Arduino IDE is installed on your computer.
2. Copy this path.
3. Search for "environmental variables" in your computer's search bar and select "Edit the system environmental variables."
4. Click the "Environment Variables" button.
5. Under "System Variables," find the "Path" variable and click "Edit."
6. Click "New" and paste the path of the Arduino IDE installation folder.

Connecting Arduino Hardware:

Arduino offers various boards, each with specific features. Common ones include Arduino Uno, Arduino Nano and Arduino Mega. To connect Arduino to your computer:

Plug the Arduino board into your computer using a USB cable.

Uploading Arduino Sketches:

Arduino sketches are programmes written in the Arduino programming language. They consist of two essential functions: ***setup() and loop()***. To upload a sketch:

Write your Arduino sketch in the Arduino IDE.

Select your Arduino board model under the "Tools" menu.

Choose the correct port under the "Tools" menu.

Click the "Upload" button (right arrow icon). The IDE compiles the code and uploads it to the Arduino board.

Troubleshooting and Debugging:

Common issues include incorrect drivers, port selection, or syntax errors. Read error messages carefully and search online forums for solutions. Use resources like Arduino's official website, forums, and tutorials to find solutions.

Exploring Arduino Libraries and Examples:

Libraries are pre-written code snippets that extend Arduino's functionality. To use them:

In the IDE, go to "Sketch" > "Include Library" to include a library in your sketch.

To use examples, go to "File" > "Examples" to access a variety of pre-built sketches.

Learning Tasks

1. Evaluate the potential challenges that might arise from incorrect configuration of environmental variables when using the Arduino IDE. How can such challenges be troubleshot and resolved effectively?
2. Design a flowchart illustrating the sequence of events that occur from writing Arduino code in the IDE to uploading and executing it on the connected Arduino board. Highlight the role of environmental variables in this process.
3. Devise a comprehensive guide detailing advanced techniques for optimising the interaction between the Arduino IDE and hardware. Include methods to streamline the configuration of environmental variables, troubleshoot common issues, and ensure efficient code uploading and execution.
4. Assess the implications of relying solely on default settings and not configuring environmental variables when using the Arduino IDE. Analyse potential drawbacks in terms of performance, compatibility and development workflow.
5. Create a tutorial video demonstrating the installation, environmental variable configuration, and successful interface setup between the Arduino IDE and Arduino hardware. Incorporate real-time demonstrations, explanations and troubleshooting tips.
6. Have learners try their hands on configuring the environment variable of Arduino.

Pedagogical Exemplars

1. **Experiential Learning:** Have learners watch videos of Arduino IDE and how it functions. Learners make observations and share with the whole class by adding to what others say. Explain how both the interface and the platform work.
2. **Experiential Learning:** Learners should try their hands on configuring the Arduino IDE and interface with other hardware for basic functions.
3. **Game-based learning:** Using games or simulations to teach Arduino to enable learners to visualise complex concepts, practice problem-solving, and experiment with different scenarios. Learners should share ideas and experiences.

Key Assessment

Level 3 Strategic reasoning:

Select at least three (3) of the following questions:

1. Explain the process of installing and configuring environmental variables in the Arduino IDE to interface with Arduino hardware. Provide step-by-step instructions and highlight the significance of this setup.
2. Compare and contrast the advantages and disadvantages of configuring environmental variables versus manually specifying hardware parameters in the Arduino IDE. Discuss situations where one approach might be more beneficial than the other.
3. Describe potential conflicts that might arise when multiple versions of the Arduino IDE are installed on the same system. Propose strategies to mitigate these conflicts and ensure successful communication with Arduino hardware.
4. Create a comprehensive troubleshooting guide for resolving common errors encountered during the installation and configuration of environmental variables for Arduino IDE. Include detailed solutions and explanations for each error scenario.
5. Assess the impact of incorrect environmental variable configuration on the Arduino development process. Discuss potential consequences such as failed uploads, incorrect code execution, or hardware communication issues and suggest preventive measures.

Level 4 Extended critical thinking and reasoning:

Select at least three (3) of the following questions:

1. Analyse the role of environmental variables in the Arduino IDE's functionality. Explain how these variables streamline the process of interfacing with Arduino hardware and discuss their significance in cross-platform development.
2. Develop a comprehensive tutorial that covers advanced topics related to environmental variable configuration for the Arduino IDE. Include instructions for setting up variables for different operating systems, managing multiple Arduino boards and incorporating third-party libraries seamlessly.
3. Assess the long-term implications of maintaining environmental variable configurations across various Arduino projects. Discuss strategies for managing these configurations efficiently, ensuring consistency and adapting them to evolving hardware and software requirements.
4. Critically analyse the necessity of environmental variables in the context of other microcontroller programming environments. Compare and contrast their role in Arduino's development ecosystem with similar environments like Platform IO.
5. Develop a troubleshooting handbook that addresses a wide range of challenges users might encounter while configuring environmental variables and interacting with Arduino hardware. Provide systematic solutions and strategies to overcome each challenge effectively.

Section 10 Review

1. Would learners be able to describe the CISC, RISC and ARISC architectures?
2. Can learners specify the use cases for RAM/ROM?
3. Would learners be able to describe the memory architectures of RAM and ROM?
4. Can learners install and configure the environmental variables of the Arduino IDE and interface with the Arduino hardware successfully?

Further Reading

1. Malik, S., Hussain, W., Sheikh, A. A., 2015, Comparison of RISC and CISC Architectures, International Journal of Scientific and Engineering Research

Teaching/Learning Resources

1. Arduino Embedded System Kits
2. Video documentaries
3. Audio-visual equipment and laptops with MS Office installed

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