MANUFACTURING ENGINEERING

CURRICULUM FOR SECONDARY EDUCATION (SHS 1 - 3)

NaCCA

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

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Enquiries and comments on this Curriculum should be addressed to:

The Director-General
National Council for Curriculum and Assessment (NaCCA)
Ministry of Education

P. O. Box CT PMB 77
Cantonments Accra

Telephone: 0302909071, 0302909862

Email: info@nacca.gov.gh

Website: www.nacca.gov.gh

FOREWORD

Through the National Council for Curriculum and Assessment (NaCCA), Ghana's Ministry of Education has introduced a series of curriculum reforms to improve the quality and relevance of learning experiences in pre-tertiary schools in the country. These reforms will improve learning through the introduction of innovative pedagogies that encourage critical thinking and problem-solving. For a long time, our learners memorise facts and figures, which does not develop their analytical and practical skills. The Ministry recognises that learners need to be equipped with the right tools, knowledge, skills and competencies to deal with the fast-changing environment and the challenges facing their communities, the nation and the world.

These curriculum reforms were derived from the Education Strategic Plan (ESP 2018-2030), the National Pre-tertiary Education Curriculum Framework (NPTECF) and the National Pre-Tertiary Learning Assessment Framework (NPLAF), which were all approved by Cabinet in 2018. The new standards-based curriculum implemented in 2019 in basic schools, aims to equip learners to apply their knowledge innovatively to solve everyday problems. It also prioritises assessing learners' knowledge, skills, attitudes, and values, emphasising their achievements. The content of the basic school standards-based curriculum was therefore designed to promote a curriculum tailored to the diverse educational needs of the country's youth. It addresses the current curriculum's deficiencies in learning and assessment, especially in literacy and numeracy. These reforms have been carried out in phases. The curriculum for the basic school level – KG, Primary and Junior High School (JHS) – was developed and implemented from 2019 to 2021.

The curriculum for Senior High School (SHS), Senior High Technical School (SHTS) and Science, Technical, Engineering and Mathematics (STEM), which constitutes the next phase, is designed to ensure the continuation of learning experiences from JHS. It introduces flexible pathways for progression to facilitate the choice of subjects necessary for further study, the world of work and adult life. The new SHS, SHTS and STEM curriculum emphasises the acquisition of 21st Century skills and competencies, character development and instilling of national values. Social and Emotional Learning (SEL), Information Communications Technology, Gender Equality and Social Inclusion, have all been integrated into the curriculum. Assessment – formative and summative has been incorporated into the curriculum and aligned with the learning outcomes throughout the three-year programme.

The Ministry of Education's reform aims to ensure that graduates of our secondary schools can successfully compete in international high school competitions and, at the same time, be equipped with the necessary employable skills and work ethos to succeed in life. The Ministry of Education, therefore, sees the Senior High School (SHS) curriculum as occupying a critical place in the education system – providing improved educational opportunities and outcomes for further studies, the world of work and adult life – and is consequently prioritising its implementation.

ACKNOWLEDGEMENTS

This standards-based SHS curriculum was created using the National Pre-Tertiary Learning Assessment Framework (NPLAF), the Secondary Education Assessment Guide (SEAG), and the Teacher and Learner Resource Packs which include Professional Learning Community (PLC) Materials and Subject Manuals for teachers and learners. All the above-mentioned documents were developed by the National Council for Curriculum and Assessment (NaCCA). The Ministry of Education (MoE) provided oversight and strategic direction for the development of the curriculum with NaCCA receiving support from multiple agencies of the MoE and other relevant stakeholders. NaCCA would like to extend its sincere gratitude, on behalf of the MoE, to all its partners who participated in the professional conversations and discussions during the development of this SHS curriculum.

In particular, NaCCA would also like to extend its appreciation to the leadership of the Ghana Education Service (GES), the National School Inspectorate Authority (NaSIA), the National Teaching Council (NTC), the Commission for Technical and Vocational Education and Training (Commission for TVET), West African Examinations Council (WAEC) and other agencies of the MoE that supported the entire process. In addition, NaCCA acknowledges and values the contributions made by personnel from various universities, colleges of education Industry players, Vice Chancellors Ghana, Vice Chancellors Technical Universities as well as educators and learners working within the Ghana education landscape.

Special appreciation is extended to consultants who contributed to development of the curriculum. The development process involved multiple engagements between national stakeholders and various groups with interests in the curriculum. These groups include the teacher unions, the Association of Ghana Industries, and heads of secondary schools.

CONTENTS

THE SHS CURRICULUM OVERVIEW

The vision for this curriculum is to ensure the nation has a secondary education system that enables all Ghanaian children to acquire the 21st Century skills, competencies, knowledge, values and attitudes required to be responsible citizens, ready for the world of work, further studies and adult life. The nation's core values drive the SHS curriculum, and it is intended to achieve Sustainable Development Goal 4: 'Inclusive, equitable quality education and life-long learning for all'. Above all, it is a curriculum enabling its graduates to contribute to the ongoing growth and development of the nation's economy and well-being.

The curriculum is inclusive, flexible, and robust. It was written under the auspices of the National Council for Curriculum and Assessment by a team of expert curriculum writers across Ghana. It reflects the needs of critical stakeholders, including industry, tertiary education, the West African Examination Council, SHS learners, teachers, and school leaders. It has been written based on the National Pre-Tertiary Learning and Assessment Framework and the Secondary Education Policy.

The key features of the curriculum include:

- flexible learning pathways at all levels, including for gifted and talented learners and those with deficiencies in numeracy and literacy, to ensure it can meet the needs of learners from diverse backgrounds and with different interests and abilities.
- the five core learning areas for secondary education: science and technology, language arts, humanities, technical and vocational and business; with emphasis placed on STEM and agriculture as integral to each subject.
- a structured, standards-based approach that supports the acquisition of knowledge, skills and competencies, and transition and seamless progress throughout secondary education, from JHS to SHS and through the three years of SHS.
- a focus on interactive approaches to teaching and assessment to ensure learning goes beyond recall enabling learners to acquire the ability to understand, apply, analyse and create.
- guidance on pedagogy, coupled with exemplars, demonstrating how to integrate cross-cutting themes such as 21st Century skills, core competencies, the use of ICT, literacy and mathematics, Social Emotional Learning, Gender Equality and Social Inclusion as tools for learning and skills for life. Shared Ghanaian values are also embedded in the curriculum.

The curriculum writing process was rigorous and involved developing and using a Curriculum Writing Guide which provided systematic instructions for writers. The process was quality assured at three levels: through (a) evaluation by national experts, (b) trialling curriculum materials in schools and (c) through an external evaluation by a team of national and international experts. Evidence and insights from these activities helped hone the draft's final version. The outcome is a curriculum coherently aligned with national priorities, policies and the needs of stakeholders. A curriculum tailored to the Ghanaian context ensures that all learners benefit from their schooling and develop their full potential.

The following section highlights the details of the front matter of the draft curriculum. The vision, philosophy and goal of the curriculum are presented. This is followed by the details of the 21st Century skills and competencies, teaching and learning approaches, instructional design and assessment strategies. The template for the curriculum frame, which outlines the scope and sequence, the design that links the learning outcomes to particular 21st Century skills and competencies, as well as Gender Equality and Social Inclusion, Social and Emotional Learning and Ghanaian values are presented together with the structure of the lesson frame showing the links between the content standards, learning indicators with their corresponding pedagogical exemplars and assessment strategies.

INTRODUCTION

Effective implementation of this Senior High School (SHS) curriculum is the key to creating a well-educated and well-balanced workforce that is ready to contribute to Ghana's progress by harnessing the potential of the growing youth population, considering the demographic transition the country is currently experiencing (Educational Strategic Plan [ESP] 2018-2030). SHS curriculum aims to expand equitable, inclusive access to relevant education for all young people, including those in disadvantaged and underserved communities, those with special educational needs and those who are gifted and talented. Senior High School allows young people to develop further skills and competencies and progress in learning achievement, building from the foundation laid in Junior High School. This curriculum intends to meet the learning needs of all high school learners by acquiring 21st Century skills and competencies to prepare them for further studies, the world of work and adult life. Changing global economic, social and technological context requires life-long learning, unlearning, and continuous processes of reflection, anticipation and action.

Philosophy of Senior High School Curriculum

The philosophy underpinning the SHS curriculum is that every learner can develop their potential to the fullest if the right environment is created and skilled teachers effectively support them to benefit from the subjects offered at SHS. Every learner needs to be equipped with skills and competencies of interest to further their education, live a responsible adult life or proceed to the world of work.

Vision of Senior High School Curriculum

The vision of the curriculum is to prepare SHS graduates equipped with relevant skills and competencies to progress and succeed in further studies, the world of work and adult life. It aims to equip all learners with the 21st Century skills and competencies required to be responsible citizens and lifelong learners. When young people are prepared to become effective, engaging, and responsible citizens, they will contribute to the ongoing growth and development of the nation's economy and well-being.

Goal of Senior High School Curriculum

The goal of the curriculum is to achieve relevant and quality SHS through the integration of 21st Century skills and competencies as set out in the Secondary Education Policy. The key features to integrate into the curriculum are:

- Foundational Knowledge: literacy, numeracy, scientific literacy, information, communication and digital literacies, 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, integrity, self-directed learning, self-confidence, adaptability and resourcefulness, leadership, and responsible citizenship.

The JHS curriculum has been designed to ensure that learners are adequately equipped to transition seamlessly into SHS, where they will be equipped with the relevant knowledge, skills and competencies. The SHS curriculum emphasises character building, acquisition of 21st Century skills and competencies and nurturing core values within an environment of quality education to ensure the transition to further study, the world of work and adult life. This requires the delivery of robust secondary education that meets the varied learning needs of the youth in Ghana. The SHS curriculum, therefore, seeks to develop learners to become technology-inclined, scientifically literate, good problem-solvers who can think critically and creatively and are equipped to communicate with fluency, and possess the confidence and competence to participate fully in Ghanaian society as responsible local and global citizens – (referred to as 'Glocal citizens').

The SHS curriculum is driven by the nation's core values of truth, integrity, diversity, equity, discipline, self-directed learning, self-confidence, adaptability and resourcefulness, leadership, and responsible citizenship, and with the intent of achieving the Sustainable Development Goal 4: 'Inclusive, equitable quality education and life-long learning for all'. The following sections elaborate on the critical competencies required of every SHS learner:

Gender Equality and Social Inclusion (GESI)

- Appreciate their uniqueness about others.
- Pay attention to the uniqueness and unique needs of others.
- Value the perspective, experience, and opinion of others.
- Respect individuals of different beliefs, political views/ leanings, cultures, and religions.
- Embrace diversity and practise inclusion.
- Value and work in favour of a democratic and inclusive society.
- Be conscious of the existence of minority and disadvantaged groups in society and work to support them.
- Gain clarity about misconceptions/myths about gender, disability, ethnicity, age, religion, and all other excluded groups in society
- Interrogate and dispel their stereotypes and biases about gender and other disadvantaged and excluded groups in society.
- Appreciate the influence of socialisation in shaping social norms, roles, responsibilities, and mindsets.
- Identify injustice and advocate for change.
- Feel empowered to speak up for themselves and be a voice for other disadvantaged groups.

21st Century Skills and Competencies

In today's fast-changing world, high school graduates must be prepared for the 21st Century world of work. The study of Mathematics, Science, and Language Arts alone is no longer enough. High school graduates need a variety of skills and competencies to adapt to the global economy. Critical thinking, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity, and social skills are needed. These skills help learners to keep up with today's fast-paced job market. Employers want workers with more than academic knowledge. The 21st Century skills and competencies help graduates navigate the complex and changing workplace. Also, these help them become active citizens who improve their communities. Acquisition of 21st Century skills in high school requires a change in pedagogy from the approach that has been prevalent in Ghana in recent years. Teachers should discourage and abandon rote memorisation and passive learning. Instead, they should encourage active learning, collaboration, and problem-solving, project-based, inquiry-based, and other learner-centred pedagogy should be used. As well as aligning with global best practices, these approaches also seek to reconnect formal education in Ghana with values-based indigenous education and discovery-based learning which existed in Ghana in pre-colonial times. This is aligned with the 'glocal' nature of this curriculum, connecting with Ghana's past to create confident citizens who can engage effectively in a global world. Digitalisation, automation, technological advances and the changing nature of work globally mean that young people need a new set of skills, knowledge and competencies to succeed in this dynamic and globalised labour market.

Critical Thinking and Problem-Solving Competency

- Ability to question norms, practices, and opinions, to reflect on one's values, perceptions, and actions.
- Ability to use reasoning skills to come to a logical conclusion.
- Being able to consider different perspectives and points of view
- Respecting evidence and reasoning
- Not being stuck in one position
- Ability to take a position in a discourse
- The overarching ability to apply different problem-solving frameworks to complex problems and develop viable, inclusive, and equitable solution options that integrate the above-mentioned competencies, promote sustainable development,

Creativity

- Ability to identify and solve complex problems through creative thinking.
- Ability to generate new ideas and innovative solutions to old problems.
- Ability to demonstrate originality and flexibility in approaching tasks and challenges.
- Collaborating with others to develop and refine creative ideas
- Ability to incorporate feedback and criticism into the creative process
- Utilising technology and other resources to enhance creativity
- Demonstrating a willingness to take risks and experiment with new approaches
- Adapting to changing circumstances and further information to maintain creativity

- Integrating multiple perspectives and disciplines to foster creativity
- Ability to communicate creative ideas effectively to a variety of audiences

Collaboration

- Abilities to learn from others; to understand and respect the needs, perspectives, and actions of others (empathy)
- Ability to understand, relate to and be sensitive to others (empathic leadership)
- Ability to deal with conflicts in a group
- Ability to facilitate collaborative and participatory problem-solving
- Ability to work with others to achieve a common goal.
- Ability to engage in effective communication, active listening, and the ability to compromise.
- Ability to work in groups on projects and assignments.

Communication

- Know the specific literacy and language of the subjects studied
- Use language for academic purposes
- Communicate effectively and meaningfully in a Ghanaian Language and English Language
- Communicate confidently, ethically, and effectively in different social contexts.
- Communicate confidently and effectively to different participants in different contexts
- Ability to communicate effectively verbally, non-verbally and through writing.
- Demonstrate requisite personal and social skills that are consistent with changes in society
- Ability to express ideas clearly and persuasively, listen actively, and respond appropriately
- Ability to develop digital communication skills such as email etiquette and online collaboration.
- Ability to engage in public speaking, debate, and written communication.

Learning for Life

- Understand subject content and apply it in different contexts
- Apply mathematical and scientific concepts in daily life
- Demonstrate mastery of skills in literacy, numeracy, and digital literacy.
- Develop an inquiry-based approach to continual learning.
- Be able to understand higher-order concepts and corresponding underlying principles.
- Participate in the creative use of the expressive arts and engage in aesthetic appreciation.
- Use and apply a variety of digital technologies
- Be digitally literate with a strong understanding of ICT and be confident in its application.
- Be equipped with the necessary qualifications to gain access to further and higher education and the world of work and adult life
- Ability to apply knowledge practically in the workplace so that they are able to utilise theory by translating it into practice.
- Develop their abilities, gifts and talents to be able to play a meaningful role in the development of the country
- Be able to think critically and creatively, anticipate consequences, recognise opportunities and be risk-takers
- Ability to pursue self-directed learning with the desire to chart a path to become effective lifelong learners.
- Independent thinkers and doers who show initiative and take action.
- Ability to innovate and think creatively, building on their knowledge base so that they take risks to achieve new goals
- Ability to think critically and solve problems so that they become positive change agents at work, in further study and in their personal lives.
- Be motivated to adapt to the changing needs of society through self-evaluation and ongoing training
- Be able to establish and maintain innovative enterprises both individually and in collaboration with others.
- Be able to ethically prioritise economic values to ensure stability and autonomy
- Show flexibility and preparedness to deal with job mobility
- Be committed towards the improvement of their quality of life and that of others
- Feel empowered in decision-making processes at various levels e.g., personal, group, class, school, etc.

- Be able to seek and respond to assistance, guidance and/or support when needed.
- Ability to make and adhere to commitments.
- Adopt a healthy and active lifestyle and appreciate how to use leisure time well.
- Be enthusiastic, with the knowledge, understanding and skill that enable them to progress to tertiary level, the world of work and adult life.
- Ability to transition from school to the world of work or further study by applying knowledge, skills and attitudes in new situations.
- Be independent, have academic and communication skills such as clarity of expression (written and spoken), and the ability to support their arguments.
- Be innovative and understand the 21st Century skills and competencies and apply them to everyday life.

Global and Local (Glocal) Citizenship

- Appreciate and respect the Ghanaian identity, culture, and heritage
- Be conscious of current global issues and relate well with people from different cultures
- Act in favour of the common good, social cohesion and social justice
- Have the requisite personal and social skills to handle changes in society
- Appreciate the impact of globalisation on the society.
- Ability to be an honest global citizen displaying leadership skills and moral fortitude with an understanding of the wider world and how to enhance Ghana's standing.

Systems Thinking Competency

- Ability to recognise and understand relationships
- Ability to analyse complex systems
- Ability to think of how systems are embedded within different domains and different scales
- Ability to deal with uncertainty

Normative Competency

- Ability to understand and reflect on the norms and values that underlie one's actions
- Ability to negotiate values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions

Anticipatory Competency

- Ability to understand and evaluate multiple futures – possible, probable, and desirable
- Ability to create one's vision for the future.
- Ability to apply the precautionary principle
- Ability to assess the consequences of actions
- Ability to deal with risks and changes

Strategic Competency

- Ability to collectively develop and implement innovative actions that further a cause at the local level and beyond.
- Ability to understand the bigger picture and the implications of smaller actions on them

Self-Awareness Competency

- The ability to reflect on one's role in the local community and (global) society
- Ability to continually evaluate and further motivate one's actions
- Ability to deal with one's feelings and desires

Social Emotional Learning (SEL): Five Core Competencies with Examples

1. *Self-Awareness*

Understanding one's emotions, thoughts, and values and how they influence one's behaviour in various situations. This includes the ability to recognise one's strengths and weaknesses with a sense of confidence and purpose. For instance:

- *Integrating personal and social identities;*
- *Identifying personal, cultural, and linguistic assets;*
- *Identifying one's emotions;*
- *Demonstrating honesty and integrity;*
- *Connecting feelings, values, and thoughts;*

- *Examining prejudices and biases;*
- *Experiencing self-efficacy;*
- *Having a growth mindset;*
- *Developing interests and a sense of purpose;*

2. *Self-Management*

The capacity to control one's emotions, thoughts, and actions in a variety of situations and to realise one's ambitions. This includes delaying obtaining one's desires, dealing with stress, and feeling motivated and accountable for achieving personal and group goals. For instance:

- *Managing one's emotions;*
- *Identifying and utilising stress-management strategies;*
- *Demonstrating self-discipline and self-motivation;*
- *Setting personal and group goals;*
- *Using planning and organisation skills;*
- *Having the courage to take the initiative;*
- *Demonstrating personal and collective agency;*

3. *Social Awareness*

The capacity to comprehend and care for others regardless of their backgrounds, cultures, and circumstances. This includes caring for others, understanding larger historical and social norms for behaviour in different contexts, and recognising family, school, and community resources and supports. For instance:

- *Recognising others' strengths*
- *Demonstrating empathy and compassion*
- *Caring about others' feelings*
- *Understanding and expressing gratitude*
- *Recognising situational demands and opportunities*
- *Understanding how organisations and systems influence behaviour*

4. *Relationship Skills*

The capacity to establish and maintain healthy, beneficial relationships and adapt to various social situations and groups. This includes speaking clearly, listening attentively, collaborating, solving problems and resolving conflicts as a group, adapting to diverse social and cultural demands and opportunities, taking the initiative, and asking for or offering assistance when necessary. For instance:

- *Communicating effectively;*
- *Building positive relationships;*
- *Demonstrating cultural competence;*
- *Working as a team to solve problems;*
- *Constructively resolving conflicts;*
- *Withstanding negative social pressure;*
- *Taking the initiative in groups;*
- *Seeking or assisting when needed;*
- *Advocating for the rights of others.*

5. *Responsible Decision-Making*

The capacity to make thoughtful and constructive decisions regarding acting and interacting with others in various situations. This includes weighing the pros and cons of various personal, social, and group well-being actions. For example:

- *Demonstrating curiosity and an open mind;*
- *Solving personal and social problems;*
- *Learning to make reasonable decisions after analysing information, data, and facts;*
- *Anticipating and evaluating the effects of one's actions;*
- *Recognising that critical thinking skills are applicable both inside and outside of the classroom;*
- *Reflecting on one's role in promoting personal, family, and community well-being;*
- *Evaluating personal, interpersonal, community, and institutional impacts*

Learning and Teaching Approaches

Learning and teaching should develop learners as self-directed and lifelong learners. Learners must be helped to build up deep learning skills and competencies to develop the ability to acquire, integrate and apply knowledge and skills to solve authentic and real-life problems. Learners need to be exposed to a variety of learning experiences to enable them to collaborate with others, construct meaning, plan, manage, and make choices and decisions about their learning. This will allow them to internalise newly acquired knowledge and skills and help them

to take ownership of their education. The 21st Century skills and competencies describe the relevant global and contextualised skills that the SHS curriculum is designed to help learners acquire in addition to the 4Rs (Reading, wRiting, aRithmetic and cReativity). These skills and competencies, as tools for learning and teaching and skills for life, will allow learners to become critical thinkers, problem-solvers, creators, innovators, good communicators, collaborators, digitally literate, and culturally and globally sensitive citizens who are life-long learners with a keen interest in their personal development and contributing to national development.

Given the diverse needs of learners, teachers need to have a thorough grasp of the different pedagogies as they design and enact meaningful learning experiences to meet the needs of different learners in the classroom. The teaching-learning techniques and strategies should include practical activities, discussion, investigation, role play, problem-based, context-based, and project-based learning. Active learning strategies have become increasingly popular in education as they provide learners with meaningful opportunities to engage with the material. These strategies emphasise the use of creative and inclusive pedagogies and learner-centred approaches anchored on authentic and enquiry-based learning, collaborative and cooperative learning, differentiated teaching and learning, holistic learning, and cross-disciplinary learning. They include experiential learning, problem-based learning, project-based learning, and talk-for-learning approaches. Some of the pedagogical exemplars to guide learning and teaching of the SHS curriculum include:

- **Experiential Learning:** Experiential learning is a hands-on approach to learning that involves learners in real-world experiences. This approach focuses on the process of learning rather than the result. Learners are encouraged to reflect on their experiences and use them to develop new skills and knowledge. Experiential learning can take many forms, including internships, service learning, and field trips. One of the main benefits of experiential learning is that it allows learners to apply what they have learned in the classroom to real-world situations. This can help them develop a deeper understanding of the material and make connections between different concepts. Additionally, experiential learning can help learners develop important skills such as critical thinking, problem-solving and communication.
- **Problem-Based Learning:** Problem-based learning is an approach that involves learners in solving real-world problems. Learners are presented with a problem or scenario and are asked to work together to find a solution. This approach encourages learners to take an active role in their learning and helps them develop important skills such as critical thinking and problem-solving. One of the main benefits of problem-based learning is that it encourages learners to take ownership of their learning. By working together to solve problems, learners can develop important skills such as collaboration and communication. Additionally, problem-based learning can help learners develop a deeper understanding of the material as they apply it to real-world situations.
- **Project-Based Learning:** Project-based learning is a hands-on approach to learning that involves learners in creating a project or product. This approach allows learners to take an active role in their learning and encourages them to develop important skills such as critical thinking, problem-solving, collaboration, and communication. One of the main benefits of project-based learning is that it allows learners to apply what they have learned in the classroom to real-world situations. Additionally, project-based learning can help learners develop important skills from each other and develop a deeper understanding of the material.
- **Talk for Learning Approaches:** Talk for learning approaches (TfL) are a range of techniques and strategies that are used to encourage learners to talk by involving them in discussions and debates about the material they are learning. This approach encourages learners to take an active role in their learning and helps them develop important skills such as critical thinking, collaboration and communication and also makes them develop confidence. One of the main benefits of TfL is that it encourages learners to think deeply about the material they are learning. By engaging in discussions and debates, learners can develop a deeper understanding of the material and make connections between different concepts.
- **Initiating Talk for Learning:** Initiating talk for learning requires the use of strategies that would encourage learners to talk in class. It helps learners to talk and participate meaningfully and actively in the teaching and learning process. Apart from developing skills such as communication and critical thinking, it also helps learners to develop confidence. Some strategies for initiating talk among learners are Activity Ball; Think-Pair-Share; Always, Sometimes, Never True; Matching and Ordering of Cards.
- **Building on What Others Say:** Building on what others say is an approach that involves learners in listening to and responding to their classmates'

ideas. This approach encourages learners to take an active role in their learning and helps them develop important skills such as critical thinking and communication. One of the main benefits of building on what others say is that it encourages learners to think deeply about the material they are learning. By listening to their classmates' ideas, learners can develop a deeper understanding of the material and make connections between different concepts. Additionally, building on what others say can help learners develop important skills such as collaboration and reflection. Some of the strategies to encourage learners to build on what others say are brainstorming, concept cartoons, pyramid discussion, and 5 Whys, amongst others.

- **Managing Talk for Learning:** Managing talk for learning requires the use of various strategies to effectively coordinate what learners say in class. Effective communication is a crucial aspect of learning in the classroom. Teachers must manage talk to ensure that learners are engaged, learning, and on-task in meaningful and purposeful ways. Some strategies for managing learners' contributions are debates, think-pair-share, sage in the circle etc.
- **Structuring Talk for Learning:** One effective way to shape learners' contributions is to structure classroom discussions. Structured discussions provide a framework for learners to engage in meaningful dialogue and develop critical thinking skills. Teachers can structure discussions by providing clear guidelines, such as speaking one at a time, listening actively, and building on each other's ideas. One popular structured discussion technique is the "think-pair-share" method. In this method, learners think about a question or prompt individually, and then pair up with a partner to discuss their ideas. Finally, the pairs share their ideas with the whole class. This method encourages all learners to participate and ensures that everyone has a chance to share their thoughts. Another effective way to structure talk for learning is to use open-ended questions. Open-ended questions encourage learners to think deeply and critically about a topic. They also promote discussion and collaboration among learners. Teachers can use open-ended questions to guide classroom discussions and encourage learners to share their ideas and perspectives. Other strategies that can be used are Concept/Mind Mapping, "Know," "Want to Know," "Learned" (KWL); Participatory Feedback; and the 5 Whys.
- **Diamond Nine:** The Diamond Nine activity is a useful tool for managing talk for learning in the classroom. This activity involves ranking items or ideas in order of importance or relevance. Learners work in groups to arrange cards or sticky notes with different ideas or concepts into a diamond shape, with the most important idea at the top and the least important at the bottom. The Diamond Nine activity encourages learners to think critically about a topic and prioritise their ideas. It also promotes collaboration and discussion among group members. Teachers can use this activity to introduce a new topic, review material, or assess student understanding.
- **Group Work/Collaborative Learning:** Group work or collaborative learning are effective strategies for managing talk for learning in the classroom. These strategies encourage learners to work together to solve problems, share ideas, and learn from each other. Group work and collaborative learning also promote communication and collaborative skills that are essential for success in the workplace and in life. To implement group work effectively, teachers must provide clear guidelines and expectations for group members. They should also monitor group work to ensure that all learners are participating and on-task. Teachers can also use group work as an opportunity to assess individual student understanding and participation.
- **Inquiry-Based Learning:** Learners explore and discover new information by asking questions and investigating.
- **Problem-Based Learning:** Learners are given real-world problems to solve and must use critical thinking and problem-solving skills.
- **Project-Based Learning:** Learners work on long-term projects that relate to real-world scenarios.
- **Flipped Classroom:** Learners watch lectures or instructional videos at home and complete assignments and activities in class.
- **Mastery-Based Learning:** Learners learn at their own pace and only move on to new material once they have mastered the current material.
- **Gamification:** Learning is turned into a game-like experience with points, rewards, and competition.

These strategies provide learners with opportunities to engage with the material in meaningful ways and develop important skills such as critical thinking, problem-solving, collaboration, and communication. By incorporating these strategies into their teaching, teachers can help learners develop a deeper understanding of the material and prepare them for success in the real world. Effective communication is essential for learning in the classroom. Teachers must manage talk to ensure that learners are engaged in learning and on-task. Strategies such as structuring

talk for learning, using Diamond Nine activities, and implementing group work/ collaborative learning can help teachers manage talk effectively and promote student learning and engagement. By implementing these strategies, teachers can create a positive and productive learning environment where all learners can succeed.

Universal Design for Learning (UDL) in the SHS Curriculum

The design of the curriculum uses UDL to ensure the creation of flexible learning environments that can accommodate a wide range of learner abilities, needs, and preferences. The curriculum is designed to provide multiple means of engagement, representation, and action and expression, so teachers can create a more inclusive and effective learning experience for all learners. UDL is beneficial for all learners, but it is particularly beneficial for learners needing special support and learners who may struggle with traditional teaching approaches. The integration of UDL in the pedagogy is aimed at making learning accessible to everyone and helping all learners reach their full potential. For instance, teachers need to:

- incorporate multiple means of representation into their pedagogy, such as using different types of media and materials to present information.
- provide learners with multiple means of action and expression, such as giving them options for how they can demonstrate their learning.
- consider incorporating multiple means of engagement into their choice of pedagogy, such as incorporating games or interactive activities to make learning more fun and engaging.

By doing these, teachers can help ensure that the curriculum is accessible and effective for all learners, regardless of their individual needs and abilities.

Curriculum and Assessment Design: Revised Bloom's Taxonomy and Webb's Depth of Knowledge

The design of this curriculum uses the revised Bloom's Taxonomy and Webb's Depth of Knowledge (DoK) as frameworks to design what to teach and assess.

The Revised Bloom's Taxonomy provides a framework for designing effective learning experiences. Understanding the different levels of learning, informed the creation of activities and assessments that challenge learners at the appropriate level and help them progress to higher levels of thinking. Additionally, the framework emphasises the importance of higher-order thinking skills, such as analysis, evaluation, and creation, which are essential for success in today's complex and rapidly changing world. This framework is a valuable tool for educators who want to design effective learning experiences that challenge students at the appropriate level and help them develop higher-order thinking skills. By understanding the six levels of learning and incorporating them into their teaching, educators can help prepare students for success in the 21st century. The six hierarchical levels of the revised Bloom's Taxonomy are:

1. **Remember** – At the foundation is learners' ability to remember. That is retrieving knowledge from long-term memory. This level requires learners to recall concepts—identify, recall, and retrieve information. Remembering is comprised of identifying, listing, and describing. Retrieving relevant knowledge from long-term memory includes, recognising, and recalling is critical for this level.
2. **Understand** – At understanding, learners are required to construct meaning that can be shown through clarification, paraphrasing, representing, comparing, contrasting and the ability to predict. This level requires interpretation, demonstration, and classification. Learners explain and interpret concepts at this level.
3. **Apply** – This level requires learners' ability to carry out procedures at the right time in a given situation. This level requires the application of knowledge to novel situations as well as executing, implementing, and solving problems. To apply, learners must solve multi-step problems.
4. **Analyse** – The ability to break things down into their parts and determine relationships between those parts and being able to tell the difference between what is relevant and irrelevant. At this level, information is deconstructed, and its relationships are understood. Comparing and contrasting information and organising it is key. Breaking material into its constituent parts and detecting how the parts relate to one another and an overall structure or purpose is required. The analysis also includes differentiating, organising and attributing.
5. **Evaluate** – The ability to make judgments based on criteria. To check whether there are fallacies and inconsistencies. This level involves information evaluation, critique, examination, and formulation of hypotheses.
6. **Create** – The ability to design a project or an experiment. To create, entails learners bringing something new. This level requires generating information—planning, designing, and constructing.

Webb's Depth of Knowledge (DoK) is a framework that helps educators and learners understand the level of cognitive engagement required for different types of learning tasks. The framework includes four levels. By understanding the four DoK levels, educators can design learning activities that challenge students to engage in deeper thinking and problem-solving. DoK is an essential tool for designing effective instruction and assessments. By understanding the different levels of DoK, teachers can design instruction and assessments that align with what they intend to achieve. DoK is a useful tool for differentiating instruction and providing appropriate challenges for all learners. Teachers can use DOK to identify students who need additional support or those who are ready for more advanced tasks. The four levels of Webb's' DoK assessment framework are:

- **Level 1: Recall and Reproduction –** Assessment at this level is on recall of facts, concepts, information, and procedures—this involves basic knowledge acquisition. Learners are asked specific questions to launch activities, exercises, and assessments. The assessment is focused on recollection and reproduction.
- **Level 2: Skills of Conceptual Understanding –** Assessment at this level goes beyond simple recall to include making connections between pieces of information. The learner's application of skills and concepts is assessed. The assessment task is focused more on the use of information to solve multi-step problems. A learner is required to make decisions about how to apply facts and details provided to them.
- **Level 3: Strategic Reasoning** – At this level, the learner's strategic thinking and reasoning which is abstract and complex is assessed. The assessment task requires learners to analyse and evaluate composite real-world problems with predictable outcomes. A learner must apply logic, employ problem-solving strategies, and use skills from multiple subject areas to generate solutions. Multitasking is expected of learners at this level.
- **Level 4: Extended Critical Thinking and Reasoning –** At this level of assessment, the learner's extended thinking to solve complex and authentic problems with unpredictable outcomes is the goal. The learner must be able to strategically analyse, investigate, and reflect while working to solve a problem, or changing their approach to accommodate new information. The assessment requires sophisticated and creative thinking. As part of this assessment, the learner must know how to evaluate their progress and determine whether they are on track to a feasible solution for themselves.

The main distinction between these two conceptual frameworks is what is measured. The revised Bloom's Taxonomy assesses the cognitive level that learners must demonstrate as evidence that a learning experience occurred. The DoK, on the other hand, is focused on the context—the scenario, setting, or situation—in which learners should express their learning. In this curriculum, the revised Bloom's taxonomy guided the design, and the DoK is used to guide the assessment of learning. The taxonomy provides the instructional framework, and the DoK analyses the assignment specifics. It is important to note that Bloom's Taxonomy requires learners to master the lower levels before progressing to the next. So, suppose the goal is to apply a mathematical formula. In that case, they must first be able to identify that formula and its primary purpose (remember and understand). The cognitive rigour is therefore presented in incremental steps to demonstrate the learning progression. When measuring assessments in DoK, learners move fluidly through all levels. In the same example, while solving a problem with a formula, learners recall the formula (DoK 1) to solve the problem (DoK 2 and DoK 3). Depending on the difficulty of the problem to be solved, the learner may progress to DoK 4.

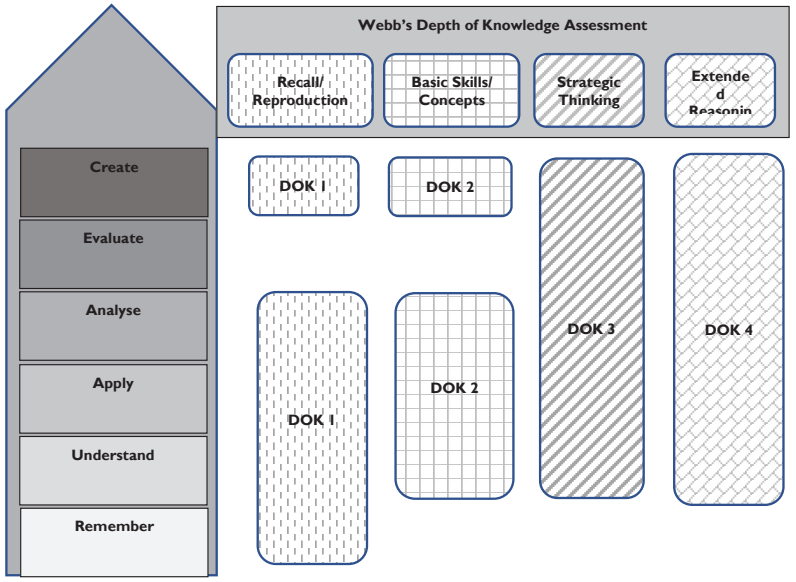

Figure 1: Revised Bloom Taxonomy combined with Webb's Depth of Knowledge for Teaching and Assessment

The structure of teaching and the assessment should align with the six levels of Bloom's knowledge hierarchy and DoK shown in Figure 1. Each level of DoK should be used to assess specific domains of Bloom's Taxonomy as illustrated in the table below:

Depth of Knowledge (DoK) Assessment	Bloom's Taxonomy applied to DoK
• Level 1: Recall and Reproduction	• Remembering, Understanding, Application, Analysis and Creation
• Level 2: Basic Skills and Concepts	• Understanding, Application, Analysis and Creation
• Level 3: Strategic Thinking	• Understanding, Application, Analysis, Evaluation and Creation
• Level 4: Extended Reasoning	• Understanding, Application, Analysis, Evaluation and Creation

In line with the National Pre-Tertiary Learning and Assessment Framework, the Secondary Education Assessment Guide (SEAG) requires that classroom assessments should cover **Assessment as learning (AaL), Assessment of learning (AoL) and Assessment for learning (AfL).** Therefore, teachers should align the Revised Bloom's Taxonomy with the DoK framework of assessment. Formative assessments should include classroom discussions, project-based assignments, and self-reflection exercises, while summative assessments should include standardised tests and rubric-based evaluations of learners' work. It is important to seek feedback from learners themselves, as they may have unique insights into how well they are developing these skills in the classroom.

To assess 21st Century skills and competencies in the classroom, teachers will have to use a combination of both formative and summative assessments to evaluate learners' acquisition of these skills and competencies. For instance:

- Identify the specific 21st Century skills and competencies to be assessed. For instance, you might want to assess *critical thinking, problem-solving, or creativity*.
- Align the skills and competencies with the DoK levels. For example, lower DoK levels might be more appropriate for assessing basic knowledge and comprehension, whereas higher DoK levels might be more appropriate for assessing more complex skills such as *analysis, synthesis, and evaluation*.
- Develop assessment items that align with the DoK levels and the skills and competencies you want to assess. These items should be designed to elicit evidence of learning across the different levels of the DoK framework.
- Administer the assessment and collect data. Analyse the data to gain insights into student learning and identify areas where learners may need additional support or instruction.

The DoK framework is a powerful tool for assessing the acquisition of 21st Century skills and competencies in the classroom, helping teachers to better understand how learners are learning and identify areas for improvement.

Educational success is no longer about producing content knowledge, but rather about extrapolating from what we know and applying the knowledge creatively in new situations.

The overall assessment of learning at SHS should be aligned with the National Pre-Tertiary Learning and Assessment Framework and the Secondary Education Assessment Guide. Formative and summative assessment strategies must be used.

Definition of Key Terms and Concepts in the Curriculum

- **Learning Outcomes:** It is a statement that defines the knowledge, skills, and abilities that learners should possess and be able to demonstrate after completing a learning experience. They are specific, measurable, attainable, and aligned with the content standards of the curriculum. It helps the teachers to determine what to teach, how to teach, and how to assess learning. Also, it communicates expectations to learners and helps them to better master the subject.
- **Learning Indicators:** They are measures that allow teachers to observe progress in the development of capacities and skills. They provide a simple and reliable means to evaluate the quality and efficacy of teaching practices, content delivery, and attainment of learning outcomes.
- **Content Standards:** It is a statement that defines the knowledge, skills, and understanding that learners are expected to learn in a particular subject area or grade level. They provide a clear target for learners and teachers and help focus resources on learner achievement.
- **Pedagogical Exemplars:** They are teaching examples used to convey values and standards to learners. Pedagogical Exemplars are usually demonstrated through teacher behaviour.
- **Assessment:** It is the systematic collection and analysis of data about learners' learning to improve the learning process or make a judgement on learner achievement levels. Assessment is aimed at developing a deep understanding of what learners know, understand, and can do with their knowledge because of their educational experiences. Assessment involves the use of empirical data on learners' learning to improve learning. Assessment is an essential aspect of the teaching and learning process in education, which enables teachers to assess the effectiveness of their teaching by linking learner performance to specific learning outcomes.
- **Teaching and Learning Resources:** Teaching and learning resources are essential tools for teachers to provide high-quality education to their learners. These resources can take various forms, including textbooks, audiovisual materials, online resources, and educational software. It is also important to avoid stereotypes and use inclusive language in teaching and learning resources. This means avoiding language that reinforces negative stereotypes and using language that is respectful and inclusive of all individuals regardless of their background. Using a consistent tone, style, and design is very important.

PHILOSOPHY, VISION AND GOAL OF MANUFACTURING ENGINEERING

Philosophy

An effective education in Manufacturing Engineering needed for sustainable industrialisation and economic growth should provide learners with opportunities and hands-on experiences to expand, change, enhance and modify the ways in which they view the world. This can be achieved when skilled facilitators provide the enabling environment that promotes the construction of learners' own knowledge, based on their prior experiences leading to the development of critical thinkers, problem solvers and innovators equipped with 21st century skills and competencies.

Vision

Equip graduates with the relevant knowledge and skills to design, analyse and control local and global manufacturing processes.

Goal

To adopt hands-on educational priorities to meet the global economic and industrial demands through the training of 21st century graduates and life-long learners for industry and higher education.

Contextual Issues

Manufacturing is key to achieving national development goals and placing Ghana as a competitive economic hub in the West African sub region. Manufacturing industries need highly skilled manpower to support their operations (Examples from AGI). There is, therefore, the need to equip the learner with requisite skills in manufacturing that will let them fit in the manufacturing industry if further study is undertaken or can complete further study in any field of interest with an added advantage of having skills needed to fit in the manufacturing industry.

Manufacturing is a broad discipline that includes products on different scales hence there is a need to customise training programmes to reflect national or regional manufacturing preferences to make it relevant.

Manufacturing requires the fabrication of a product, tool or system. Lack of well-resourced manufacturing laboratories for hands-on practice and fabrication, industries for field studies and skilled technical support staff will affect the development and training of innovative graduates.

Rationale

Manufacturing is an important part of a country's development. When a country is able to manufacture its own products, it boosts industrialisation and enhances economic growth. The study of manufacturing engineering builds on scientific theories to help learners develop the right skills and knowledge for product design, analysis, processing and production.

As humans grow up in an increasingly technological and scientifically advanced world, they need to be scientifically literate to understand issues and be able to manufacture quality products to feed the growing industry in an efficient and cost effective manner.

The provision of quality manufacturing engineering education rests on skilled facilitators creating the right environment with well-equipped resources for learners to be creative, innovative and critical thinkers equipped with the right skills for industry and higher education.

MANUFACTURING ENGINEERING CURRICULUM DEVELOPMENT PANEL

WRITERS		
	Name	Institution
1.	Dr. Samuel Boahen	Kwame Nkrumah University of Science and Technology
2.	Dr. Mizpah Ama D. Rockson	Kwame Nkrumah University of Science and Technology
3.	Issahaku Iddrisu	Ada Senior High Technical School
REVIEWERS		
	Name	Institution
1.	Prof. Francis Davis	Kwame Nkrumah University of Science and Technology
CURRICULUM WRITING GUIDE TEAM		
	Name	Institution
1.	Prof. Winston Abroampa	Kwame Nkrumah University of Science and Technology
2.	Cosmos Eminah	University of Education, Winneba
3.	Aaron Akwaboah	Ministry of Education
4.	Evans Odei	Achimota School
5.	Paul Michael Cudjoe	Prempeh College
6.	Ahmed Amihere	University of Education, Winneba

NaCCA TEAM			
1.	Prof. K. O. Kwarteng	12.	Bridget Anku
2.	Prof. Edward Appiah	13.	Anthony Sarpong
3.	Mr. Matthew Owusu	14.	Seth Nii Nartey
4.	Reginald Quartey	15.	Kenneth Wontumi
5.	Joana Vanderpuije	16.	Sharon Antwi-Baah
6.	Anita Collison	17.	Dennis Adjasi
7.	Rebecca Abu Gariba	18.	Ogyampo S. Amankwah
8.	Genevieve Mensah	19.	Abigail Owusu Oduro
9.	Veronica Odom	20.	Priscilla B. Plange
10.	Joachim Seyram Honu	21.	Abigail Birago Owusu
11.	Dr. Mercy Nyamekye	22.	Uriah Otoo

EXTERNAL QUALITY ASSURANCE TEAM			
1.	Prof. Kwame Akyeampong	4.	Dr. Esinam Avornyo
2.	Dr. Jane Cullen	5.	Dr. Christopher Yaw Kwaah
3.	Dr. Sean Higgins		

SCOPE AND SEQUENCE

Manufacturing Engineering Summary

S/N	STRAND	SUB-STRAND	YEAR 1			YEAR 2			YEAR 3		
			CS	LO	LI	CS	LO	LI	CS	LO	LI
1.	Materials for Manufacturing	Classification of Materials	2	1	4	2	1	6	2	1	5
		Properties of Materials	2	1	4	2	1	4	2	1	4
2.	Design and Prototyping	Design and Drawing for Manufacturing	2	1	4	3	1	6	2	1	4
		Rapid Prototyping	2	1	4	1	1	2	2	1	4
3	Manufacturing Tools, Equipment and Processes	Manufacturing Tools and Equipment	2	1	4	2	2	4	2	2	4
		Manufacturing Processes	2	1	2	2	1	4	2	1	4
		Safety, Quality and the Environment	2	2	2	2	1	5	2	2	5
Total			**14**	**8**	**24**	**14**	**8**	**31**	**14**	**9**	**30**

Overall Totals (SHS 1 – 3)

Content Standards	42
Learning Outcomes	25
Learning Indicators	85

YEAR ONE

Subject **MANUFACTURING ENGINEERING**
Strand **1. Materials for Manufacturing**
Sub-Strand **1. Classification of materials**

Learning Outcomes	**21st Century Skills and Competencies**	**GESI[1], SEL[2] and Shared National Values**
1.1.1.LO.1		
Demonstrate understanding of the performance of materials.	**Collaboration and Communication:** • Learners collaborate and communicate respectfully in collecting materials to the classroom, grouping them, and discussing the relationship between materials science and materials engineering. • Learners collaborate in groups to identify and classify materials as metals or non-metals • Learners in think-pair-shares communicate respectfully to group materials according to their industrial use **Critical Thinking:** Learners brainstorm and discuss the career path of materials science and engineering. **Collaboration, Communication and Presentation Skills, and Critical Thinking:** Learners in think-pair-shares communicate respectfully in identifying materials, processing methods, and performance. Learners think critically and share their ideas in groups and also receive feedback from their group members.	**GESI:** Creating an inclusive learning environment that support all learners and using varying kinds of group activities ensures; • respect and tolerance for diversity and views of differently abled learners. • awareness of self and uniqueness of others. • promotion of interrelationships and recognising others' strengths and weaknesses and supporting one another, especially girls in a male dominated discipline. **SEL:** Using interactive and group pedagogies that are inclusive will enable learners; • set group target and learn to work with others to achieve them • tolerate others' opinion and examine their own opinion, decisions and conclusions drawn on issues and be collectively and individually responsible for decisions made.

[1] Gender Equality and Social Inclusion
[2] Socio-Emotional Learning

		• learn to manage their emotions and sentiments during group discussions and when peers critique contributions. **National Core Values**: • Accountability • Honesty • Respect and tolerance of diversity • Responsibility

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.1.1.CS.1	1.1.1.LI.1	1.1.1.AS.1
Demonstrate knowledge and understanding of the fundamentals of engineering materials.	**Explain the relationship between materials science and engineering.** **Experiential Learning/Nature Walk:** Learners go around their community in mixed-ability groups, bring to the classroom, different materials available in their communities, and group materials such as stone, wood, clay, skin, plastics, etc. into metals and non-metals, polymers, composite materials, and semiconductors. **Collaborative Learning:** In mixed-ability groups, write and relate the relevance of the materials identified in driving technological advancement in industries. For example, steel helps in the development of automobiles while semiconductors are used in the electronic industry. Learners think-pair-share and relate materials' structure, processing, properties, and performances based on their observations from the educational tour and present their results for feedback. Use mind maps or webbing to structure learners' contributions. **Talk for Learning Approaches:** • In different task and jigsaw groups, learners discuss the relationship between materials science and materials engineering and their career paths in industry and academia (such as Design engineers, Materials Engineers, Metallurgists, Product or Process Scientists, Research Scientists, Technical Sales Engineers, Computer-Aided Design Engineers etc.). Learners return to their mother groups to present and discuss what they did in the other groups. • In different task mixed ability or gender groups, learners discuss the effect of material processing on their structure, properties, and performance using the materials brought to class as case studies and share findings with the class. • In same groups, learners mention any structure of properties of the materials they brought in class and suggest the possibilities of inducing these properties into a mater. Use tables or webbing to organise presentations for learners. **Experiential Learning:** Learners embark on a tour to any local material manufacturing or processing site to observe the methods used for material processing and the anticipated performance enhancement. Learners share observations with the class in a respectful manner.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Textbooks • Educational tour	• Locally available materials

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.1.1.CS.2	1.1.1.LI.1	1.1.1.AS.1
Demonstrate knowledge and understanding of how to classify materials according to their use.	**Distinguish between different kinds of materials according to their use.** **Collaborative Learning:** In mixed-ability groups, leaners identify different materials used to produce components and group them under metallic and non-metallic materials. Let learners share findings with the class while encouraging them to tolerate critiques and contributions.	**Level 1 Recall** Level 2 Skills of conceptual understanding Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
	1.1.1.LI.2	1.1.1.AS.2
	Group materials based on their applications i.e., clothing, building, food automobiles, electronic, medical. **Talk for Learning:** Learners think-pair-share and group components according to their application in the clothing, building, automobile, food processing and electronic industries and identify the materials used in producing the components in the various industries such as: • Clothing Industry: Cotton, wool, silk, leather, fibers etc. • Building Industry: Wood, earth, cement, steel, plastic, stone, glass, bamboo, carbon fibre, straw etc. • Automobile Industry: Steel, rubber, plastics, aluminium etc. • Food processing industry: Raw materials (fish, nuts, fruits, vegetables etc.), stainless steel, plastics, paper, glass, aluminium etc. Electronic Industry: Semi-conductors, Medical Industry: Biomaterials Structure contributions of pairs using webbing or concept maps. Encourage learners to respect and tolerate others' contributions and critiques.	Level 1 Recall **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Textbooks	

Subject **MANUFACTURING ENGINEERING**
Strand **1. Materials for Manufacturing**
Sub-Strand **2. Properties of Materials**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
1.1.2.LO.1		
Examine the physical and mechanical properties of materials.	**Collaboration:** Learners collaborate, interact and share ideas while working in groups and pairs. **Communication and Presentation Skills:** Learners communicate respectfully to perform the experiment and present their results to the class. **Critical Thinking:** Learners observe and critically analyse the changes in the behaviour of the properties of water and metal and relate these changes to their thermal properties. **Collaboration, Communication and Critical Thinking:** Learners collaborate in groups to identify and communicate the magnetic properties of materials and receive feedback.	**GESI:** Providing the opportunity for diverse learners to actively participate in all lessons in an inclusive manner and using GESI responsive language as pedagogy ensures; • awareness of personal biases and stereotypes of especially girls in engineering programmes. • respect and tolerance for individuals' uniqueness and peculiarities. • sensitivity to the interrelatedness of the various spheres of life, groups and individuals. **SEL:** Whiles working in mixed ability groups and interact with peers, learners; • accept critiques to enable them examine their opinions and thought processes. • respect others' opinions and learn to manage their emotions when contributions are challenged. **National Core Values:** • Patriotism • Faithfulness • Honesty

		• Loyalty • Discipline • Respect • Humility • Assertiveness • Good Citizenship

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.1.2.CS.1	1.1.2.LI.1	1.1.2.AS.1
Demonstrate knowledge and understanding of the physical properties of materials.	**Explain thermal conductivity, specific heat capacity, thermal expansion, melting point and thermal diffusivity as thermal properties of materials.** **Experiential Learning:** In mixed-ability groups, learners heat a metal iron and boil water in the laboratory, observe the changes in the behaviour of the metal iron and water when heat is passed through them and present their findings to the class. Encourage them to accept criticisms and contributions made by others. **Talk for Learning:** Based on the observations made in the heating of the metal iron and water, discuss with learners the thermal properties of materials such as thermal conductivity, specific heat capacity, thermal expansion, melting point and thermal diffusivity. Use concept maps to structure contributions.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	1.1.2.LI.2	1.1.2.AS.2
	Explain electrical conductivity, electrical resistivity, dielectric strength and temperature coefficient of resistance as electrical properties of materials. **Research-Based Learning:** Learners read from the library or Internet or watch videos on the electrical properties of materials (e.g., electrical conductivity, electrical resistivity, dielectric strength and temperature coefficient of resistance) and share summaries in class. **Experiential Learning:** In mixed-ability groups, learners perform electrical conductivity test for water and hydrochloric acid, measure the electrical properties of the water and hydrochloric acid and present their results to the class for feedback. Encourage groups to accept and tolerate feedback given by peers.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Metal iron • Water • Heat source	• Laboratory • Textbook • Electrical conductivity test equipment • Hydrochloric acid • Audio-visuals • Projectors

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.1.2.CS.2	1.1.2.LI.1	1.1.2.AS.1
Demonstrate knowledge in the mechanical properties of materials.	**Explain hardness, brittleness, ductility, strength, malleability, toughness, elasticity and plasticity as mechanical properties of materials.** **Research-Based Learning:** Learners in mixed-ability groups read from the library and Internet on the mechanical properties of materials (i.e. hardness, brittleness, ductility, strength, malleability, toughness, elasticity and plasticity) and let each group present their findings to the class and receive feedback. **Talk for Learning:** In a class, learners discuss the importance of the mechanical properties of materials in product design. Summarise views using webbing or mind maps.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	1.1.2.LI.2	1.1.2.AS.2
	Explain permeability, retentivity and reluctance as magnetic properties of materials. **Research-Based Learning:** In mixed-ability groups, learners research on the magnetic properties of materials such as permeability, retentivity and reluctance from the library or Internet and present their findings to the class to receive feedback. **Talk for Learning:** In a class, discuss the relevance of the magnetic properties of materials to the manufacturing industries. Summarise views using concept maps or webbing.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Textbooks • Internet access • Library	• Library resource • Internet access • Audio-visuals • Projectors

Subject **MANUFACTURING ENGINEERING**
Strand **2. Design and Prototyping**
Sub-Strand **1. Design and Drawing for Manufacture**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
1.2.1.LO.1		
Use drawing instruments properly to draw the borderline and title block for a drawing.	**Communication Skills:** Learners communicate as they explain uses of tools.	**GESI:** As facilitators steer discussions, they are mindful to stay off biases, stereotypes, and prejudices and place efforts to provide well-balanced examples. This will make learners; • aware of their personal biases and stereotypes, embrace diversity, and practice inclusion. • embrace tolerance and empathy among each other. • develop emotional intelligence as others critique their submissions. learn to listen to others of different gender and abilities, thus developing tolerance and listening skills. **SEL:** Using inclusive and interactive pedagogies will enable learners; • examine their opinions and that of others to enable them make informed decisions. • interact meaningfully and respectfully with peers while tolerating their views. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

1.2.1.LO.2		
Apply the principle of development of surfaces to develop products.	**Collaboration, Creativity, Critical Thinking, Communication and Presentation Skills:** Learners interacting in mixed ability groups share ideas and communicate. Learners critically examine principles and apply them creatively in developing products.	**GESI:** Promoting inclusivity in the classroom by encouraging every learner to actively participate in lessons, cross sharing of ideas and thoughts between and among groups and individuals ensures; • respecting individuals of varying beliefs, religion and cultures. • being sensitive to the inter-relatedness of the various spheres of life, groups and individuals. • being aware of personal biases and stereotypes. • embracing diversity and practice inclusion. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work • Integrity
1.2.1.LO.3		
Explain the use of the design process in solving problems.	**Collaboration, Critical Thinking, Creativity, Communication and Presentation Skills:** Learners in mixed-ability groups interact with one another and examine the use of the design process in solving problems.	**GESI:** As all learners are supported in an inclusive environment and given equal opportunities, they will; • appreciate, value, and embrace diversity as they are made to work in groups. • learn to amicably resolve conflicts and embrace differing opinions. • develop emotional intelligence as their submissions are critiqued by others. **SEL:** Working in groups in an inclusive setting that supports all learners ensures that learners; • interact with peers and set group goals and pull resources to achieve them. • manage their emotions as they interact with colleagues while tolerating one another's views.

		National Core Values: • Tolerance • Integrity • Accountability • Humility • Assertiveness • Patriotism
1.2.1.LO.4		
Use freehand sketches and visualisation of objects to express a design idea.	**Creativity, Critical thinking, Collaboration and Communication:** Learners think critically and creatively to create a design concept using freehand sketching. Learners discuss their design concepts with group members and receive feedback.	**GESI:** As all learners are supported in an inclusive environment and given equal opportunities they will; • embrace tolerance and empathy among themselves. • learn to resolve conflicts and embrace differing opinions amicably. • develop emotional intelligence as others critique their submissions. **National Core Values:** • Tolerance • Integrity • Accountability • Humility • Assertiveness • Patriotism

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.2.1.CS.1	1.2.1.LI.1	1.2.1.AS.1
Demonstrate knowledge and skill in the development of surfaces.	**Demonstrate the use of drawing instruments in product design.** **Talk for Learning**: Through questioning, ask learners to bring drawing instruments (such as pencils, protractor, compass, divider, set squares, clippers, Tee-square, drawing board, drawing sheet, eraser, French curves, scale rule, circle and ellipse templates, etc.) to class and let learners identify them and their uses. **Practice-Based Learning:** Let learners practice the use of their drawing instruments to set out drawing sheets on the drawing board and draw boarder lines and Title blocks. Learners display their drawing for others to critique.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	1.2.1.LI.2	1.2.1.AS.2
	Develop the surfaces of models for manufacturing. **Experiential Learning:** Using paper boxes, learners in mixed-ability groups fold and unfold empty boxes along their lines to understand the principle of development of surfaces. **Talk for Learning:** Learners discuss the methods of development of surfaces such as parallel-line development, radial-line development, triangulation development and approximate development. Learners add to what others say. Organize contributions using webbing. **Project-Based Learning**: Learners in mixed-ability groups develop cones and cylinders at the workshop using the principle of surface development and present their works in class.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	1.2.1.LI.3	1.2.1.AS.3
	Demonstrate understanding of the design process. **Talk for Learning:** Using a typical problem in the community, lead learners to discuss the design process, focusing on; • Defining the problem • Research/asking questions to understand the problem	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning**

	• Brainstorming potential solutions (conceptual designs) • Deciding on a solution using evaluation criteria essential to the solution • Developing the solution • Making a prototype of the solution • Testing the prototype • Improving the design based on results from the test **Experiential Learning:** Learners in mixed-ability groups use the design process to propose solutions to a typical problem in their community and present their solutions to the class. Groups critique what others have done in a respectful and tolerant manner.		**Level 4 Extended critical thinking and reasoning**
	1.2.1.LI.4		1.2.1.AS.4
	Demonstrate the importance of freehand sketching and visualisation of objects in the design of products. **Project-Based Learning:** Let learners in think-pair-share use only pencil, paper and eraser to sketch any idea or concept they may want to design using freehand. Learners discuss their sketches and give feedbacks.		**Level 1 Recall** Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Drawing instruments • Paper boxes	• Textbooks • Metal sheets	• Supplementary reading materials. • Drawing instruments

Subject **MANUFACTURING ENGINEERING**
Strand **2. Design and Prototyping**
Sub-Strand **2. Rapid Prototyping**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
1.2.2.LO.1		
Explain the principles and essence of rapid prototyping for product development.	**Critical Thinking:** • Learners think critically to characterise components manufactured through conventional and rapid prototyping. • Learners think critically to identify the principles and process of rapid prototyping from a video. **Communication Skills:** • Learners clearly explain the difference between conventional prototyping and rapid prototyping using the components provided in class. • Learners present their results to the class and receive feedback. **Collaboration:** Learners in mixed-ability groups discuss the principles and process of rapid prototyping. **Collaboration, Critical Thinking and Presentation Skills:** Learners in mixed-ability groups, think critically to identify and present to the class on the advantages and disadvantages of rapid prototyping **Critical Thinking and Communication:** Learners think critically to identify and communicate the industrial applications of rapid prototyping.	**GESI:** Ensuring all learners participate in class irrespective of the diversity in ability, socio-cultural backgrounds and gender, and soliciting contributions from all learners ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • knowledge of themselves and others' peculiarities, strength and weaknesses. • tolerance for diversity and respect for all. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.2.2.CS.1	1.2.2.LI.1	2.3.1.AS.1
Demonstrate knowledge and understanding of the basic principles of product prototyping and product development.	**Explain the fundamental difference between conventional prototyping and rapid prototyping.** **Experiential Learning:** Bring sample components manufactured using conventional prototyping (e.g. welding, machining) and one manufactured using rapid prototyping (e.g. 3D printing) to class and let learners describe the characteristics of each component. Use concepts maps to organise characteristics of the two **Talk for Learning:** Learners tell the major difference between conventional prototyping and rapid prototyping considering the technologies used and how quick the work pieces are produced. Encourage learners add to what others say and organize their contribution using webbing.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	1.2.2.LI.2	1.2.2.AS.2
	Discuss the principles and process of rapid prototyping. **Experiential Learning:** Show learners a video of a typical rapid prototyping process, typically 3D printing, from start to finish. **Collaborative Learning:** Learners in mixed-ability groups identify the main process of rapid prototyping such as creation of a 3D computer aided design (CAD) model of the part to be designed, conversion of the CAD model into a Standard Tessellation Language (STL) file, format slicing of the STL file into thin layers and sections, construction of the part layer by layer and post processing of the part (cleaning, joining, finishing etc.). Let learners present their results to the class and receive feedback.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Sample components manufactured using conventional prototyping and rapid prototyping • Audio-visuals • Textbooks	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.2.2.CS.2	1.2.2.LI.1	1.2.2.AS.1
Demonstrate that prototyping is essential for product development.	**Explain the advantages and disadvantages of rapid prototyping.** **Research-Based Learning:** Learners in mixed-ability groups read from the library on the advantages and disadvantages of rapid prototyping and present their findings in class to receive feedback from their colleagues. Let learners add to what others say and organize their views.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	1.2.2.LI.2	1.2.2.AS.2
	Discuss the applications of rapid prototyping in manufacturing. **Talk for Learning:** Show learners videos of the applications of rapid prototyping and lead learners to discuss the industrial applications of rapid prototyping with focus on mechanical engineering analysis and planning, medicine, electrical, textile and the arts industries.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Library resources • Textbooks • Internet access • Audio-visuals	

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing tools, equipment and processes**
Sub-Strand **1. Manufacturing tools and equipment**

Learning Outcomes	**21st Century Skills and Competencies**	**GESI, SEL and Shared National Values**
1.3.1.LO.1		
Apply the principles of marking out, measurement and gauging; and accurately use industry standards in manufacturing a product.	**Communication:** • Learners discuss the dimensioning of objects using coordinate systems. • Learners discuss the importance of standard units of measurements in the manufacturing industry. **Collaboration:** Learners in mixed-ability groups mark out dimensions and cut metal sheets. **Critical Thinking:** Learners brainstorm to set datum, and dimensions and cut work pieces. **Collaboration, Critical Thinking and Communication:** Learners in mixed-ability groups critically think to mark out the outline of a rectangular shape on a work piece. **Collaboration, and Presentation Skills:** Learners in mixed-ability groups research the standard units of measurement and present their results to the class. **Collaboration and Critical Thinking:** Learners in mixed-ability groups identify measuring gauges in the workshop, discuss their use and use the measuring gauges to measure the dimensions of a work piece.	**GESI:** Using GESI responsive pedagogies and language that supports all learners in an inclusive setting will; • enable learners to freely ask questions without intimidation. • help learners to embrace empathy and discipline among themselves. • help learners to be disciplined as deadlines are given for their projects. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.3.1.CS.1	1.3.1.LI.1	1.3.1.AS.1
Demonstrate knowledge and understanding of marking out and measurement.	**Set the datum for a work piece and select coordinates systems for dimensioning an object.** **Talk for Learning:** Discuss with learners the dimensioning of an object using cartesian, rectangular, and polar coordinate systems. Learners, in their mixed-ability groups, use the three types of a datum to mark out a rectangular shape on a cardboard. **Project-Based Learning:** • Learners in mixed-ability groups mark out and cut a rectangular shape of any dimension from a cardboard using a point, centre line, or edge as the datum. • Learners in think-pair-share use the cartesian, rectangular, and polar coordinate systems to dimension a rectangular metal component, discuss their results with colleagues, and receive feedback. Encourage learners to accept and respect contributions from peers.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	1.3.1.LI.2	1.3.1.AS.2
	Produce a mark out on a work piece. **Talk for Learning:** Lead learners to discuss the importance of marking out a work piece such as determining the outline of a work piece and the position of holes and slots. Encourage learners to add to what others say. **Experiential Learning:** Learners in mixed-ability groups mark out and cut rectangular shapes from metal sheets or wood using the necessary marking-out tools. Learners display works for others to critique and accept contributions	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Cardboard • Rectangular metal components • Wooden or metal work piece • Marking out tools	

<table>
<tr><th>Content Standards</th><th>Learning Indicators and Pedagogical Exemplars with 21st Century and GESI</th><th>Assessment</th></tr>
<tr><td>1.3.1.CS.2</td><td>1.3.1.LI.1</td><td>1.3.1.AS.1</td></tr>
<tr><td rowspan="3">Demonstrate knowledge and understanding of standards, measurement, and gauging in the manufacturing process.</td><td>Understand standard units of measurement for work pieces.

Collaborative Learning: Learners in mixed-ability groups read from the library and Internet on the standard units of measurement for work pieces, present their results to the class and receive feedback.

Talk for Learning: In pairs, learners discuss and share the importance of using standard measurements (such as linear and angular measurements) in the manufacturing industry e.g., for uniformity, quality, and accuracy.</td><td>Level 1 Recall
Level 2 Skills of conceptual understanding
Level 3 Strategic reasoning
Level 4 Extended critical thinking and reasoning</td></tr>
<tr><td>1.3.1.LI.2</td><td>1.3.1.AS.2</td></tr>
<tr><td>Describe and use gauges to measure the dimensions of a work pieces.

Collaborative Learning: Learners in mixed-ability groups identify and explain the use of measuring tools and gauges (such as vernier callipers, micrometre screw gauges, steel scales, vernier height gauges, vernier depth gauges, bevel protractors, dial gauges, engineering square, V-block and radius gauge) in the workshop.

Experiential Learning: In small groups learners use measuring tools and gauges to measure the dimensions of a work piece. Let learners share their work with others for comments.</td><td>Level 1 Recall
Level 2 Skills of conceptual understanding
Level 3 Strategic reasoning
Level 4 Extended critical thinking and reasoning</td></tr>
<tr><td>Teaching and Learning Resources</td><td colspan="2">• Textbooks
• Library resources
• Internet access
• Measuring tools and gauges
• Work pieces</td></tr>
</table>

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing tools, equipment and processes**
Sub-Strand **2. Manufacturing Processes**

Learning Outcomes	**21st Century Skills and Competencies**	**GESI, SEL and Shared National Values**
1.3.2.LO.1		
Apply the principles of bulk deformation and sheet metal working to roll, forge, cut, bend and draw metal sheets.	**Collaboration:** Learners in think-pair-share discuss the basics of metal forming. **Critical Thinking:** Learners identify the fundamentals of metal forming. **Communication and Presentation Skills:** Learners discuss and make presentations on the fundamentals of metal forming. **Collaboration, Communication and Presentation Skills:** Learners in mixed-ability groups research on bulk deformation forming processes and make presentation to the class to receive feedback. **Communication, Collaboration and Critical Thinking:** Learners in think-pair-share groups critically think and discuss dies and presses used for sheet metal working operations. **Creativity, Collaborations, Communication and Presentation Skills:** Learners in mixed-ability groups creatively manufacture components using sheet metal working processes and present their products to the class for feedback.	**GESI:** Given equal opportunities to all learners irrespective of their background and soliciting views from all learners ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • sensitivity to the inter-relatedness of the various spheres of life, groups and individuals. • awareness of personal biases, peculiarities and stereotypes. • tolerance for diversity. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work • Honesty • Truthfulness

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.3.2.CS.1	1.3.2.LI.1	1.3.2.AS.1
Demonstrate knowledge and understanding of the principles of bulk deformation and sheet metal working to roll, forge, cut, bend and draw metal sheets.	**Understand the fundamentals of metal forming.** **Experiential Learning:** • Show learners videos of metal forming processes in the metal working industry. • Learners think-pair-share basic processes in metal forming and present their findings in class. Organise learners' thoughts using mind mapping.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	1.3.2.LI.2	1.3.2.AS.2
	Discuss rolling, forging and extrusion as bulk deformation forming processes. **Experiential Learning:** Take learners on an educational tour to local metal working industries to observe rolling, forging and extrusion as metal forming processes. **Research-Based Learning:** Let learners in mixed-ability groups read on rolling, forging, and extrusion from the library or Internet, make presentations on these bulk deformation and forming processes to the class and receive feedback. **Project-Based Learning:** Let learners in mixed ability groups perform a metal rolling operation at the workshop and present results in class for feedback. Encourage and tolerate comments from colleagues.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Visuals • Projectors • Textbooks • Library resources • Educational tours • Internet access • Audio visuals	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.3.2.CS.2	1.3.2.LI.1	2.3.2.AS.1
Demonstrate knowledge and understanding of standards, measurement and gauging in the manufacturing process.	**Recognize and identify dies and presses used for sheet metal working operations.** **Talk for Learning:** • Show learners videos and charts of dyes and presses used for sheet metal working operations. • Learners discuss the difference and operating principles of the dies and presses used for sheet metal working and receive feedback.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	1.3.2.LI.2	1.3.2.AS.2
	Discuss cutting, bending and drawing as sheet metal working operations. **Project-Based Learning:** Learners in mixed ability groups manufacture components using cutting, bending and drawing of metal sheets at the workshop. Let learners present their products to the class and describe how the components were manufactured. Encourage groups to tolerate comments of colleagues and examine them critically.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Videos and charts of dies and presses used for sheet metal working • Supplementary textbooks • Workshop	• Metal cutting • Bending and drawing tools.

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing Tools, Equipment and Processes**
Sub-Strand **3. Safety, Quality and the Environment**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
1.3.3.LO.1		
Describe the importance of safety, health and environmental considerations for the manufacturing industry.	**Critical Thinking:** Learners think critically to identify the various forms of potential hazards at the workplace. **Communication and Presentation Skills:** Learners communicate and discuss the potential workplace hazards. **Communication, Collaboration and Critical Thinking:** Learners in mixed ability groups discuss and research on the general safety practices at the workplace.	**GESI:** Using mixed-ability and mixed-gender pairing, special attention given to the catch-up, regular and gifted and talented learners leads to; • respecting individuals of varying abilities, beliefs, religion and cultures. • being sensitive to the inter-relatedness of the various spheres of life, groups and individuals. • being aware of personal biases and stereotypes. • embracing diversity and practice inclusion. **National Core Values:** • Integrity • Tolerance • Open-mindedness • Patience • Integrity • Hard work

1.3.3.LO.2		
Explain the positive and negative effects manufacturing industries have on the society.	**Communication, Collaboration and Critical Thinking:** • Learners in mixed ability groups discuss the various social and economic consequences of manufacturing activities on the individual, and the society respectively. • Use (3 or 4) pyramid discussion to get learners to share their opinions on how the manufacturing industry affects the local and international economies. Let various pyramids share collated views with class.	**GESI:** Using mixed-ability and mixed-gender pairing, special attention given to the catch-up, regular and gifted and talented learners leads to; • respecting individuals of varying abilities, beliefs, religion and cultures • being sensitive to the inter-relatedness of the various spheres of life, groups and individuals. • being aware of personal biases and stereotypes. • embracing diversity and practice inclusion. **National Core Values:** • Integrity • Tolerance • Open-mindedness • Patience • Integrity • Hard work

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.3.3.CS.1	1.3.3.LI.1	1.3.3.AS.1
Demonstrate an understanding of the importance of workplace safety and workplace organizational hazards.	**Identify potential hazards in the workspace.** **Collaborative Learning:** • Show learners a video of a manufacturing workplace and let them identify the various potential hazards at the workplace. • In different task groups, identify various types of workplace hazards and present results to the class. Encourage learners to respectfully comment on presentation and tolerate criticism.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning: Level 4 Extended critical thinking and reasoning
	1.3.3.LI.2	1.3.3.AS.2
	Follow general safety practices in the workplace. **Experiential Learning:** Show learners a video of a manufacturing setting and let them identify the various safety practices to be followed at vantage locations at the workplace. **Talk for Learning:** In pairs learners discuss the general safety practices at the workplace and share with the class. **Research-Based Learning**: Learners in mixed - ability and gender groups research on the general safety practices to be followed at the workplace, present their findings to class, and receive feedback.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Audio visuals • Projector and video resources	• Textbooks • Internet access.

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.3.3.CS.2	1.3.3.LI.1	1.3.3.AS.1
Demonstrate an understanding of ways in which the manufacturing industry affects society.	**Describe the social and economic consequences that a manufacturing activity can have or has on individuals and the society.** **Research-Based Learning:** Learners in mixed-ability groups research from online and textbooks the social and economic consequences of manufacturing activities on individuals and the society and present their findings to the class to receive feedback. **Talk for Learning:** Learners discuss the major social and economic consequences of manufacturing activities on the structure and development of the society. Learners add to what others say. Organize views using webbing.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	1.3.3.LI.2	1.3.3.AS.2
	Explain how the manufacturing industry affects the local and international economy (e.g., with respect to job creation, standards of living, sustainability and conservation of the environment.) **Talk for Learning:** In different task groups learners discuss the major effects of the manufacturing industry on the local and international economy with respect to job creation; standards of living; sustainability and conservation. Each group presents to the class for additions and questions. **Practice-Based Learning:** Through questions and answer sessions learners share their opinions on the effects of the manufacturing industry on the economy of the country in specific, and present their findings to class for assessment, and receive feedback.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Textbooks • Internet access	• Supplementary materials

YEAR TWO

Subject **MANUFACTURING ENGINEERING**
Strand **1. Manufacturing Materials and Technologies**
Sub-Strand **1. Classification of Materials**

Learning Outcomes	21st Century Skills and Competencies	GESI[3], SEL[4] and Shared National Values
2.1.1.LO.1		
Classify materials as metals, ceramics and polymers based on their chemical properties, structure, synthesis and processing methods.	**Collaboration:** • Learners collaborate in collecting materials to the classroom. • Learners work in groups to understand the meaning of reactivity, flammability and toxicity as chemical properties of materials. • Learners collaborate and communicate respectfully in researching on crystalline and amorphous materials. • Learners work together in groups to identify and classify material processing methods • Learners work in groups to classify materials based on their synthesis methods. **Communication Skills:** Learners communicate respectfully in collecting materials to the classroom. **Critical Thinking:** • Learners think critically to group materials based on their chemical properties, share their ideas in groups and receive feedback. • Learners read through textbooks and critically identify and document the chemical properties of materials. • Learners think critically and group materials based on their structure. • Learners think critically to identify and classify material processing methods	**GESI:** Ensuring all learners in class irrespective of the diversity in ability, socio-cultural backgrounds, gender participate, and soliciting contributions from all learners ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • knowledge of themselves and others' peculiarities, strength and weaknesses. • tolerance for diversity and respect for all. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

[3] Gender Equality and Social Inclusion
[4] Socio-Emotional Learning

	Communication and Presentation Skills: • Learners communicate respectfully to document the chemical properties of materials and present their findings for feedback. • Learners share their ideas in groups, receive feedback from group members and present their results to the class. • Learners present their findings on the classification of materials based on their synthesis methods to the class.	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.1.1.CS.1	2.1.1.LI.1	2.1.1.AS.1
Demonstrate knowledge and understanding of chemical properties and structure of materials.	**Group materials as metals, ceramics and polymers based on their chemical properties.** **Explorative Learning:** Let learners go round their community and bring to the classroom, different materials available in their communities. **Collaborative Learning**: • Learners in mixed ability groups identify and group materials into metals and non-metals (such as polymers and ceramic materials). • Learners think-pair share and write the chemical properties (composition, microstructure and corrosion resistance) that distinguish metals from non-metals and relate these properties to their processing and use. • Learners mention any considerations to be made when processing metals for use in a specific environment due to their chemical properties.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.1.1.LI.2	2.1.1.AS.2
	Explain the chemical properties of materials as reactivity, flammability and toxicity. **Collaborative Learning:** Learners in mixed-ability groups read from the library on reactivity, flammability and toxicity as chemical properties of materials and present their results to the class for feedback. **Talk for Learning:** Learners group materials available in the local community based on their reactivity, flammability and toxicity using tables. Use questioning for learners to talk about the various materials. Use mind mapping to organise learners' thoughts.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.1.1.LI.3	2.1.1.AS.3
	Classify materials based on their structure. **Collaborative Learning:** Put learners into mixed-ability groups and let them visit the library and read on crystalline and amorphous materials. Learners think-pair-share and explain the	Level 1 Recall **Level 2 Skills of conceptual understanding**

	difference between crystalline solids and amorphous materials based on their structure and present their results to the class.		**Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Textbooks • Educational tour around the community	• Library • Audio-visuals	• ICT equipment

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.1.1.CS.2	2.1.1.LI.1	2.1.1.AS.1
Demonstrate understanding in materials processing and synthesis.	**Identify types of materials processing methods.** **Experiential Learning:** Show learners videos of material processing methods. **Collaborative Learning:** Let learners in mixed-ability groups identify, from the video, the types of materials processing methods such as shaping processes, property-enhancing processes and surface processing operations. **Experiential Learning:** Lead learners to classify material processing methods available in their communities into shaping processes, property-enhancing processes and surface processing operations.	**Level 1 Recall** Level 2 Skills of conceptual understanding Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
	2.1.1.LI.2	2.1.1.AS.2
	Classify materials as metals, ceramics and polymers according to their processing methods. **Experiential Learning:** Take learners on a tour to any available material processing company available in the community (e.g. saw mill, foundry etc.) to observe the processing of raw materials into materials that can be used to manufacture products. In the absence of a company, let learners watch on YouTube and share their thoughts. **Collaborative Learning:** Learners in mixed-ability groups identify raw materials available in their community. For example, timber, cocoa, rubber, cotton leather, gold, iron ore etc., and the materials they can be processed into (for example, Timber into wood, cocoa into cocoa powder, cotton into fabric, iron ore into steel etc.). **Talk for Learning:** Learners to identify the processes used in converting a raw material into a processed material. e.g., sawing process to convert timber into wood, smelting process to turn iron ore into steel, spinning and weaving process to turn cotton into fabric etc.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	2.1.1.LI.3	2.1.1.AS.3
	Group materials according to their synthesis.	**Level 1 Recall** **Level 2 Skills of conceptual understanding**

	Collaborative Learning: Learners, in mixed-ability groups read from the library and present to the class on how materials can be synthesised to form new materials. Encourage them to comment on presentations and tolerate others' views **Talk for Learning:** • In pairs, let learners discuss and share their understanding of material synthesis and classify materials to be synthesised as bulk materials, nanomaterials and thin films. • Learners provide examples of bulk materials, nanomaterials, thin films and their methods of synthesis.		**Level** **3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Audio-visuals • Textbooks	• Educational tour to a material processing company • ICT facilities	

Subject **MANUFACTURING ENGINEERING**
Strand **1. Manufacturing Materials and Technologies**
Sub-Strand **2. Properties of Materials**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
2.1.2.LO.1		
Explain and measure the tensile properties of materials.	**Collaboration:** • Learners work in groups to observe and critically analyse the changes in the physical structure of materials under loading. • Learners work in groups to measure the strain of a mild steel using the strain gauge method. • Learners work together to perform the tensile test and determine the tensile properties of mild steel. **Critical Thinking:** • Learners think critically to calculate the stress of mild steel from the strain gauge test. • Learners contribute in the discussion to understand elongation, elastic limit, yield strength and tensile strength. • Learners think critically to draw the stress-strain curve and determine the tensile properties of mild steel. **Communication and Presentation Skills:** Learners communicate respectfully to perform the tensile test, measure the tensile properties of steel and present their results to the class.	**GESI:** As all learners are supported in an inclusive environment and given equal opportunities they will; • appreciate, value, and embrace diversity as they are made to work in groups. • learn to amicably resolve conflicts and embrace differing opinions. • develop emotional intelligence as their submissions are critiqued by others. embrace tolerance and empathy among themselves. • learn to resolve conflicts and embrace differing opinions amicably. • develop emotional intelligence as others critique their submissions. **Nations Core Values:** • Tolerance • Integrity • Accountability • Humility • Assertiveness • Patriotism

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.1.2.CS.1	2.1.2.LI.1	2.1.2.AS.1
Demonstrate knowledge and understanding of loading, stress and strain of materials.	**Explain loading, stress and strain of materials for manufacturing.** **Experiential Learning:** Place learners into mixed-ability groups and let each group perform axial loading (compression and tension), bending loading, torsional loading and shear loading using readily available materials. **Talk for Learning**: Learners explain loading, stress and strain from the loading tests performed earlier. Guide learners to understand that stress and strain are used to deduce the properties of materials during or after manufacturing.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level** 4 Extended critical thinking and reasoning
	2.1.2.LI.2	2.1.2.AS.2
	Outline the effect of loading, stress and strain on materials. **Experiential Learning:** Learners measure the strain of materials in the laboratory using the strain gauge and determine the stress of the materials according to the applied strain. Display lab work for others to critique. **Project-Based Learning:** Put learners into mixed-ability groups and let them use the strain gauge to measure the strain and calculate the stress induced in a mild steel using the modulus of elasticity of mild steel as available in textbooks. Learners share their findings with the class and receive feedback.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Textbooks • Laboratory • Strain gauge • Laboratory equipment for performing stress-strain tests	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
1.1.2.CS.2	2.1.2.LI.1	2.1.2.AS.1
Demonstrate understanding on the tensile properties of materials.	**Explain elongation, elastic limit, modulus of elasticity, yield strength and tensile strength of materials.** **Talk for Learning:** In a question-and-answer session Learners discuss elongation, elastic limit, yield strength and tensile strength. Let different pairs look for the meaning and share with whole class. Use webbing to organize learners contribution.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.1.2.LI.2	2.1.2.AS.2
	Measure the tensile properties of steel using the tensile test. **Experiential Learning:** Let learners in mixed-ability groups perform a tensile test on mild steel to determine its tensile properties such as stress, strain, modulus of elasticity and elastic deformation. **Collaborative Learning:** Let learners in their mixed-ability groups plot the stress-strain graph from the tensile test of the mild steel and use it to determine the tensile properties of the mild steel. Let learners present their results to the class and receive feedback.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Textbooks • Videos • Mild steel Laboratory equipment for performing tensile tests	

Subject **MANUFACTURING ENGINEERING**
Strand **2. Design and Prototyping**
Sub-Strand **1. Design and Drawing for Manufacture**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
2.2.1.LO.1		
Explain the importance of freehand sketch, projection of objects, detailed and assembly drawings in product design and manufacturing.	**Critical Thinking:** • Learners think critically to identify the importance of freehand sketch in product design. • Learners brainstorm and sketch their solutions to problems using free hand sketches. • Learners brainstorm to produce isometric drawings. • Learners brainstorm to identify the difference and characteristics of detailed and assembly drawings. **Communication:** • Learners clearly and respectfully articulate their suggestions on the importance of free-hand sketch in product design. • Learners share their ideas with colleagues in a respectful manner. • Learners respectfully discuss and draw isometric projections. • Learners respectfully to discuss and share ideas on their orthographic drawings. **Collaboration:** • Learners in think-pair-share groups discuss their solutions and receive feedback from colleagues to improve upon their designs. • Learners work together in mixed ability groups to produce isometric drawings. • Learners work together to produce first-angle projections. • Learners work together to research on sectioning, dimensioning and tolerance of geometric objects in the library.	**GESI:** Ensuring all learners in class irrespective of the diversity in ability, socio-cultural backgrounds, gender and soliciting contributions from all learners ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • knowledge of themselves and others' peculiarities, strength and weaknesses. • tolerance for diversity and respect for all. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

	• Learners in mixed-ability groups communicate respectfully to identify and discuss the characteristics, difference and applications of detailed and assembly drawings. **Communication and Presentation Skills:** Learners discuss the importance of sectioning, dimensioning and tolerance of geometric objects and presents their research findings to the class.	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.2.1.CS.1	2.2.1.LI.1	2.2.1.AS.1
Demonstrate skills in freehand sketching for product design	**State the importance of freehand sketch in product design.** **Talk for Learning:** In a question and answer session, discuss the relevance of freehand sketching and how it helps to identify the right ideas and solution for a design problem.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.2.1.LI.2	2.2.1.AS.2
	Apply freehand sketch in product design. **Project-Based Learning:** • Discuss with learners a particular need in the school or local community and let them provide a free-hand sketch of their solution to the problem. • Learners think-pair-share their solutions and receive feedback from peers. Encourage learners to accept criticisms in a respectful manner.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources		

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.2.1.CS.2	2.2.1.LI.1	2.2.1.AS.1
Demonstrate that knowledge and understanding of the projection of objects is necessary for product design.	**Outline the importance of isometric projections in product design.** **Collaborative Learning:** Learners in mixed-ability groups freely create shapes using snap cubes, draw the shapes created using isometric papers and share with partners. **Talk for Learning:** Discuss with learners the importance of isometric projections, emphasising its ability to provide 3D views of objects, showing dimensions and how components fit together. Organise thoughts using mind maps. **Project-Based Learning:** Show learners physical objects, such as chair, table etc., and some advanced shapes. Let learners draw these shapes in isometric projections using drawing instruments and drawing sheets. Learners display drawings and receive feedback from colleagues in a tolerant manner.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	2.2.1.LI.2	2.2.1.AS.2
	Explain the application of first angle orthographic projection in product design. **Experiential Learning:** Show learners videos or images of real objects such as tables or chairs and their corresponding first angle orthographic views i.e. front, top and side views. **Talk for Learning:** Discuss with learners the characteristics of drawings in first angle projection using samples of first angle projection drawings. Learners think-pair-share and provide, in turns, the first angle orthographic projection of shapes created from snap cubes. Let them share their drawings with colleagues for comments.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Textbooks • Snap cubes • Isometric papers • Drawing instruments • Audio-visuals • Chats or samples of first angle projection drawings	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.2.1.CS.3	2.2.1.LI.1	2.2.1.AS.1
Demonstrate that detailed and assembly drawings are significant for product design and manufacturing.	**Outline the importance of sectioning, dimensioning, and tolerance of geometric objects.** **Collaborative/Research-Based Learning: In** mixed-ability group, let learners read on sectioning, dimensioning and tolerance of geometric objects from the library, make presentations of their findings in class and receive feedback. Using sample drawings, lead learners to discuss the importance of sectioning, dimensioning and tolerance of geometric objects.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	2.2.1.LI.2	2.2.1.AS.2
	Explain the application of detailed and assembly drawings in product design and modeling. **Collaborative Learning:** Leaners in mixed-ability groups identify the characteristics of assembly drawing and detailed drawing using sample drawings and charts. **Talk for Learning:** Lead learners to discuss the differences and applications of assembly drawing and detailed drawing using sample drawings and charts. **Practice-Based Learning:** Learners practice the principles of assembling components and preparing assembly drawings and detailed drawings using sectional views or exploded pictorial views of component parts.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Textbooks • Library facilities • Internet access • ICT equipment • Sample assemble drawing • Detailed drawing or charts	

Subject **MANUFACTURING ENGINEERING**
Strand **2. Design and Prototyping**
Sub-Strand **2. Rapid Prototyping**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
2.2.2.LO.1		
Create geometric figures using AutoCAD.	**Collaboration:** • Learners in mixed-ability groups research on the importance of using AutoCAD to create geometrical figures. • Learners in a think-pair-share group create 2D and 3D models. **Presentation Skills:** Learners present their findings in class and receive feedback. **Critical Thinking:** Learners think critically to create 2D and 3D models. **Communication:** Leaners discuss their models with colleagues and receive feedback.	**GESI:** Promoting inclusivity through the use of varying types of group activities and supporting individual learners to take initiative ensures; • being gender responsive and having the ability to tackle injustice, be aware of personal biases and stereotypes. • embracing diversity and practice inclusion. • being sensitive to the inter-relatedness of the various spheres of life, groups, and individuals. • being aware of personal biases and stereotypes. **National core values:** • Resourcefulness • Self-discipline • Leadership • Truth • Diversity • Equity • Adaptability • Responsible citizenship • Honesty • Law-abiding • Patriotism • Faithfulness • Loyalty

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI		Assessment
2.2.2.CS.1	2.2.2.LI.1		2.2.2.AS.1
Demonstrate the application of computer graphics in 2D modelling.	**Explain the importance of AutoCAD in creating geometric figures.** **Research-Based Learning:** Learners in mixed-ability groups read from the library on the importance of creating geometric figures using AutoCAD and presents findings in class. Learners comment on presentations		Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.2.2.LI.2		2.2.2.AS.2
	Use AutoCAD to create 2D and 3D models. **Experiential Learning:** Learners to create and edit 2D and 3D drawings using AutoCAD. Share drawings with the rest of the class for comments. **Project-Based Learning:** Learners individually produce 2D and 3D models of components for manufacture, share their drawings and receive feedback. Encourage learners to tolerate and respect comments.		Level 1 Recall: Level 2 Skills of conceptual understanding: **Level 3 Strategic reasoning:** **Level 4 Extended critical thinking and reasoning:**
Teaching and Learning Resources	• Textbooks • Library	• Computer laboratories • Licensed AutoCAD software	

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing Tools, Equipment and Processes**
Sub-Strand **1. Manufacturing Tools and Equipment**

Learning Outcomes	**21st Century Skills and Competencies**	**GESI, SEL and Shared National Values**
2.3.1.LO.1		
Apply measuring instrument and hand tools to manufacture engineering components.	**Communication:** • Learners identify and discuss the use of measuring tools. • Learners list available hand tools. **Collaboration:** • Learners in mixed-ability groups research together on the differences between measuring tools. • Learners in mixed-ability groups practice the use of hand tools. • Learners in mixed-ability groups measure the size of work pieces. • Learners in mixed-ability groups use hand tools to manufacture engineering components. **Presentation Skills:** • Learners present their results on the differences between measuring tools to their colleagues and receive feedback. • Learners present their results in class and receive feedback. **Critical Thinking:** • Learners think critically to read the correct measured values from the measuring instruments. • Learners differentiate between manual-hand tools and power-hand tools. • Learners brainstorm to produce a desired engineering component using hand tools. **Ethics:** Learners report the correct outcome of their product.	**GESI:** Involving all learners in class irrespective of their varying abilities, gender and backgrounds, supporting them to share their views and thoughts ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • sensitivity to the inter-relatedness of the various spheres of life, groups and individuals • awareness of personal biases, peculiarities and stereotypes. • tolerance for diversity. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Integrity

Content Standards	**Learning Indicators and Pedagogical Exemplars with 21st Century and GESI**			**Assessment**
2.3.1.CS.1	2.3.1.LI.1			2.3.1.AS.1
Demonstrate knowledge and understanding of using measuring tools	**Explain the difference between measuring tools such as rule, a vernier caliper and a micrometer screw gauge for measuring work pieces.** **Talk for Learning:** Bring rule, vernier calipers and micrometer screw gauge to the classroom, and let learners identify and explain the use of these measuring tools. **Collaborative Learning:** Learners in mixed ability groups read from the library, the difference between the rule, vernier calipers and micrometer screw gauge based on how they are used to measure a quantity in the workshop. Let learners present their findings in class and receive feedback from their colleagues.			**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.3.1.LI.2			2.3.1.AS.2
	Apply measuring tools for the measurement of work pieces. **Experiential Learning:** Learners in mixed-ability groups use rule, vernier calipers and micrometer screw gauge to measure work pieces. Share results with the rest of class for comments			**Level 1 Recall** Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Rule • Vernier callipers • Micrometer screw gauge	• Measuring tools • Audio-visuals	• Supplementary books and materials • Library	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.3.1.CS.2	2.3.1.LI.1	2.3.1.AS.1
Demonstrate knowledge understanding of Using hand tools.	**Differentiate between manual-hand tools (e.g. hacksaw, cold chisels, screw drivers, taps, dies, engineer's hammer, etc.) and power-hand tools (e.g. grinding machines, drills, electric screw drivers, etc.) in manufacturing.** **Talk for Learning:** Let learners list hand tools available in their communities and what they are used for. **Experiential Learning:** • Learners to the workshop and let them identify available hand tools such as hacksaw, engineer's files, hacksaws, chisels, screwdrivers, taps, dies, engineers' hammers, grinding tools, drilling tools, screws etc. • Learners differentiate between the identified hand tools as manual-hand tools (e.g., hacksaw, cold chisels, screw drivers, taps, dies, engineer's hammer, etc.) and power-hand tools (e.g. grinding machines, drills, electric screw, etc.) with reference to their power source and tool bits. • Learners in mixed-ability groups practise the use of the hand tools on a work piece.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.3.1.LI.2	2.3.1.AS.2
	Apply hand tools to manufacture engineering components. **Project-Based Learning:** Learners in mixed ability groups use hand tools to manufacture simple components in the workshop and present their results in class for feedback. Focus should be on marking out worksheets, hand fitting activities, cutting and shaping of components and measuring of the components.	Level 1 Recall Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Manual-hand tools • Power-hand tools • Hand tools	

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing tools, equipment and processes**
Sub-Strand **2. Manufacturing Processes**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
2.3.2.LO.1		
Explain casting and welding processes used in manufacturing engineering products.	**Collaboration:** • Learners in mixed-ability groups make presentations on their observations at the foundry. • Learners in groups communicate respectfully in discussing casting processes and manufacturing components using sand casting. • Learners in mixed-ability groups separate components into permanent and non-permanent joints, and join components using screws, bolt, and nuts to form non-permanent joints. • Learners in mixed-ability groups join components using screws, bolts, nuts, and welding. **Communication and Presentation Skills:** • Learners present their observations at the foundry to the class and receive feedback. • Learners share their results on casting with the class and also receive feedback. **Critical Thinking:** Learners discuss and share ideas on the importance of casting. **Communication Skills:** Learners present their results on the difference between non-permanent and permanent joints processes to the class and receive feedback.	**GESI:** Using inclusive strategies and pedagogies that promotes all learners' wellbeing and develops their potential promotes; • respect for others and alternative views, as well as the awareness of own biases. • protect the weak and work for betterment of society and makes learners advocate for peace and justice. • exhibit empathy towards people with special needs. **National Core Values:** • Sacrifice • Selflessness • Compassion • Fairness • Justice • Generosity • Co-operation • Commitment • Collaboration • Excellence • Resourcefulness • Self-discipline

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.3.2.CS.1	2.3.2.LI.1	2.3.2.AS.1
Demonstrate understanding of Casting Processes.	**Outline the importance of casting in manufacturing of engineering product.** **Experiential Learning:** Take learners on a tour to a foundry nearby to observe the casting of engineering products and share their observations with the class. **Collaborative Learning:** Learners in mixed-ability groups make presentations on their observations at the foundry, making emphasis on the types of molds used for casting, melting of the metal to be used for the casting, pouring of the molten metal into the mold, and freezing of the molten metal in the mold. **Talk for Learning:** Lead learners to discuss the importance of casting in the manufacturing of engineering product. Let them add to what others say and summarise using mind maps.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.3.2.LI.2	2.3.2.AS.2
	Explain the sand-casting process in manufacturing. **Experiential Learning:** Show learners a video of an industry-based sand-casting process and let learners, in think-pair-share groups, summarise the casting process and present their results to the class. **Project-Based Learning:** Learners in mixed-ability groups cast simple components in the laboratory using sand casting.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Educational tour to a foundry • Audio-visual facilities • Sand casting equipment	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.3.2.CS.2	2.3.2.LI.1	2.3.2.AS.1
Demonstrate understanding of Joining and Assembly Processes.	**Identify and explain the difference between non-permanent and permanent joining processes.** **Collaborative Learning:** Learners in mixed-ability groups bring to class components that have been joined together and separate them into components with permanent joints and those with non-permanent joints. Learners identify the joining processes used in the permanent joints (e.g., welding, soldering, brazing, or adhesive bonding) and non-permanent joints (e.g. mechanical fastening with screws, bolts, and nuts) and explain the difference between these joining processes to the class.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.3.2.LI.2	2.3.2.AS.2
	Apply screw, bolt and nut, and welding processes to assemble manufactured parts together. **Experiential Learning**: • Learners in mixed-ability groups practice the joining of components to form non-permanent joints using screws, bolts, and nuts. • Learners take turns in mixed-ability groups to join manufactured parts together using any available welding process.	Level 1 Recall Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Fasteners such as Screws, bolts, and nuts • Welding facilities	

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing Tools, Equipment and Processes**
Sub-Strand **3. Safety, Quality and the Environment**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
1.3.3.LO.1		
Discuss methods of applying different types of hazard controls.	**Collaboration, Communication Skills, and Critical Thinking:** • Learners communicate and collaborate to discuss the various types of hazard control in the manufacturing process. • Learners communicate and collaborate to discuss the various sections and relevance of an MSDS. • Learners in mixed-ability and gender groups discuss their findings from the trip; make presentations on their findings in class and receive feedback. • Learners communicate the benefits of using environmentally friendly manufacturing processes and products. • Learners communicate and research the recent trends in the local manufacturing industry and their effects on the community, and the country at large.	**GESI:** Creating an inclusive learning environment that supports all learners and using varying kinds of group activities ensures; • respect and tolerance for diversity and views of differently abled learners. • awareness of self and uniqueness of others. • promotion of interrelationships and recognising others' strengths and weaknesses and supporting each other, especially girls in a male dominated discipline. **SEL:** Using interactive and group pedagogies that are inclusive will enable learners; • set group target and learn to work with others to achieve them. • tolerate others' opinion and examine their own opinion, decisions and conclusions drawn on issues and be collectively and individually responsible for decisions made. • learn to manage their emotions and sentiments during group discussions and when peers critique contributions.

		National Core Values: • Accountability • Honesty • Respect • Tolerance of diversity • Responsibility

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.3.3.CS.1	2.3.3.LI.1	2.3.3.AS.1
Demonstrate an understanding of procedures to ensure safety in the manufacturing industry.	**Demonstrate knowledge of the various types of hazard controls (administrative, engineering, personal protective equipment).** **Experiential Learning:** Show learners a video of a manufacturing setting and let them identify the various kinds of hazards at the setting. Let them share their observations. **Collaborative Learning:** Learners in mixed-ability and gender groups research and make presentations in class on the various types of hazard control in a manufacturing process and receive feedback. **Experiential Learning:** Show learners a sample MSDS of a particular common chemical and let them identify the various important information about the chemical from the material. **Talk for Learning:** Learners discuss the various sections of an MSDS. Let them add to what others say and summarise their views using webbings. **Research-Based Learning:** Learners in mixed-ability and gender groups research and produce an MSDS for a sample chemical substance and present their findings to the class and receive feedback.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.3.3.LI.2	2.3.3.AS.2
	Analyse the effects that manufacturing activities have on the environment (e.g., the effects of waste disposal, power consumption, destruction of the environment) **Experiential Learning:** Embark on a field trip with learners to local manufacturing industries and let them find out about the waste management system; types of raw materials used and products of that industry and relate their findings to environmental safety. **Talk for Learning:** Lead learners to discuss the positive and negative activities of various manufacturing activities on the environment.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• MSDS Samples • Supplementary materials	• Internet access. • Educational field trip to a local manufacturing industry

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
2.3.3.CS.2	2.3.3.LI.1	2.3.3.AS.1
Demonstrate an understanding of ways in which the manufacturing industry affects the environment.	**Explain the benefits of using environmentally friendly processes and products in the manufacturing process.** **Experiential Learning:** Show learners a video of land, water and other environmental resources negatively affected by harmful manufacturing processes and products. Share observation with the class. **Talk for Learning:** Learners discuss the benefits of using environmentally friendly processes and products in the manufacturing process. Organise discussion with mind maps.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	2.3.3.LI.2	2.3.3.AS.2
	Describe recent trends in the local manufacturing industry (e.g., globalization, rise in energy costs, increase in environmental awareness) and their effect on the local community or the nation. **Experiential Learning**: Show learners videos and pictures of the recent developments and trends in the local manufacturing industry. **Talk for Learning:** Lead learners to discuss the recent trends in the local manufacturing industry and the effects of those trends on the local community, and the country as a whole. **Research-Based Learning:** Learners in mixed-ability and gender groups research on the recent developments in the local manufacturing industry and their effects on the nation and present their solutions in class for feedback.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Audio visuals • Projector and video resources • Supplementary material • Internet access.	

YEAR THREE

Subject **MANUFACTURING ENGINEERING**
Strand **1. Manufacturing Materials and Technologies**
Sub-Strand **1. Classification of Materials**

Learning Outcomes	21st Century Skills and Competencies	GESI[5], SEL[6] and Shared National Values
3.1.1.LO.1		
Group and identify materials as advanced materials and discuss their applications in the manufacturing industry.	**Communication Skills and Critical Thinking:** Learners brainstorm to discuss the importance of advanced materials. **Communication Skills:** Learners communicate respectfully in identifying devices in their communities that use semiconductor material. **Critical Thinking:** Learners discuss the structure of semiconductors. **Collaboration, Creativity, Communication, and Presentation Skills:** Learners research the applications of advanced materials and use smart materials to develop a product to meet the need of their school. Learners present their solutions to the class. **Collaboration, Communication Skills, Critical Thinking:** Learners collaborate and communicate respectfully to process bamboo sticks into laminated bamboo. **Collaboration, Communication and Presentation Skills, and Creativity:** Learners collaborate in groups to design and manufacture a product from laminated bamboo and present their products to the class for feedback.	**GESI:** Creating equal opportunities for all learners to participate in class, through the use of balanced gender groups leads to; • tolerance and respect for one another. • confidence and efficacy in their ability to perform. • awareness of themselves and others taking into consideration their biases and stereotypes. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Integrity

[5] Gender Equality and Social Inclusion
[6] Socio-Emotional Learning

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.1.1.CS.1	3.1.1.LI.1	3.1.1.AS.1
Demonstrate understanding in the use of advanced materials.	**Outline the importance of advanced materials such as semiconductors, biomaterials, smart materials and nanomaterials.** **Experiential Learning:** Show learners videos of the applications of semiconductors, biomaterials, smart materials, and nanomaterials and lead learners to discuss their importance.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning: Level 4 Extended critical thinking and reasoning
	3.1.1.LI.2	3.1.1.AS.2
	Explain the structure of semi-conductors as engineering materials. **Experiential Learning**: Show learners semiconductor components such as microchips and transistors and let learners identify these components and the regular devices that use them such as phones, calculators, computers, solar panels, refrigerators, microwaves, television sets, radio sets, etc. **Talk for Learning:** Learners discuss the structure of a semiconductor as a crystalline material with properties between a conductor and an insulator.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	3.1.1.LI.3	3.1.1.AS.3
	State the applications of semi-conductors, biomaterials, smart materials and nanomaterials. **Research-Based Learning**: Put learners in mixed-ability groups and let them research and make presentations on biomaterials, smart materials, nanomaterials, and their applications. Let learners provide feedback **Project-Based Learning**: Let students in mixed-ability groups identify a problem in the school, use smart materials to develop a solution to the problem, and present their results to the class for feedback.	**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**

Teaching and Learning Resources				
	• Videos on the application of semiconductors	• Nanomaterials • Textbooks	• Library resources • Internet access	• Projector • Audio-visuals

	• Biomaterials • Smart materials			

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.1.1.CS.2	3.1.1.LI.1	2.3.1.AS.1
Demonstrate knowledge of bamboo as a material for manufacturing.	**Classify bamboo based on its structure, physical properties and processing.** **Experiential Learning:** Learners bring bamboo sticks to class to identify the parts and measure the dimensions and moisture content of the bamboo. **Project-Based Learning**: Learners in mixed-ability groups process the bamboo sticks into laminated bamboo following the steps below: a) segmenting the bamboo transverse to the culm axis b) splitting the bamboo parallel to the culm axis c) planing of the bamboo culm d) treating the bamboo by bleaching and drying e) re-planing of the bamboo strips f) gluing the bamboo strips g) stacking and pressing to form a laminated material.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
	3.1.1.LI.2	2.3.1.AS.2
	State the application of bamboo in manufacturing. **Experiential Learning**: Learners in mixed-ability groups use processed laminated bamboo to create any product of their choice and present their products to the class for feedback. **Talk for Learning:** Learners discuss the local and commercial applications of bamboo such as in the construction industry, pulp and paper industry, clothing industry, furniture industry, food industry, chemical, and pharmaceutical industries.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Bamboo sticks • Tools for processing bamboo • Supplementary reading materials	

Subject **MANUFACTURING ENGINEERING**
Strand **1. Manufacturing Materials and Technologies**
Sub-Strand **2. Properties of Materials**

Learning Outcomes	**21st Century Skills and Competencies**	**GESI, SEL and Shared National Values**
3.1.2.LO.1		
Explain and measure the mechanical properties of bamboo and explain that materials can fail through creep, fatigue or fracture.	**Critical Thinking, Collaboration, and Communication Skills:** • Learners collaborate in groups and communicate respectfully to research and discuss the mechanical properties of bamboo. • Learners research on forms on failure in materials, share their findings with colleagues and discuss the difference between the forms of material failure. **Collaboration, Communication and Presentation Skills, and Critical Thinking:** • Learners collaborate in groups and communicate respectfully to measure the tensile strength of bamboo. • Learners collaborate in think-pair-share groups to research the failure of materials according to creep, fatigue and fracture. Learners think critically and communicate their findings to the class. Learners receive feedback from their colleagues and the facilitator.	**GESI:** Ensuring all learners in class irrespective of the diversity in ability, socio-cultural backgrounds, gender and soliciting contributions from all learners ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • knowledge of themselves and others' peculiarities, strength and weaknesses. • tolerance for diversity and respect for all. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

Content Standards	**Learning Indicators and Pedagogical Exemplars with 21st Century and GESI**		**Assessment**
3.1.2.CS.1	3.1.2.LI.1		3.1.2.AS.1
Demonstrate knowledge of mechanical properties of bamboo.	**Explain the mechanical properties of a bamboo material.** **Research-Based Learning:** Learners in mixed-ability groups research on the mechanical properties of bamboo (such as compressive strength, hardness, tensile strength, and flexural strength) and discuss their results in class for feedback.		Level 1 Recall Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
	3.1.2.LI.2		3.1.2.AS.2
	Measure the tensile strength of bamboo material. **Experiential Learning:** Learners in mixed-ability groups perform a tensile test on a bamboo sample in the laboratory, compare the results with the tensile strength of steel, and present their results to the class for feedback.		**Level 1 Recall** Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Textbooks • Library resource	• Internet access • Tensile test machine	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.1.2.CS.2	3.1.2.LI.1	3.1.2.AS.1
Demonstrate understanding of the failure of materials.	**Explain the term failure of materials.** **Research-Based Learning**: Learners in mixed-ability groups research on the failure of materials and present their findings to the class to receive feedback. Learners comment on the presentations in a respectful and tolerant manner	**Level 1 Recall** Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
	3.1.2.LI.2	3.1.2.AS.2
	Distinguish between creep, fatigue or fracture in failure of materials. **Research-Based Learning:** Learners research on creep, fatigue and fracture as forms of failure in materials and share their findings with their colleagues. **Talk for Learning:** Learners to establish the differences between creep, fatigue or fracture with emphasis on the initiation and cause of the failure, the material types and the extent of damage caused to the materials. In pairs, leaners tabulate differences and share with the class.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Library resources • Textbooks	• Internet access

Subject **MANUFACTURING ENGINEERING**
Strand **2. Design and Prototyping**
Sub-Strand **1. Design and Drawing for Manufacture**

Learning Outcomes	**21St Century Skills and Competencies**	**GESI, SEL and Shared National Values**
3.2.1.LO.1		
Understand the representation of materials, machine components, limits, and fits in production drawings.	**Collaboration, Communication Skills, and Critical Thinking:** Learners communicate respectfully and identify materials and machine components from production drawings. Learners think critically to draw and share ideas on the conventions used to represent materials and machine components in a production drawing. **Collaboration:** Learners work together to research on the applications of limits and fits. **Communication and Presentation Skills:** Learners share their findings on the applications of limit and fit in production drawing. **Critical Thinking:** Learners think critically to practice and evaluate the limits and fits of components in production drawings. **Collaboration, Communication, and Presentation Skills:** Learners in mixed-ability groups read the application of detailed drawings from the library and present their results to the class for feedback. **Collaboration:** Learners in think-pair-share discuss their part drawings and receive feedback.	**GESI:** Working with each other in an inclusive way, cross sharing of knowledge and understanding between and among groups and individuals for instance leads to; • respecting individuals of varying beliefs, religion and cultures. • being sensitive to the inter-relatedness of the various spheres of life, groups and individuals. • being aware of personal biases and stereotypes. • embracing diversity and practice inclusion. **National Core Values:** • Tolerance • Friendliness, • Open-mindedness • Patience • Commitment • Hard work

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.2.1.CS.1	3.2.1.LI.1	3.2.1.AS.1
Demonstrate knowledge and understanding of the importance of the representation of materials and machine components in production drawing.	**Outline the importance of the representation of materials and machine components in production drawing.** **Experiential Learning:** Bring a typical production drawing to class and lead learners to identify conventions of materials and machine components used in production drawing (such as representations for metals, glass, packing and insulating materials, wood, concrete, liquids, shafts, pitch, bearings, screw threads, springs, and gears). **Talk for Learning:** Lead learners to discuss the importance of representing materials and machine components in production drawing. **Collaborative Learning:** Individual learners practice the drawing of the conventions in representing material and machine components in a production drawing. Learners share drawing and received comments in a tolerant manner.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
	3.2.1.LI.2	3.2.1.AS.2
	Explain the application of limits and fits in production drawing. **Experiential Learning:** Show learners a typical production drawing in class and lead them to identify limits and fits as used in the production drawing. **Collaborative Learning:** Learners in mixed-ability groups research on the application of limit systems (such as tolerance, limits, deviation, actual deviation, upper deviation, lower deviation, and allowance) as used in production drawings, and share their findings with the class. **Talk for Learning:** Lead learners to discuss zone line, standard tolerances, rules for dimensioning tolerances, hole basis and shaft basis for fits, selection of fits, limit gauges, machining symbols, and an indication of roughness as used in production drawings. **Practice-Based Learning**: Learners in mixed-ability groups practice the evaluation of limits and tolerances for a component according to the following steps: selection of appropriate fit based on the functional requirement, selection of the type of shaft and hole, selection of tolerance grade for shaft and hole, evaluation of standard tolerance and evaluation of limits and tolerance.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**

Teaching and Learning Resources	• Sample production drawings • Textbooks	• Library resources • Internet access

Content Standards	**Learning Indicators and Pedagogical Exemplars with 21st Century and GESI**			**Assessment**
3.2.1.CS.2	3.2.1.LI.1			3.2.1.AS.1
Demonstrate understanding in Production drawing II.	**Explain the application of detailed drawings in production drawings.** **Research-Based Learning**: Learners in mixed-ability groups read from the library on the application of detailed drawings in production drawings, present their findings in class and receive feedback.			**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
	3.2.1.LI.2			3.2.1.AS.2
	Draw part-drawings of a machine part. **Practice-Based Learning:** Individual learners draw a single part of a product providing the material used, dimensions, tolerances, surface finish, joining techniques, etc., needed to manufacture it. Learners share drawing with peers and receive comments.			**Level 1 Recall** Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Library resources • Textbooks	• Internet access • Projectors	• Audio-visuals • Machine component	

Subject **MANUFACTURING ENGINEERING**
Strand **2. Design and Prototyping**
Sub-Strand **2. Rapid Prototyping**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
3.2.2.LO.1		
Explain rapid prototyping (RP) technologies and use them to build a prototype.	**Communication Skills and Critical Thinking:** • Learners discuss the importance of rapid prototyping in manufacturing. • Learners discuss the differences between solid-based and liquid-based rapid prototyping technologies. **Collaboration, Critical Thinking, Communication, and Presentation Skills:** Learners in mixed-ability groups research the use of powder-based rapid prototyping technologies in manufacturing and present their findings in class. **Creativity, Critical Thinking, Collaboration, Communication, and Presentation Skills:** Learners communicate respectfully and critically think to identify a problem, design a solution, and create a prototype using available rapid prototyping technologies.	**GESI:** Encouraging all learners in class irrespective of the diversity in gender, ability and backgrounds and supporting each of them to share their views ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • knowledge of themselves and others' peculiarities and stereotypes. • tolerance for diversity and respect for all. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.2.2.CS.1	3.2.2.LI.1	3.2.2.AS.1
Demonstrate understanding in rapid prototyping technologies I.	**Explain the importance of rapid prototyping technologies.** **Experiential Learning:** Show learners videos of rapid prototyping technologies and lead them to discuss the importance of rapid prototyping in manufacturing. Organise their thoughts using concept maps or webbing.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
	3.2.2.LI.2	3.2.2.AS.2
	Distinguish between solid-based and liquid-based rapid prototyping technologies. **Experiential Learning:** Show learners videos of solid-based rapid prototyping technologies such as selective sintering, laminated objective manufacturing, and fused deposition modeling, and liquid-based rapid prototyping technologies such as stereo lithography, solid ground curing, and droplet deposition manufacturing. **Talk for Learning:** Learners to discuss the difference between solid-based and liquid-based rapid prototyping based on their basic concepts and techniques. Organise ideas and views using mind maps.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Audio-visuals • Projectors • Videos on RP technologies	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI			Assessment
3.2.2.CS.2	3.2.2.LI.1			3.2.2.AS.1
Demonstrate skills in rapid prototyping II.	**Explain powder-based prototyping technology in manufacturing.** **Research-Based Learning:** Learners in mixed-ability groups research the use of podwer-based rapid prototyping technologies such as selective laser sintering and three-dimensional printing in manufacturing and present their results in class for feedback.			**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
	3.2.2.LI.2			3.2.2.AS.2
	Build a prototype using available technologies. **Project-Based Learning**: • Learners in mixed-ability groups identify a problem or need in the community, design a solution, and prototype a physical model using available rapid prototyping technologies. • Learners present their prototypes in class and receive feedback.			Level 1 Recall Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Library resource • Textbooks	• Internet access • Projectors	• Audio visuals • RP Technologies	

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing Tools, Equipment and Processes**
Sub-Strand **1. Manufacturing Tools and Equipment**

Learning Outcomes	**21st Century Skills and Competencies**	**GESI, SEL and Shared National Values**
3.3.1.LO.1		
Recognise and use cutting tools and modern machine tools.	**Collaboration, Communication and Presentation Skills, and Critical Thinking:** Learners communicate respectfully to research and make presentations on cutting tools. Learners think critically to identify and classify cutting tools. **Collaboration, Critical Thinking and Communication Skills:** Learners in think-pair-share discuss the application and use of cutting tools and receive feedback. **Collaboration, Critical Thinking, Communication, and Presentation Skills:** Learners in mixed-ability groups research on CNC machines and present their findings in class. **Collaboration, Critical Thinking, Presentation and Communication Skills:** Learners in mixed-ability groups research, discuss and make presentations on the operation and applications of CNC machines.	**GESI:** Promoting inclusivity in the classroom by encouraging every learner to actively participate in lessons, cross sharing of ideas and thoughts between and among groups and individuals ensures; • respecting individuals of varying beliefs, religion and cultures. • being sensitive to the inter-relatedness of the various spheres of life, groups and individuals. • being aware of personal biases and stereotypes. **SEL:** Embracing diversity and practice inclusion **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work • Integrity

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.3.1.CS.1	3.3.1.LI.1	3.3.1.AS.1
Demonstrate knowledge and understanding of the use of cutting tools and modern machine tools.	**Identify and classify cutting tools used in manufacturing.** **Research-Based Learning**: Learners in mixed-ability groups research on cutting tools for woodwork, metalwork and machining, and present their results in class for feedback. **Experiential Learning:** Show learners cutting tools at the workshop and lead them to classify the cutting tools according to their use (e.g., milling, boring, drilling, grinding, shaping, planing, broaching etc.) and cutting-edge type such as (single-point cutting tool, double-point cutting tool and multi-point cutting tool).	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	3.3.1.LI.2	3.3.1.AS.2
	Demonstrate the application and use of cutting tools in manufacturing. **Experiential Learning:** Learners visit a local manufacturing industry and observe the use and applications of cutting tools used in woodwork and metal works. Learners share observation with class. **Talk for Learning:** Through question and answers, learners discuss the application and use of cutting tools and receive feedback.	Level 1 Recall Level 2 Skills of conceptual understanding: **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Cutting tools • Textbook • Library resource • Educational tour to a local manufacturing industry	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.3.1.CS.2	3.3.1.LI.1	3.3.1.AS.1
Demonstrate understanding of modern machine tools.	**Explain computer numerically controlled (CNC) machine as a machine tool.** **Experiential Learning**: • Show learners a video of a CNC machine in operation. • Let learners in mixed-ability groups read on CNC machines and make presentations explaining how different they are from machine tools used in most local industries.	Level 1 Recall **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
	3.3.1.LI.1	3.3.1.AS.1
	Understand the operation and application of a CNC machine. **Experiential Learning:** Take learners on an educational tour to a manufacturing industry to observe the operation and application of CNC machines and share observations with the class. **Research-Based Learning:** • Learners in mixed-ability groups read from the library and Internet on the operation and applications of CNC machines and present their results to the class for feedback. • Learners to discuss the operation and industrial applications of CNC machines. Organise contributions by learners.	**Level 1 Recall** Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Textbooks • Library resources • Internet access • Audio-visuals • Projectors • Videos on CNC machines.	

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing Tools, Equipment and Processes**
Sub-Strand **2. Manufacturing Processes**

Learning Outcomes	21st Century Skills and Competencies	GESI, SEL and Shared National Values
3.3.2.LO.1.1.1		
Explain the working principles of a center-lathe machine and use the lathe machine to perform a simple material removal process.	**Collaboration, Communication and Presentation Skills:** Learners in groups research on material removal processes and the operation of the center-lathe machine and make presentations to the class. **Critical Thinking:** Learners discuss material removal processes using the center-lathe machine. **Collaboration, Communication Skills and Critical Thinking:** Learners in think-pair-share discuss the use of center-lathe machines to perform turning, drilling and milling operations. **Collaboration, Communication Skills and Critical Thinking:** Learners in think-pair-share discuss the use of grinding machines to perform grinding operations. **Creativity, Critical Thinking, Collaboration, Communication, and Presentation Skills:** Learners communicate respectfully and critically think to manufacture a component using center-lathe machine.	**GESI:** Ensuring all learners in class irrespective of the diversity in ability, socio-cultural backgrounds, gender and soliciting contributions from all learners ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • knowledge of themselves and others' peculiarities, strength and weaknesses. • tolerance for diversity and respect for all. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment • Hard work

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.3.2.CS.1	3.3.2.LI.1	3.3.2.AS.1
Demonstrate understanding of material removal processes using conventional machining processes.	**Discuss the fundamentals of material removal processes and principles of operation of the center-lathe machine.** **Research-Based Learning**: Learners in mixed-ability groups read from the library on material removal processes such as conventional machining, abrasive processes and non-traditional machining. Learners share their research with the class. **Experiential Learning:** Show learners videos of a lathe machine being used to manufacture a component. Take learners on a tour to a manufacturing industry to observe the operation of a center-lathe machine. Learners share observation with the class. **Talk for Learning:** A learner leads the class to discuss material removal processes using the center-lathe machine. Structure learners' contributions using mind maps or concept maps.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning
	3.3.2.LI.2	3.3.2.AS.2
	Recognise and gain understanding of turning, drilling and milling operations using the center-lathe machine. **Experiential Learning:** • Show learners the parts and controls of the centre-lathe machine for performing turning, drilling and milling operations. • Show learners videos of turning, drilling and milling operations as performed by a centre-lathe machine. **Collaborative Learning:** Learners in pairs discuss and share the use of center-lathe machines to perform turning, drilling and milling operations to receive feedback.	Level 1 Recall **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning

Teaching and Learning Resources	• Educational tour • Library resources	• Internet access • Textbooks	• Entre-lathe machine • Videos of centre-lathe machine performing turning	• Drilling and milling operations.

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.3.2.CS.2	3.3.2.LI.1	3.3.2.AS.1
Demonstrate understanding of material removal processes using abrasive processes.	**Recognise and gain understanding of grinding operations.** **Experiential Learning:** • Show learners the parts and controls of a surface grinding machine performing grinding operations through pictures or videos. Learners share their observations with colleagues. • Show learners videos of industrial applications of surface grinders used in performing grinding. Learners think-pair-share the use of a surface grinder to perform grinding operations and receive feedback.	Level 1 Recall Level 2 Skills of conceptual understanding **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning:
	3.3.2.LI.2	3.3.2.AS.2
	Perform a material removal process using a lathe machine. **Experiential Learning:** Learners in mixed-ability groups manufacture a component using the center-lathe machine and present results to the class for feedback.	Level 1 Recall Level 2 Skills of conceptual understanding Level 3 Strategic reasoning **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Surface grinder • Videos of grinding machines performing grinding operations • Centre-lathe machine	

Subject **MANUFACTURING ENGINEERING**
Strand **3. Manufacturing Tools, Equipment and Processes**
Sub-Strand **3. Safety, Quality and the Environment**

Learning Outcomes	**21st Century Skills and Competencies**	**GESI, SEL and Shared National Values**
3.3.3.LO.1		
Explain regulations and compliance issues and procedures for the manufacturing industry.	**Communication Skills and Critical Thinking:** Learners discuss and share ideas on relevant safety tests based on national and international guidelines and principles for manufacturing processes. **Collaboration, Communication Skills, and Critical Thinking:** Learners communicate respectfully and identify the various regulatory agencies; regulatory agency penalties and criteria for corrective actions for the manufacturing process.	**GESI:** Given equal opportunities to all learners irrespective of their background and soliciting views from all learners ensures; • respect for individuals of varying beliefs, religion, backgrounds and cultures. • sensitivity to the inter-relatedness of the various spheres of life, groups and individuals. • awareness of personal biases, peculiarities and stereotypes. • tolerance for diversity. **National Core Values:** • Tolerance • Friendliness • Open-mindedness • Patience • Commitment and Hard work • Honesty and Truthfulness

3.3.3.LO.2		
Apply quality control and quality assurance practices for efficient and effective manufacturing processes.	**Collaboration, Communication Skills, and Critical Thinking:** • Learners communicate respectfully and identify the relevant tools such as charts, and linear relationships for analysing and using quality data for decision making. • Learners in think-pair-share collaborate and discuss successfully the various tools used to analyse quality data for decision making. **Communication Skills and Critical Thinking:** Learners discuss the various functions of quality assurance and quality control in the manufacturing process.	**GESI:** Using mixed-ability and mixed-gender pairing, special attention given to the catch-up, regular and gifted and talented learners leads to; • respecting individuals of varying abilities, beliefs, religion and cultures. • being sensitive to the inter-relatedness of the various spheres of life, groups and individuals. • being aware of personal biases and stereotypes. • embracing diversity and practice inclusion. **National Core Values:** • Integrity • Tolerance • Open-mindedness • Patience • Integrity • Hard work

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.3.3.CS.1	3.3.3.LI.1	3.3.3.AS.1
Demonstrate an understanding of safety regulations and compliance in the manufacturing industry.	**Analyse relevant safety tests based on national and international guidelines and principles.** **Talk for Learning**: Learners identify and discuss relevant national and international regulatory agencies responsible for manufacturing processes. **Research-Based Learning:** Learners in mixed-ability groups research the relevant safety tests for manufacturing processes based on the National and International guidelines and principles, and present their findings in class, and receive feedback.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	3.3.3.LI.2	3.3.3.AS.2
	Examine the regulatory agency penalties, and criteria for corrective actions. **Talk for Learning:** Learners discuss the various regulatory agency fines and penalties for manufacturing processes. **Collaborative Learning:** Learners in mixed-ability and gender groups research and discuss the various criteria for corrective actions in manufacturing processes. Present findings to the class for comments.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
Teaching and Learning Resources	• Supplementary materials • Internet access	

Content Standards	Learning Indicators and Pedagogical Exemplars with 21st Century and GESI	Assessment
3.3.3.CS.2	3.3.3.LI.1	3.3.3.AS.1
Demonstrate an understanding of the use of quality assurance and quality control in manufacturing.	**Describe the role of quality control in manufacturing processes.** **Talk for Learning:** Lead learners to identify and discuss the major difference between quality assurance and quality control. **Collaborative Learning:** Learners in mixed-ability and gender groups research and discuss the major role of quality control in the manufacturing process.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	3.3.3.LI.2	3.3.3.AS.2
	Explain the various functions of quality control and quality assurance in the manufacturing process. **Experiential Learning:** Show learners a video of a quality control laboratory and activities in a quality control process in a typical manufacturing industry. **Talk for Learning:** Learners discuss the various functions of quality assurance and quality control in the manufacturing process. Organise thoughts using concept maps.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** Level 4 Extended critical thinking and reasoning
	3.3.3.LI.3	3.3.3.AS.3
	Analyse and utilize quality control data to make decisions. **Talk for Learning:** Learners discuss the various tools for analysis, and interpretation of quality data for decision making in a manufacturing process. **Practice-Based Learning:** Give learners a sample quality data from a typical manufacturing process and let them in think-pair-share analyse and interpret the data using charts, measures of central tendencies, and linear relationships for decision -making.	**Level 1 Recall** **Level 2 Skills of conceptual understanding** **Level 3 Strategic reasoning** **Level 4 Extended critical thinking and reasoning**
Teaching and Learning Resources	• Supplementary materials • Internet access	• Projectors and videos on quality control activities in a quality control laboratory • Textbooks