A Practical Guide to Assessment for Learning

The specification for

TLM Level 1 and Level 2 Certificates in Smart Product Design and Manufacture

Ian Lynch, Jing Lu, Garry Bulmer

High Quality Qualifications for the
2017 School League Tables onward

ISBN

TLM Technology and Quality Assurance

This is version 1.0 of the specification for TLM/BCA Level 1 and Level 2 qualifications in Smart Product Design and Manufacture developed in association with Black Country Atelier.

The assessment model for the qualifications presented in this publication was designed by TLM in consultation with Black Country Atelier Ltd.

The Learning Machine Ltd, Unit 4D Gagarin, Lichfield Road Industrial Estate, Tamworth, Staffordshire, B79 7GN (www.theingots.org)

Black Country Atelier Ltd, 7 Mary Street, Birmingham B3 1UD (www.blackcountryatelier.com/education)

Contents

1. Introduction

1.1 These qualifications have the purpose of providing pupils with practical technical knowledge, understanding and skills in designing and manufacturing contemporary technological artefacts. A principal focus is on industrially produced Smart consumer devices incorporating user- and environmentally responsive, customised products and systems. We believe these new and innovative qualifications provide the most inclusive and cost-effective qualifications available for a new Smart Design and Manufacture curriculum. They preserve the necessary rigour for stretching the highest attaining candidates while including the great majority of the Key stage 4 cohort. In addition, there is a clear intention to reduce the bureaucratic overhead on teachers while preserving the benefits of coursework for motivating learners and dealing validly with recognition of competence in what are essentially practical, technical and pre-vocational skills and activities. We have demonstrated that we can provide Level 1 and Level 2 qualifications that are accessible to all learners while still differentiating the top performing students. This enables a clear progression route for the weakest mainstream learners through to identifying those that are likely to be successful in academic A levels and beyond into the associated professions.

1.2 TLM Level 1 and Level 2 Certificates in Smart Product Design and Manufacture are qualifications that embody a highly relevant modern approach to product and technology development, design engineering and advanced manufacture. Product and technology innovation is under pressure to be both sustainable and accessible utilising various media streams to create new benefits for customers and clients. For example adding intelligence and interactive user interfaces to existing and new products is a critical strategy to satisfy these needs. 3D printing and the internet is providing product designers and engineers direct access to manufacturing capacity with low-investment and short lead-times. There has never been a better time for product designers to take projects to market. The global management

consultancy group, McKinsey's, reported on the continued importance of manufacturing to global economies, and the value of new technologies such as 3D printing to drive massive transformations in products and services across a number of sectors from engineering to medicine to consumer goods.

http://www.mckinsey.com/insights/manufacturing/the_future_of_manufacturing

http://www.mckinsey.com/insights/business_technology/disruptive_technologies

The boundary between creative arts and engineering is becoming blurred as digital technologies are becoming much easier to use, and manufacturing processes are readily available to all, from micro-businesses and craftsmen to international engineering corporations. A new world where digital and physical processes are made more accessible, knowledge and competence in creating new ideas and preparing them for manufacture and new markets is becoming increasingly important. The unprecedented opportunities and applications of Smart design and manufacturing systems and processes across multiple industries ensure learner knowledge and skills gained through these qualifications are applicable across a wide range of professional careers and sectors opening up progression routes to both academic and vocational higher level learning.

Further, academic depth and rational critical analysis of progress to ensure successful projects will be critical to integrate a range of subjects demanded by industry in a landscape of rapid technology change and business complexity. [reference from McKinsey report on importance of understanding complex network and systems]

The qualifications offer teachers and learners the opportunity to develop a range of skills, knowledge and understanding that is not available in the core academic curriculum. The content is fundamental to

successful engagement in the professional aspects of product and systems design relevant to innovation and manufacturing sectors of industry. At Level 1 these will support all by leaving progression routes open to Level 2 and Level 3 in a range of hi-tech digital learning.

1.3 This specification is for two qualifications, one at Level 1 and the other at Level 2, targeted on secondary schools. It has the following key benefits.

- devised in consultation with leading industry consultants, professional bodies and universities
- clear and flexible unit based structure referenced to the European Qualifications Framework (EQF).
- straightforward assessment of competence in real rather than contrived contexts.
- grading through controlled exams introduced progressively from KS3 to KS4.
- provides a focus for continuing professional development for teachers through moderation/verification feedback.
- moderation/verification of coursework on demand.
- examination opportunities per year.
- use of open source cloud based technologies to reduce costs and add value for schools.
- reduced bureaucracy for teachers and flexibility for them to target specific interests.

1.4 These qualifications lend themselves to formative assessment practices allied to summative differentiation by outcome that can optimise and motivate attainment for individuals rather than assume all will reach a certain level or grade at a particular time. We do this by providing a coursework component that is competence based, reflecting the best and most up to date research in assessment in the workplace complemented by a short academic style examination.

1.5 All candidates must complete the coursework before being eligible to take the exam. This provides an incentive to complete the

coursework and makes it less likely that those sitting an exam are ill-prepared.

1.6 The Level 1 exam grades candidates across a range from Pass through Merit and Distinction to Distinction*. The Level 2 exam grades candidates from grade C through B and A to A*. The two qualifications at Level 1 and Level 2 can stand alone but they are designed to provide a coherent progression route starting with coursework at Level 1 and then a multiple choice on-line exam to determine the Level 1 grades. Level 2 coursework is differentiated from Level 1 by more demanding assessment criteria and the general RQF level descriptor for Level 2. If coursework is completed to the Level 2 standard the candidate can go on to take the Level 2 exam which will then differentiates grades A*-C.

1.7 In this way we can provide valid competence based assessment and rigorous testing of knowledge and understanding at a lower cost than both traditional vocational and academic methods applied separately. If replicated across schools it would potentially save significantly on current expenditure on assessment and examinations, but more importantly teacher time. There is research evidence that this approach should enhance motivation that will result in higher attainment by supporting both performance-approach goals that focus on displaying competence and performance-avoidance goals focus on avoiding a display of incompetence. (Conclusions from Effects of Classroom Assessment Practices on Students' Achievement Goals, Hussain Alkharusi Sultan Qaboos University, Oman.)

2. Summary of the qualifications specifications

2.1 The Level 2 certificate is graded across 4 levels from A*- C with A* the highest grade equating to 80%+ of the available marks and grade C equating to a minimum of 50%. The Level 1 certificate is graded across 4 levels, pass, merit, distinction and distinction* on the same basis as the Level 2.

Content

2.2 The qualification content has been designed for use in schools by referencing it to similar assessments carried out in current Level 1 and 2 qualifications. It is designed to meet the needs of employers, through consultation with leading design and manufacturing agencies, progressive universities and professional bodies representing a wide section of the industry. Guidance for coursework is aligned with the CBI employment criteria.
http://www.cbi.org.uk/business-issues/education-and-skills/in-focus/employability/
Guidance takes into account the lack of experience of many teachers in this area ensuring that the most academically able can be stretched and routed to appropriate academic progression at Level 3. Strong industry support provides great potential for staff development, keeping teachers up to date in what is still a rapidly changing sector. Unlike purely academic qualifications, regular reference is made to practical skills and standards and the use of real equipment and technology rather than simulations or generic terms only. There is an emphasis on increasing understanding of the importance of innovation and technology to the UK economy, for example the government backed Technology Strategy Board specifically backs development of new innovative products and supports business to take those product through prototype to production and to market.

Assessment

2.3 The qualifications at both Level 1 and Level 2 have two assessment components both of which cover the full content of the qualifications.

1. Coursework assessed in terms of competence in practical areas where knowledge and understanding can be applied in real and motivating contexts.
2. An externally set and externally marked examination to assess knowledge and understanding that underpins user competence.

2.4 Both qualifications are unit based and each consists of 3 units. Units have credit values in the regulated qualifications framework (RQF). A minimum of 15 credits is needed for each qualification equating to 120 guided learning hours. The mode of teaching is entirely up to the school. One delivery strategy is to teach over 3 or 4 years starting with Level 1 and building to the highest performance possible at Level 2.

2.5 The synoptic examination of knowledge and understanding that is used for grading is based on a syllabus related to **all** the available criteria across **all** units. The design does not allow candidates to compensate for weak coursework by doing well in the exam only. They must complete the coursework to a satisfactory standard at the level to be eligible to take the examination. A weak examination performance will limit the attainment to a pass and could prevent the award of any grade at all. It is likely that candidates with a satisfactory coursework performance will at least pass at the level but that is not inevitable and they must take the exam to pass. The exam then provides an additional very low cost dimension to external moderation/verification feedback for the coursework. Centres with a high proportion of candidates judged to be satisfactory on coursework yet failing to gain sufficient marks in the examination flag up a need for further investigation and will help prioritise CPD.

Summary of the rationale

2.6 The assessment is specifically designed to motivate learning that will support the highest grade(s) attainable by each candidate but also broader aspects of learning that can not be assessed in a traditional exam. Learners must demonstrate that they can achieve at least 15 credits before being eligible for the examination with both coursework and exam covering the entire subject content. There is considerable

flexibility to enable contexts of individual interest to be explored in depth. Those that have completed the coursework in areas of personal interest and to a high standard are far less likely to fail to achieve at least the minimum standards set in the examination. This ensures basic practical competence in realistic and motivating scenarios as well as at least some general knowledge and understanding in the more academic sense.

Aggregation of marks

2.7 Level 1 candidates will gain 30 marks from providing coursework evidence that meets the Level 1 assessment criteria as determined by their assessor with independent external moderation/verification samples. They are then eligible to take the examination which provides a further potential 70 marks. A pass requires 50 marks, pass with merit 60 marks, pass with distinction 70 marks and pass with distinction* 80 marks or more overall. Candidates can take this examination when their assessors judge **that** they are ready and when they have completed the coursework to a Level 1 standard.

2.8 Level 2 candidates will gain 30 marks from providing coursework evidence that meets the Level 2 assessment criteria as determined by their assessor with independent moderation/verification samples. They are then eligible to take the examination which provides a further potential 70 marks. If the candidate achieves a total score of 50 marks from the coursework and the examination they will be awarded a grade C. For 60 marks or more a grade B, for 70 marks or more a grade A and for 80 marks or more a grade A*. In this way those candidates that are more suited to academic work will be differentiated from those more likely to benefit from further practically based study at Level 2 or Level 3. The examination questions get progressively more difficult and those achieving the highest marks will be those most likely to be suited to academic A level study at Level 3.

2.9 Any candidate that completes the coursework to a satisfactory standard at Level 2 but fails to gain sufficient marks in the examination can take the Level 1 examination if they have not already been awarded

the Level 1 certificate. We expect this situation to be relatively rare but from an individual's point of view it prevents them doing 2 years' work and coming away with nothing because they had a bad day in an exam or missed the exam through unavoidable personal circumstances.

2.10 An optional subscription model that covers all these qualifications means that schools can enter as many candidates as they believe can meet the criteria and there are no hidden costs such as late entry fees, double entries or replacement certificate fees. This maximises the opportunities for learners to get their achievements recognised without the school worrying about financial penalties.

3. Qualification Content

3.1 The qualification is made up from units in the Regulated Qualifications Framework (RQF). The RQF is referenced to the European Qualifications Framework (EQF), the largest system for referencing nationally accredited qualifications in the world. Unit credit is designed to be compatible with the European international credit transfer system ECVET. The units were designed by TLM in collaboration with teachers currently working in the classroom, industry consultants, professional bodies and universities. In order to provide learners with the skills needed by all sector employers, extensive consultation with business leaders has taken place. This specification is a distillation of this extensive market research specifically geared to supporting learning in schools. There is an emphasis on developing the transferable knowledge, skills and competences that will support raised attainment in the core subjects of the curriculum as well as providing the grounding needed for future hi-tech manufacturing industry professionals. There are references to science and mathematics especially in terms of 3D geometry, energy efficiency and sustainability, dynamics, mechanics and measurement, computer numeric control. Specialist vocabulary with words such as sustainability, life cycle, user interface, product performance, Smart embedded electronics, energy efficiency, digital fabrication, visual and functional prototypes, critical paths, will help support technical English at a level beyond that of most adults.

Key subject aims

3.2 The over-arching aim is to enable learners to develop knowledge skills and capabilities that under-pin applying digital technologies to create "intelligent" physical products, using modern processes designed to exploit agile manufacturing technologies, and capabilities employed via the internet or via Smart electronic devices.

3.3 A principal focus is on industrially produced Smart consumer devices incorporating user and environmentally responsive, customised products and systems.

Subordinate aims include:

- acquisition of technical understanding, knowledge and skills that are not provided in the mainstream academic curriculum.
- developing the skills that under-pin employability across a wide range of sectors
- gaining practical experience and competence with contemporary product and systems design, rapid prototyping and manufacturing technologies including 3D printing
- gaining practical experience and competence by applying 'Smart' technology to transform passive products to active products, and active products to connected products
- developing practical skills in creativity and problem solving in the context of creating solutions to project briefs
- developing practical skills in problem analysis, and making real things work
- developing the skills to collaboratively develop product concepts through to functional prototypes
- develop practical skills applying additive and direct design to product manufacturing technology
- knowledge in the field of critical evaluation, feedback and iterative design.

Knowledge and understanding

3.4 The following knowledge and understanding will be required to underpin the desired learning outcomes for each qualification. At each level the understanding needed is in keeping with the RQF general description of the qualification level.

- Demonstrate knowledge and understanding associated with product and system design development and advanced manufacture terms:

Product life cycle, project planning, visual prototype, functional, aesthetic and pre-production prototypes, 2D, 3D, embedded electronics, rapid prototyping, 3D printing, additive manufacture, computer aided design, fit and clearance, tolerance, sketch design and modelling, user interface, environment sensing, sustainability, project plans, design for manufacture (DFM), user testing and evaluation, ergonomics and anthropometrics.

- Demonstrate mathematical knowledge associated with quantitative methods, programming, simple statistics, algebra, geometry, Cartesian coordinates, 2D and 3D, rotation axis and planes, perspectives, computer numeric control.
- Demonstrate scientific knowledge associated with physical properties of atoms and electrons, voltage and electricity, magnets and electromagnets and applications in motors and relays, material science and basic mechanical properties of materials such as stress, breaking point, fatigue, bending, elasticity and using them within product application.
- Demonstrate knowledge and understanding associated with the information and data terms:
  Data, information, file type, file properties, compatibility, export, import, conversion, units, scale, visualisation, render, computer aided design, computer aided manufacture, digital modelling, physical modelling, measurements, standards, input output, analogue, digital, logic, controller, software, program, transducer, sensor.
- Deal with unfamiliar contexts drawing on leaning and information provided.

3.5 Opportunities are provided to support the following skills, the great majority of which will be assessed directly in coursework in valid contexts. Projects expose and develop skills to work with design and advanced manufacturing processes, iteration and development, in order to give a practical taste of the skills and competencies that under-pin a range of careers and industries related to contemporary product development and manufacture. These include numeracy, literacy, engineering, design, creative arts, science and embedded software

development. Further by focusing on practical applications of technology, we complement some of the more academic subjects by demonstrating the application of theory in realistic context driven projects. Through a range of design processes and prototypes, learners will design a “Smart Product” (consumer, home or environment focused) that uses modern technology to help find solutions for user defined problems locally, nationally, and internationally. Solutions address issues of energy consumption, food and materials scarcity, social and online connectedness in an internet age. Sustainability is an embedded theme. A range of appropriate tasks follow the journey of the product including:

- analyse and interpret product design briefs
- gather information and research to support design briefs
- research and develop creative product concepts
- use CAD visualization to communicate exterior product concepts
- use CAD to carry out digital simulation such as FEA, technical feasibility, and initial review against brief
- use CAD to develop 3D Models suitable for production using additive manufacturing technology
- use and integrate smart-electronic modules to create functional prototypes
- analyse product life cycle including strategies to reduce carbon footprint, whether through the function of the product itself or through minimising waste from the products manufacture process.
- study of interdisciplinary teams.

Unit contents

3.6 The content of units is in Annexe C below with guidance in interpreting the criteria. These are available in more detail on the TLM community learning site and will be linked to progressively more free and open supporting resources and guidance as these become available.

3.7 All centres have an assigned Account Manager who will be very pleased to help at any time. Our aim is to give professional assessors, most of whom are qualified teachers, the confidence to make judgements with a minimum of bureaucracy so that they can focus their time on maintaining their professional knowledge and skills and support learning through effective teaching rather than “chasing paper”.

3.8 There is often a confusion between bureaucracy and rigour, since unnecessarily complex bureaucracy can actually detract from rigour by obscuring the importance of the outcomes in unnecessary process. We also encourage coursework to be carried out in valid and real contexts rather than as contrived simulations. Competence is best assessed in context. All assessors must sign an agreement to uphold standards and feedback from moderation/verification will support consistency.

3.9 Websites - TLM provides support through a cloud based system for evidence management linked to grading and certification. Providing assessment grades and the management of certification through the Awards Site is mandatory and all assessors are provided with training in its use. It is simply a matter of recording learner competence against the unit criteria as the evidence is collected and claiming a certificate on behalf of the learner when a unit has been fully assessed. All assessors must sign an agreement to uphold standards before they can use this site. BCA provides support through a cloud-based Virtual Learning Environment. This provides support for both learners and teachers.

3.10 The use of the community learning site is optional at no additional cost. It **provides** facilities for learners to submit their evidence online, linking it to the assessment criteria across single or multiple units. The assessor can accept or reject this evidence and comment on it providing a full audit trail for evidence. Moderator/verifiers can get immediate access to this evidence and so it is potentially a lot more efficient than alternative methods. No paper, no emails with file attachments are necessary. There are facilities for progress tracking that can be based on criteria and/or units and reports that can be

shared securely online with parents. The system can be linked as an extension to any standards compliant VLE/e-portfolio system for centres that are already committed to a specific VLE product. Training can be provided and free support is available from your Account Manager. The aim is to eliminate all paper based bureaucracy, all screen shots and referencing that draws time away from teaching. As far as possible we want assessment of real tasks in real contexts that are truly representative of a real working environment. This is a fundamental goal for the competence based assessment at the heart of the Qualifications and Credit Framework and European Vocational Education and Training policy (ECVET). It is the way in which most employers will judge the effectiveness of individuals in their tasks at work.

3.11 Telephone and e-mail support is available to all Centres. There is a general convention of firstname.secondname@theingots.org for e-mail addresses. It is usually best to e-mail your account manager in the first instance. Google hangouts can be arranged for video conferencing support.

4. Assessment including e-assessment

Assessment summary

Coursework

4.1 Evidence has to be provided against the unit assessment criteria from practical tasks related to the learners' everyday work. This is likely to be from specialist lessons related to Design Technology but can and should include evidence from across the curriculum, for example from maths, science, computing or the creative arts. The way evidence is gathered is up to the assessor, the only requirement is that it clearly supports the judgements against the assessment criteria and the relevant learning outcomes and reflects the learners' personal competence. If on moderation the account manager finds gaps in evidence related to a particular candidate they will request more evidence before approving the award of the unit certificate. Assessors must then adjust their work to ensure all their learners are providing the appropriate level and breadth of evidence. We encourage early submission of at least some evidence so that assessors are confident from the feedback that what they are providing is sufficient (and indeed not over-kill). In this way we can maintain standards while supporting improved efficiency.

4.2 Synoptic assessment has become a popular term. In essence all the coursework assessment is synoptic in that the evidence provided is against collectively synoptic assessment criteria underpinning the learning outcomes for the unit and mostly assessed in the context of holistic projects. Synoptic evidence of competence to a minimum value of 15 credits across the units is mandatory for both the level 1 and level 2 certificates. This equates to a minimum of 120 guided learning hours.

4.3 At level 1, there are 3 units of 5 credits each. The 5 credit units each require 40 GLH giving a total of 15 credits and 120 GLH. Dividing into a unit structure is for convenience and compatibility with international conventions for referencing national qualifications frameworks and to enable credit transfer e.g. as in the European system ECVET. It is **NOT** intended to determine the method of delivery. Teachers are free to

cover units concurrently deciding where the elements are logically related. We encourage the use of the flexibility provided to target particular interests of learners to motivate them in persevering in difficult areas and to raise the level of expectation in cognitive development.

4.4 At Level 1 and 2, the central project within the curriculum is the design and construction of a ‘Smart Product’ following industry standard commercial practices, which include the use of Computer Aided Design and Rapid Prototyping techniques using industry standard software. This provides young learners with direct and motivating experience of the tools and skills that are in high demand in a wide range of careers not only in manufacturing industries, but also in many allied and supporting occupations. These skills are of wider use in what will become home manufacturing as additive manufacturing falls in cost to a level where the equipment can be bought by DIY practitioners.

4.5 There is an obvious progression from Level 1 to Level 2 with learners gaining increasing capacity to tackle academic style questions requiring explanations and more detailed understanding and insight. Level 2 coursework requires increasing self-sufficiency in line with the RQF global level 2 descriptor. The outcomes for individuals in terms of the broad level descriptors allied to the assessment criteria, verified by the teacher/assessor and externally moderated by TLM will determine the final outcome. Grouping learners is up to the school but the design enables maximum flexibility. Some students can achieve Level 1 first for example in Year 8 and 9 and then progress to Level 2 units in Year 10 and finally to a Level 2 grade through the exam and academic revision. Others might be split into Level 1 and Level 2 in Year 10 and work over two years to the particular level with level 1 learners progressing to Level 2 post-16 e.g. through a related SVQ.

Progression and inclusion

4.6 There are some fundamental misunderstandings of unit based assessment with regards to progression and inclusion. The paragraphs below will explain how criticisms related to these issues can be rejected. Having higher levels of professional expectation and improved and

lower cost CPD strategies is better than “dumbing down” to less professional approaches.

4.7 Smart Product Design and Manufacture is a unique project based learning programme that introduces product innovation and advanced manufacturing industry skills to students using an industry recognised progression route. We consider that students who achieve a Level 1 qualification in Smart Product Design and Manufacture will have improved their numeracy skills through applied mathematics embedded throughout the programme and will benefit through improved literacy as well as through other employability and design skills. For those schools interested in using Smart Product Design and Manufacture in Key Stage 3, students progressing through Level 1, will receive a qualification recognised by government and endorsed by industry that prepares them for Level 2 achievement enhancing motivation through reward. Students, having enjoyed, completed and succeeded at Level 1 by the age of 14 years will be more likely to be successful at Level 2 and with higher grades. This provides an improved strategy for increasing the numbers getting the higher A*-C GCSE equivalent grades by the age of 16, providing a much better basis for progression to Level 3.

4.8 Smart Product Design and Manufacture offers an interesting and broad education experience in its own right and links to career progression in the engineering, design, creative arts, embedded software development and technology industries, enabling students to see the links between them. There are growing career opportunities focused on innovative product development that require a maintenance of curiosity and affinity with change. The provision at Level 1 and Level 2 underpins progression to Level 3 and the Level 3 qualification will have many of the characteristics of undergraduate study supporting better capacity to cope in degree courses.

4.9 It is very unlikely that any learner embarking on a TLM qualification based on these methods will not achieve at least some kind of recognition for their work at a level appropriate to their current attainment level with a progression route from where they end up to

higher levels. Clearly some will take longer than others. This inclusion is achieved without sacrificing rigour for the highest attainers since the questions in the examination targeting the A/A* grades can be as difficult as necessary without risking weaker candidates dropping out of a grade altogether. Indeed able students can start Level 3 work in KS4 differentiated by outcome where appropriate. Currently there is a good argument that candidates achieving A* and A grades across all their subjects are not being adequately stretched in KS4.

4.10 Beyond Level 2 it will be possible for work supporting Level 2 units to be converted to Level 3 by candidates if they provide evidence that is clearly at the higher level. For the highest attainers this provides an accelerated route to Level 3 so that they are not just marking time at the end of KS4. This is where current systems fail the highest level attainers. Some individuals can cope with university level work in KS4, not many but these individuals matter just as much as those with learning disabilities and so we need systems flexible enough to cope with them.

4.11 Coursework, particularly at Level 2 should reflect useful and meaningful activities with practical activities useful to other people and the wider community as well as the candidates themselves. Examples might be to interrogate an existing design brief or tackle an energy efficiency issue in their own school. We want to encourage work that reflects contemporary society using industrial tools and technologies that enable ALL individuals to contribute not only those that can afford to. Projects lend themselves to cross-curricular work supporting raising attainment in other subjects, numeracy, literacy, science and information skills but also aesthetic subjects such as art and design. for many learners it is more motivating to learn through creating original work (or original remixes of other people's work) that has a real and practical purpose than to do simulations or theoretical exercises. This is a fundamental part of TLM's coursework philosophy and founded in research evidence.

5. Criticisms of coursework answered

Criticism 1: Coursework is too susceptible to plagiarism and other forms of dishonesty.

5.1 A Google search will have a high chance of finding any extended text that has been copied from an online source. If we are genuinely concerned about "copying from the internet" simply inform teachers of how to combat the issue using freely available tools. Require teachers to accept professional responsibility for the authenticity of their learners' evidence. If teachers really want to cheat why would they not simply tell students the answers to an exam? If learners want to cheat why not simply forge a convincing looking certificate? There is no tradition of easy certificate authentication so there is a high probability that forgery will be successful. A complementary examination means that we can check back to see if individual teachers are "passing" student coursework for a disproportionately high number that then fail the examination. That provides an evidence source to cross-reference the quality assurance in order to better target staff development. Work smarter not harder!

Criticism 2: Unit based assessment means that knowledge is in compartments.

5.2 Unit structures are for administrative convenience **NOT** teaching plans. There is nothing to stop elements of several units being supported through one or more projects concurrently. Most academic syllabuses are divided up into sections. That is no different in practice to labelling the sections units. There is no requirement to assess units at a particular time. If most evidence is provided at the end of the course across all units why is that any different from a controlled synoptic terminal examination? If teachers do not teach unit based courses effectively, train the teachers, don't blame the tools. If we are really worried about compartmentalised knowledge why preserve a subject based curriculum?

Criticism 3: Unit based assessment does not support progression.

5.3 On the contrary, the scope of unit based qualifications organised in a levelled framework provides a better support for progression when the unit content and structure is designed for that purpose. Where qualifications are opportunistically designed to simply target one level in a terminal examination that is only representative of a subset of the learning, there is a good argument that progression is badly supported but that is true of any qualification whether unit based or not.

Criticism 4: Competence based assessment has to be lowered to the level of the least difficult assessment criterion.

5.4 In well designed assessment units the assessment criteria are contextualised to the general level specified in the overall level descriptors. This means all assessment criteria should be interpreted in terms of that overall level descriptor, not taken on face value in isolation. It is impossible to measure anything with absolute precision and it is scientifically bogus to claim we can, even if it is politically sensitive to admit that there will be some uncertainty in assessment outcomes when applied to individuals. This is true of both coursework based and exam based methods. The important thing is to get a reasonably consistent set of outcomes within the expected degrees of uncertainty. The competence based component of these qualifications is intended to provide a baseline consistent with the general level descriptor and to motivate beyond basic competence by providing the flexibility to pursue contextual interests of individuals. Grading is achieved by a terminal examination. This means we can match the assessment method to the aspect of attainment such that we cover all aspects of learning but we also provided reliable differentiation that can accurately inform progression routes for individuals as well as motivate all, not just those that are good at exams.

Criticism 5: Exams have always been the tried and trusted way of assessing attainment. There is no need for anything else.

5.5 Written examinations have been widely used for academic assessments in schools and universities. However, that is largely due to their academic heritage where theory is often more important than practice. Even so, coursework is well-established where there are practical elements e.g. in science and medicine. Few jobs assess prospective candidates exclusively using written exams. In most practical areas from brain surgery to teaching, no-one would trust a written examination on its own to prove competence. That is not to say such examinations are not of value. The key is to use coursework **and** examinations intelligently together in order to provide something that is better than either treated in isolation. Ideological arguments of one method of assessment to the exclusion of another are simply political rather than rational.

6. The Examinations

6.1 Examinations at Level 1 and Level 2 are primarily for grading. They are externally set and externally marked. The details of the way grades relate to marks are provided above in section 2. The examinations also provide a cross-reference in order to increase confidence in the validity of the coursework component.

Weightings

6.2 There are two classes of objectives. AO1, AO2, AO3 are generic assessment objectives:

AO1 – Recall, select and communicate knowledge and understanding.

AO2 – Apply knowledge and understanding through analysis, reasoned judgements and drawing conclusions.

AO3 – Practical and technical skills related to applying skills knowledge and understanding in context.

6.3 Additionally, the qualification units each specify subject specific learning outcomes. The qualification design draws on both classes of objective to ensure balanced representation and that the assessment is a valid representation of what has been learnt.

6.4 The assessment objectives provided by the unit learning outcomes are evenly weighted in the coursework element since all must be achieved in order to pass.

6.5 The synoptic examination is directly related to the unit learning outcomes and assessment criteria under-pinned by the content definitions in section 3 and the guidance in the unit descriptions. This is designed to be broadly representative of the knowledge and understanding associated with the learning outcomes, testable in a synoptic terminal controlled examination related to the learning outcomes. This enables grading the qualification to inform progression to higher levels whereas the course work ensures that there is basic

competence in their practical implementation in real and relevant contexts.

6.6 At Level 1 the examination weighting of AO1 is 50% and AO2 50%. At level 2 the examination is weighted 40% AO1 and 60% AO2 in the examination and approximately equally in the coursework.

6.7 The overall weighting of the objectives varies depending on the grade because for higher grades AO2 contributes a greater proportion of the marks. This is a deliberate strategy because AO2 is most important when it comes to academic learning at Level 3. The assessment will therefore better inform progression pathways while still having the characteristic of inclusion. At level 2.

Grade C approximately weighted AO1 - 40%, AO2 - 40%, AO3 20%. Grade A* approximately weighted AO1 - 25%, AO2 - 65%, AO3 10%

6.8 This then provides evidence that the Grade A* candidate is likely to be more suited to future academic study whereas the Grade C candidate is likely to find it difficult to cope with courses highly dependent on academic testing.

Learner entry and costs

6.9 The TLM subscription model enables schools to enter learners at times convenient to them. There are no late entry fees and no additional fees should a learner fail to produce evidence at a particular level but can meet the criteria at a lower level. This can reduce costs to the school by more than 50% when compared to GCSEs and teacher time is taken into account, significantly more than this when compared to some GCSE alternatives. Examination entry will depend on whether or not learners meet the coursework criteria. This again saves money because the school is not paying for examination administration for learners that are unlikely to be successful or for whom there is little or no benefit in taking an exam. There are no fees for replacement certificates or verification of certificates because all certificates can be

directly authenticated against a secure database. For details of current subscription costs please contact us or refer to the web site.

Online examination and e-assessment

6.10 The examinations can be delivered in a traditional paper based format or online. There is a surcharge for paper based examining reflecting the extra cost involved. The online versions have a secure web user interface and require no software installation. They can run through any standards compliant web browser on any type of computer. The user is restricted to an area in the centre of the screen during the examination and has no access to the internet, or any other storage device without moving the mouse pointer out of the secure area and this will set off a warning. Persistence will result in disqualification from the examination. Since the Level 2 online exam contains open-ended questions it has to be physically marked and so the results will not be immediately available but we will aim to have these ready within 2 weeks of taking the exam. The Level 1 examination is multiple choice questions and so the results will be available immediately. For those taking the examinations in the traditional paper based format it is likely to take 4 weeks to finalise results.

6.11 TLM provides optional on-line tools for managing coursework evidence through the community learning site at www.theingots.org. This is a free service because it will reduce time and hence costs for both the Awarding Organisation and the Centre. To optimise efficiency, self and peer assessment validated by the assessor are supported. Not all centres are ready for this and it is therefore not a mandatory requirement.

6.12 It is mandatory for all assessors to record grades in the on-line mark book. This is because to access the mark book all assessors have to sign an agreement to uphold standards and so any grade recorded by an assessor is effectively subject to that agreement. All grades must be recorded and in place before and award can be requested. Once an award is requested evidence samples will be sought. If the Centre uses the on-line evidence management system, mark book grades are

transferred automatically and the account manager has immediate access to all the evidence and any assessor learner dialogue associated with the award. This is clearly more efficient and it is what we are working towards for all centres. We always welcome feedback so we can continue to improve the systems to reduce the bureaucratic overhead and support better formative as well as summative assessment as a strategy for raising standards.

Examination windows

6.13 The exam will be available by giving 6 weeks notice or more and paying the exam fee at least 1 week prior to the exam being sat. It is the Centre's Principal Assessor's responsibility in line with the agreement signed with TLM to ensure that security is maintained for the examination. No candidate should have prior access to the questions in an examination paper either directly or indirectly, before they sit the paper. We will have several versions of the examination available and if there is any suspicion of compromise of security, the Principal Assessor should contact TLM to work out a solution. Assuming there is no malpractice, it might simply be a matter of scheduling an alternative paper. Papers will be planned to be of similar difficulty. Candidates can retake an examination once if they have not claimed a qualification based on a previous result. Once the result is finalised they must wait 6 months before resitting the entire qualification. In order to gauge readiness for the examination the centre can request a "mock" examination. This will be conducted identically to the real thing and will cost the same amount. It will just not count in the qualification. Mocks should be requested in the same way as the real exam.

Internal standardisation of coursework

6.14 The Principal Assessor has the ultimate responsibility for consistency in assessment standards within a centre and has signed an agreement to that effect. All assessors have signed a contract agreeing to uphold standards and should therefore co-operate with the Principal Assessor and Account Manager at TLM to ensure that standards across the centre are consistent. It is advisable to send work samples to TLM early to check that evidence is at the right standard so that there is time

to make any adjustments necessary to the course and learner expectations. TLM will generally check a higher quantity of work from new assessors and feedback to ensure that they are confident to make appropriate judgements over time. This reduces risk and improves efficiency in the longer term.

Authentication

6.15 All assessors must take reasonable steps to ensure that any coursework evidence submitted by candidates is a true reflection of the candidates' competence. This is in keeping with the assessor undertaking to uphold and maintain standards in the contract with TLM.

6.16 Certificates can be authenticated directly online using the certificate number or by scanning the QR code on the certificate. There is no charge and it makes it more likely that certificates will be checked and that in turn improves security. Certificate forgeries are a significant problem when authentication is not simple and straightforward because convincing forgeries are easy to achieve with recent technologies and will get easier as time goes on.

7. Other considerations

Access arrangements and special requirements

7.1 All TLM's qualifications are intended to be accessible, as widely as possible. There is an extensive policy documented on the web site at https://theingots.org/community/ofqual_policies RQF D2

Centres should contact TLM if they have any questions related to accessibility issues.

Language

7.2 The language for provision of this qualification is English only. This will only change if we have a significant demand in another language that is sufficient to cover the additional costs involved and some cultural alterations will be needed. TLM will actively support any work in this line that can be shown to cover costs.

Malpractice

7.3 TLM has comprehensive policies and procedures for dealing with malpractice. These are documented with links on the web site at https://theingots.org/community/ofqual_policies RQF A8 Assessors should be familiar with these policies and make them clear to candidates. Assessors should inform their account manager if they suspect any instance of malpractice that could have a material effect on the outcome of any assessments, either for themselves or colleagues. This is part of the upholding of standards that is part of the contract with TLM.

Equality of opportunity

7.4 TLM promotes equality of opportunity through policies and procedures. These are again documented in detail on the web site at https://theingots.org/community/ofqual_policies RQF D2

8. Resources, support and training

8.1 A clear goal of these qualifications is to enable learners to support their own learning and to reduce dependency in order to become "lifelong learners". The IT revolution makes this progressively easier. As far as possible we encourage the use of technology and up to date methods, especially those based on empirical evidence.

8.2 TLM encourages the use of free and open source applications to reduce costs and to further inclusion. Many of the key software applications needed to support the assessed units are available freely from a range of open source platforms. Even though it is not Open Source, Sketchup, one of the world's most popular design software applications and can be used without charge. It has capability ranging from beginner to professional, including 3D modelling, visualisation and export to manufacture functionality.

8.3 Integrated aspects of the Smart Design and Manufacture programme ensure that teachers and learners receive a fully supported, expertly enhanced, stimulating and challenging learning experience. It is anticipated that teachers will soon grow in confidence, develop their own networks of industry based support and be able to develop new projects of their own – ones that may be unique to their local context or that offer specific targeted challenges. If this acts as a catalyst for better teaching associated with assessment for learning methods, it is likely that the effects on staff development and better use of technologies to support learning will go far beyond the product design sector.

8.4 The curriculum introduces new areas of learning that include close engagement with the world of work and academia. Teachers and learners alike will find it rewarding, challenging and exciting – a combination that guarantees successful outcomes and a learning environment that is happy, productive and fun.

8.5 Smart Design and Manufacture qualifications are designed to support learning that enables progression to Further Education, Higher Education and employment for a wider range of young people. They also provide a focus for low cost and sustainable staff development that can keep teachers up to date with the technologies that can enhance the capacity for learners to gain the competencies required to make them employable as well as academically knowledgeable.

9. Grade Descriptions

At Level 2 **grade A** candidate will exhibit most the following characteristics.

9.1 Candidates demonstrate a high level of independence in using their knowledge and understanding to support activities beneficial to themselves and others in everyday contexts. They recall, select and communicate a thorough knowledge and understanding of the general competences needed to support lifelong learning and personal well-being.

9.2 They apply knowledge, understanding and skills to a variety of situations, selecting and using knowledge and information efficiently to solve problems and produce effective support for their own learning as well as the needs of others. They relate these to comparable activities in the world of work. They manipulate and process data efficiently and effectively based on objective criteria. They interpret information and transfer knowledge and understanding from familiar to unfamiliar contexts. They work creatively exploring and developing ideas. They adopt systematic approaches to safety, promoting secure and responsible practices.

9.3 They use scientific methods to analyse problems such as control of variables and observations to identify needs and opportunities. They set hypotheses in relevant contexts and critically analyse and evaluate the knowledge they gain. They review their own work and that of others making supportive and constructive criticism where appropriate. They communicate effectively, demonstrating a clear sense of purpose and audience.

A **grade C** candidate will exhibit most of the following characteristics

9.4 Candidates demonstrate the ability to select and use relevant knowledge, ideas, skills and procedures to complete well-defined tasks and address straightforward problems. They take responsibility for

completing tasks and procedures and exercising autonomy and judgement subject to overall direction or guidance.

9.5 They use understanding of facts, procedures and ideas to complete well-defined tasks and address straightforward problems in supporting their learning. They interpret information and ideas related to the social and commercial impact of their actions, showing awareness of the types of information that are relevant to their areas of study. They identify, gather and use relevant information to inform their actions and make judgements about how effective their actions have been.

9.6 They work safely and securely, identifying key risks, taking reasonable actions to avoid them. They collaborate in reviewing their work evaluating the way they and others use their construction knowledge and skills and they take positive actions to improve. They use standard English and IT to communicate effectively, demonstrating some consideration of purpose and audience.

9.7 Level 1 candidates will use relevant knowledge, skills and procedures to complete routine tasks. They will take responsibility for completing tasks and procedures subject to direction or guidance. Distinction* candidates will show knowledge and understanding that is indicative of Level 2 work in at least some areas.

Annexe A - example examination Level 1

The following principles will apply to the design and structure of each exam.

Questions will vary in the general area of the required learning outcomes specified in the units and cover all the assessment criteria in the approximate proportions presented in this document. Questions will reflect a balance of the content listed and explained in the guidance in keeping with Level 1 as defined by the RQF global level descriptors.

Each question is worth 2 marks.

Questions

1. A project brief is

a) a homework diary.

b) the things to be done to complete a project.

c) market research.

d) evaluating a project.

2. A project brief considers

a) users of the products.

b) price of the products.

c) environmental impact of producing and using the products.

d) all of the above.

3. A project time line is

a) a chart that helps you organise project deadlines and milestones.

b) a record of how the project went.

c) how long it takes you to get a design idea.

d) a list of the cost of materials.

4. A plan view is

a) a flattened view of a product looking from the top down

b) an outline of a project time line

c) a type of paper

d) a 3D view of a product

5. Computer Aided Design includes

a) 3D Scanning.

b) mesh modelling.

c) solid modelling.

d) any of the above.

6. A profile curve is

a) the size of an object.

b) a 2D curve used to make a 3D object.

c) a prototype of an object.

d) a photograph of an object being designed.

7. A photo-realistic render is

a) a computer generated image.

b) a photograph of an object shown on a computer.

c) wallpaper designed on a computer.

d) the paint used on circuit boards.

8. An .svg file is?

a) a 2D vector based graphic file format.

b) a photograph file.

c) a 3D solid model file.

d) a file used to control machine actions.

9. A 3D CAD model is said to be “water tight” if

a) the surfaces have adjoining edges with no gaps.

b) the model will float in a water tank.

c) the machine making the design is accurate.

d) the graphics software is open source.

10. A digital design can be made into a physical object using

a) 3D casting.

b) 3D printing.

c) 3D scanning.

d) 3D photography.

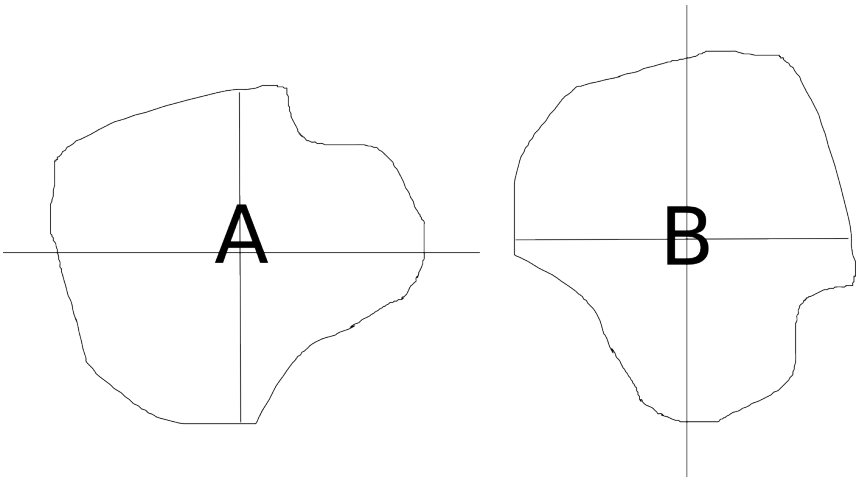
11. A 3D volume can be made from 2D flat sheets in the form of

a) nets

b) lines

c) grids

d) graphs



12. If you want to rotate a design from position A to position B, how many degrees would you need to rotate it by?

a) 10 degrees

b) 90 degrees

c) 180 degrees

d) 360 degrees

13. The number of faces on a cube is

a) 4

b) 6

c) 8

d) 12

14. An example of a computer language used to control 3D printers is

a) Gcode.

b) Raspberry Pi.

c) Java.

d) Remote Control.

15. A prototype is used to

a) show a user or client a finished product.

b) test new ideas before manufacturing many products.

c) write up the design specification.

d) hire a professional team.

16. To cut 2D sheet material I would use

a) laser cutting.

b) a hand turned lathe.

c) injection moulding.

d) photocopying.

17. A 3D printer could use

a) ABS plastic

b) Chocolate

c) PLA plastic

d) any of the above

18. A design for a USB device casing will need to consider

a) the size of any existing USB electronic components.

b) the data speed of the USB port.

c) the make and model of computer.

d) the programs to be stored in the USB memory.

19. A "Smart" product that can sense and react to the environment would have to include

a) a microcontroller.

b) a good colour scheme.

c) an attractive shape for the case.

d) an earth for electrical safety.

20. For assembling flat sheet material into 3D objects I would use

a) chaining.

b) laminating.

c) stitching.

d) soldering.

21. To make a product by programming a computer to drive a machine I would use

a) CTC.

b) COC.

c) CBC.

d) CNC.

22. **A part can be 3D printed in 20 minutes. By reducing its fill density, it can print in12 minutes, how much time will be saved over 50 builds?**

    a) 12 minutes.

    b) 5 days.

    c) 400 minutes.

    d) 1 week.

23. **A 3D CAD model can be used to make a 2D surface by**

    a) decimation

    b) unfolding

    c) pixellation

    d) sketching

24. **You want to make a model that is half the size of the actual design in CAD. What scale factor would you apply to the CAD design?**

    a) 1:100

    b) 1:2

    c) 2:1

    d) 1:20

25. **To draw a cylinder in CAD with a diameter of 10 cm and height of 30 cm the designer should input a radius and height measurement of**

    a) radius: 50mm, height: 300mm

    b) radius: 10mm, height 30mm

    c) radius: 5mm, height 15mm

    d) radius: 100mm, height 200mm

26. **Which components need to be embedded in a Smart home automation system that controls your home heating**

    a) a temperature sensitive transducer.

    b) SDRAM.

    c) fan.

    d) a hard drive.

27. **For an object that can be mass produced using 3D printing it is necessary to consider**

    a) 3D printing build time per part

    b) Material cost

    c) Build quality

    d) All of the above

28. **To integrate Smart design into a product a designer must include**

    a) CAD

    b) CAM

    c) 3D printing

    d) Logic

29. To track and review how a project is progressing a designer should refer to

a) the original project brief.

b) a family friend.

c) a newspaper.

d) the 3D printer manual.

30. I want to combine a laser cut case with a circuit board in my new Smart product. I should pay particular attention to the

a) voltage settings.

b) dimensions.

c) materials used.

d) laser settings

31. The biggest energy savings in a home will come from use of

a) a lamp dimmer to reduce brightness in the day.

b) resistors in all circuits.

c) a transformer to increase the voltage at all the sockets.

d) a thermostat to reduce maximum room temperature.

32. A suitable transducer for input to a micro-controller managing the heating system in a building is a

a) thermistor.

b) resistor.

c) LDR.

d) potentiometer.

33. **A Smart device measures a patient's blood pressure during the day and sets off an alarm if it rises too quickly. The Smart device records the blood pressure readings by**

    a) mapping.

    b) sampling.

    c) ramping.

    d) damping.

34. **A project needs to switch on a motor if the temperature falls below a certain level in either of two separate rooms. To make this work requires connecting**

    a) two sensors in series with the motor.

    b) three sensors in series with the motor.

    c) two sensors in parallel with each other.

    d) three sensors in parallel with each other.

35. **BEGIN**

    IF Voltage > 5 :Output = 0

    END

This code is likely to.

    a) set the output to 5 volts.

    b) set the voltage to 5 volts.

    c) switch the output on if the input voltage is zero.

    d) switch the output off if the voltage rises above 5 volts.

Annexe B - Example examination Level 2

The following principles will apply to the design and structure of each exam.

Questions will vary in the general area of the required learning outcomes specified in the units and cover all the assessment criteria in the approximate proportions presented in this document. Questions will reflect a balance of the content listed and explained in the guidance in keeping with Level 2 as defined by the RQF global level descriptors.

Questions

1. A business might want to offer consumers the option to customise their products because

a) it is cheaper for the business to manufacture those products.
b) customers want more choice in their design decisions.
c) the products will last longer.
d) the products can be made quicker.

2. 'Cradle to cradle' design means

a) a product is designed so all the parts can be recycled and used again.
b) a product is designed to be cheap and thrown away at the end of its use.
c) a product is designed for transfer of support between objects.
d) a product is designed to hold sleeping babies.

3. A mind map is

a) a scan of your brain.
b) a diagram outlining different project ideas.
c) a map of a local town.
d) a chart showing the structure of the brain.

4. I can use CAD modelling to

a) design a 3D solid object.
b) make a plasticine head.
c) paint a landscape scene.
d) build a tailors dummy.

5. To make a 3D landscape using layers, I could build

a) a castle.
b) a geography model.
c) a topographic model.
d) a typography model.

6. I want to design my work for a laser cutter. The best file format for a simple 2D design is

a) .dxf.
b) .svg.
c) .dwg.
d) any of the above.

7. For preparing a job for manufacture on a milling machine I should use a file with the extension

a) .mil.
b) .stl.
c) .cam.
d) .std.

8. **I am designing a boat and I need to give it strength to maintain its shape. To do this I can use**

a) ribs.
b) le.g.s.
c) bones.
d) bilges.

9. **To make a cup from the profile below**

a) rotate 180 about the base
b) rotate 360 about the central axis
c) reflect the shape about the central axis
d) reflect the shape about the central axis.

10. **A photograph is made up of**

a) pixels.
b) lines.
c) mesh.
d) surfaces.

11. **An engineer wants to create a large complicated 3D model to test some ideas. Explain how he might design the model so he can try out his ideas and make changes efficiently.** (1 mark)

12. **Explain how you might produce a photorealistic 3D image of a model you have designed for your client.** (2 marks)

13. **Explain how a 3D printer manufactures a product using the words tool path, nozzle, and material.** (3 marks)

14. **What is a polygon?** (1 mark)

15. **Why are polygons important in 3D scanning?** (2 marks)

16. **Spatial resolution depends on the smallest distance between two points. How is this principle applied in images made up from polygons?** (2 marks)

17. **A cube with side 10mm is a component in a design. What is the volume of the cube?** (2 marks)

18. **For the cube in question 17 what is its mass if the density of the material is 5000 kg/m^3?** (2 marks) (Hint: Check the answer is sensible!)

19. **My customer likes my overall concept design so I suggest building a functional prototype. Provide an example of a functional prototype.** (1 mark)

20. **Explain the difference between a digital prototype and a physical prototype.** (2 marks)

21. **Your client wants you to manufacture a box from 3mm acrylic. The kerf (k) is 1mm with your laser cutter. Two pieces of the box need to interlock tightly. What is the minimum gap (x) you should specify in your .dxf file so there is a snug fit?** (2 marks)

22. **Give an example of a standards body. What is the purpose of these organisations?** (3 marks)

23. **I am making a prototype that is 10% the size of the client specification for mass produced manufacture. What scale should I work to?** (1 mark)

24. **I want to save energy in my work place which is well insulated. Explain how I might do this using a Smart device or devices.** (5 marks)

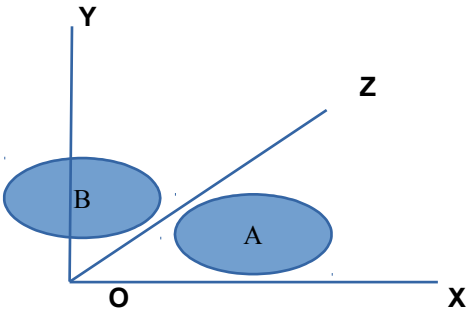
25. **In order to fund your project you need to raise capital. Name 3 ways in which capital can be raised and for one, explain the risks involved.** (6 marks)

26. **Explain the roles of a CAD Designer and an Engineer in manufacturing and say how they are similar and how they are different.** (4 marks)

27. **Give three reasons why it is an advantage to produce a digital prototype before manufacturing a physical prototype. (**3 marks)

28. **For a project that you have carried out explain a problem you encountered in prototyping and how you overcame it.** (3 marks)

29.



Which plane would you rotate this shape in to go from position A to B?
(1 mark)

30. Give an example of a transducer and explain how it is used in a practical Smart technology device (3 marks)

31. Explain the purpose of an analogue to digital converter. (ADC) (2 marks)

32. An analogue electrical signal is changing 50 times per second. It has a maximum voltage of +25.5 volts and a minimum of 0 volts.

For an 8 bit ADC what will the smallest voltage change detectable for this signal? (2 marks)

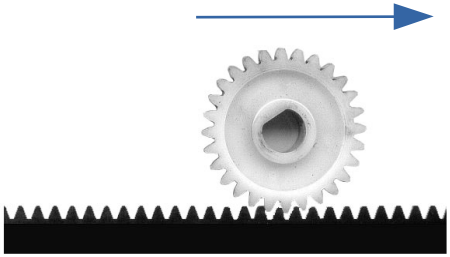
If the ADC can take samples at a rate of 1 million per second how many samples will be taken in one complete cycle for the signal? (2 marks)

33. A. Explain the difference between a stepper motor and a DC motor.
(2 marks)

B. What force is used to drive a rotor inside a stepper motor?
(1 mark)

C. If each step of a stepper motor moves through 2°, how many steps will be needed for one complete revolution? (1 mark).

D. A stepper motor is attached to a gear wheel rack and pinion mechanism to convert rotational motion to linear motion. If the gear wheel attached to the stepper motor has a circumference of 12 mm use the result you calculated in C above to say how precisely the position of the rack can be moved? (1 mark)



Annexe C - Level 1 Units
Level 1 Smart Product Design and Manufacture
Unit 1: Product Design and Visualisation
5 credits (40 GLH)

1. Relate opportunities and constraints to a product design.	**2. Visualise product solutions to meet identified needs.**	**3. Present evaluations of designs.**
1.1 identify opportunities for a product or solution.	2.1 identify key aspects in a design brief.	3.1 collect evidence for presenting the design.
1.2 identify constraints on a product or solution.	2.2 gather information to develop a solution.	3.2 present strengths and weaknesses in a visual prototype.
1.3 consider commercial sustainability of a product or solution.	2.3 design and test sketches and models to visualise a solution.	3.3 use appropriate digital and/or physical models to support presenting a design.
	2.4 use appropriate digital and physical media to design a product.	3.4 receive feedback from presenting a design.
	2.5 prepare a visual prototype of the solution.	3.5 act on feedback to improve a design.

Assessor's guide to interpreting the criteria

General Information

RQF general description for Level 1 qualifications

- RQF general description for Level 1 qualifications
- Achievement at RQF level 1 (EQF Level 2) reflects the ability to use relevant knowledge, skills and procedures to complete routine tasks. It includes responsibility for completing tasks and procedures subject to direction or guidance.
- Use knowledge of facts, procedures and ideas to complete well-defined, routine tasks. Be aware of information relevant to the area of study or work
- Complete well-defined routine tasks. Use relevant skills and procedures. Select and use relevant information. Identify whether actions have been effective.
- Take responsibility for completing tasks and procedures subject to direction or guidance as needed

Requirements

- Standards must be confirmed by a trained Level 1 Assessor or higher
- Assessors must at a minimum record assessment judgements as entries in the online mark book on the INGOTs.org certification site.
- Routine evidence of work used for judging assessment outcomes in the candidates' records of their day to day work will be available from their e-portfolios and online work. Assessors should ensure that relevant web pages are available to their Account Manager on request by supply of the URL.
- When the candidate provides evidence of matching all the criteria to the specification, subject to the guidance below, the assessor can request the award using the link on the certification site. The Account Manager will request a random sample of evidence from candidates' work that verifies the assessor's judgement.

- When the Account Manager is satisfied that the evidence is sufficient to safely make an award, the candidate's success will be confirmed and the unit certificate will be printable from the web site.
- Each unit at Level 1 has recommended 40 guided learning hours based on time required to complete by an average learner.

Assessment Method

Assessors can score each of the criteria N, L, S or H. N indicates no evidence and it is the default setting. L indicates some capability but some help still required to meet the standard. S indicates that the candidate can match the criterion to its required specification in keeping with the overall level descriptor. H indicates performance that goes beyond the expected in at least some aspects. Candidates are required to achieve at least S on all the criteria to achieve the full unit award. Once the candidate has satisfied all the criteria by demonstrating practical competence in realistic contexts they achieve the unit certificate.

Expansion of the assessment criteria

Level 1 Smart Product Design and Manufacture

Unit 1: Product Design and Visualisation

5 credits (40 GLH)

1. Relate opportunities and constraints to a product design.

1.1 I can identify opportunities for a product or solution.

Candidates should be able to make connections between the opportunities presented and the product proposal.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: At level 1, simple associations are good enough. This could be an opportunity to introduce some basic

research methods to find out what demand there might be for a product of this type.

1.2 I can identify constraints on a product or solution.

Candidates should be able to identify possible constraints on the proposed product.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be able to appreciate that any proposal will have constraints. These could be classified e.g. materials, costs, safety, accessibility, precision, market groups etc. Level 1 candidates should be guided in classifications but they should be able to identify the constraints within the classifications.

1.3 I can consider commercial sustainability of a product or solution.

The candidate will consider the issues related to achieving commercial sustainability for a prototyped product.

Evidence: From portfolios, assessor observations.

A**dditional information and guidance:** Candidates consider the issues involved in going from a prototype to a commercial product. Cost of materials, cost of manufacture, cost of distribution and advertising. They should know some of the ways of raising finance for a project. Environmental issues such as disposal and energy generation in the manufacturing process, health and safety, intellectual property can all be important. How would they go about getting a patent? Would an open source hardware route be better? At level 1 it is enough to generate awareness of the issues and focus on a limited number of interests. Commercial sustainability is not necessarily with profit from direct sales margins. It simply means there is some way of sustaining a product once it is developed. It could be a service around the product, something that is increasingly the case with products.

2. Visualise product solutions to meet identified needs.

2.1 I can identify key aspects in a design brief.

The candidate will be able to take a design brief and identify key aspects in order to consider their approach.

Evidence: From portfolios, local testing, assessor observations

Additional information and guidance: Candidates should be familiar with the concept of a design brief. They should be presented with several design briefs and demonstrate the capacity to consider specific requirements that might be needed for each key aspect. At Level 1 the design briefs can be fairly structured. For example, what material is specified? What does it cost? What does it do? Is it available? The key point of this criterion is getting candidates to focus on the priorities for research and planning in response to identified needs.

2.2 I can gather information to develop a solution.

The candidate will be able to gather information from several sources in order to develop their design.

Evidence: From portfolios, assessor observations.

Additional information and guidance: Candidates should be able to use the key facts identified in the design brief to consider design parameters such as shape, size, form, or constraints such as having to fit and accommodate existing or external systems, environmental impact and other factors within their own knowledge base and then use research from books, the internet and people to support their own ideas. Candidates should produce a blog or diary to document their findings and organise the information they gather. This should include relevant details, for example, sizing, form, fit, or function, performance or user experience.

2.3 I can design and test sketches and models to visualise a solution.

The candidate will be able to create and test ideas through visual means.

Evidence: From portfolios, assessor observations.

Additional information and guidance: Candidates will produce a range of visual evidence of their approach to the problem demonstrating the evolution of their thinking. This will include for example, mind-maps, sketches, collages, computer drawings, and might be supplemented with written or audio supporting commentary. There should be clear evidence of how their research helped them develop their ideas beyond what they already knew themselves. At Level 1 structured guidance will need to be given in order for the candidate to achieve rich outcomes.

2.4 I can use appropriate digital and physical media to design a product.

The candidate will use a range of media to contribute to product design.

Evidence: From portfolios, the visual prototype, assessor observations.

Additional information and guidance: The design tools will include an increasing understanding of software principles used in design and any other appropriate modelling materials such as paper, plasticine, plastic etc.

2.5 I can prepare a visual prototype of a product.

The candidate will produce a visual prototype of a product.

Evidence: Portfolio images of the digital prototype at various stages, assessor observations.

Additional information and guidance: Candidates will produce a visual prototype through the input of information and data into suitable software and media to realise their visual prototype. This could be 2D or 3D models in CAD, computer based drawing and design tools and/or physical models. Any information and data required to create suitable digital models for a project can be accepted as long as it clearly meets the project brief or solution. Candidates' briefs should include the need

for at least one Smart technology or element that invites user interaction. For example, a learner could use Computer Aided Design to design the external form of a Smart food packaging. This would involve drawing on a computer and contribute information on RFID sensor functionality. At this stage it is a visual prototype and so the key priority is to be able to show sufficient detail of what the product might look like given the functional needs required from it. Project design should take into account any physical products or systems which it may need to reasonably accommodate within the project. At a simple level it could be cut outs or blanks in a casing or housing that allow external peripherals to be inserted during assembly. The sketch designs in this integrated form should explore both form and function, at a simple level. At Level 1 guidance will be needed in keeping with the RQF global level descriptor.

3. Present evaluations of designs.

3.1 I can collect evidence for presenting the design.

The candidate will prepare their presentation using the evidence gathered and collected in their portfolio.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates will gather the information they need to make their presentation. Level 1 candidates should be able to gather information but they will need help with structure and organisation.

3.2 I can present strengths and weaknesses in a visual prototype.

The candidate will identify a range of strengths and weaknesses in the visual prototype of the design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should be taught to be critical of their work and to classify strengths and weaknesses both from their perspective and through peer review and asking others.

At Level 1 this is likely to be incomplete but it is desirable to get them started on critical approaches at least in principle.

3.3 I can use appropriate digital and/or physical models to support a presentation of the design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should use a range of means to support their presentation. Designing for manufacture requires candidates to understand a number of external product requirements including designing for assembly, clearances and tolerances, regulatory requirements for specific types of products or specific uses. Candidates should be aware that the first way to evaluate their final product is against the specification in the design brief and any visual prototypes should relate strongly to the brief. Their digital and physical models should be used to demonstrate this. If things have changed they should be able to say why. At Level 1 they will need support in explaining and communicating the reasons but they should demonstrate that they can identify them. Being able to describe and explain them is a characteristic of Level 2.

3.4 I can receive feedback from presenting a design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should receive feedback graciously from any source and should consider it objectively. At Level 1 this might need support and time for them to gain control over emotions and part of the purpose is to achieve a mature response to criticism even where it appears to be unjustified.

3.5 I can act on feedback to improve a design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should show evidence of acting on feedback even if it is in the end to do nothing because they have considered the evidence and make a judgement that any changes will be detrimental or inappropriate in some way. In most

cases some changes will be needed to the design before it is used to start producing the product. These changes could be in structure, colour, functional aspects or aesthetics.

Unit 2: Product Manufacture
5 credits (40 GLH)

1. Relate a product design to its manufacture.	**2. Use tools and information to support the manufacturing process.**	**3. Present evaluation of manufacturing processes**
1.1 I can check quality in a design in preparation for manufacture.	2.1 I can select the tools needed for manufacture.	3.1 I can collect evidence for presenting the manufacturing process.
1.2 I can use scale and dimensions to associate plans with manufacture.	2.2 I can prepare information to manufacture a product.	3.2 I can present strengths and weaknesses in the manufacturing process.
1.3 I can prepare and document files to support the process of moving from design to manufacture.	2.3 I can use manufacturing tools with appropriate precision and attention to safety.	3.3 I can use appropriate digital and/or physical models to support a presentation of the manufacturing process.
1.4 I can make adjustments to a design as a result of feedback from the manufacturing process.	2.4 I can fabricate a product using appropriate materials and settings.	3.4 I can receive feedback from presenting the manufacturing process.
	2.5 I can finish or assemble parts and components.	3.5 I can act on feedback to improve my work.
	2.6 I can identify and correct errors to make improvements to my work.	

Assessor's guide to interpreting the criteria

General Information

RQF general description for Level 1 qualifications

- RQF general description for Level 1 qualifications
- Achievement at RQF level 1 (EQF Level 2) reflects the ability to use relevant knowledge, skills and procedures to complete routine tasks. It includes responsibility for completing tasks and procedures subject to direction or guidance.
- Use knowledge of facts, procedures and ideas to complete well-defined, routine tasks. Be aware of information relevant to the area of study or work
- Complete well-defined routine tasks. Use relevant skills and procedures. Select and use relevant information. Identify whether actions have been effective.
- Take responsibility for completing tasks and procedures subject to direction or guidance as needed

Requirements

- Standards must be confirmed by a trained Level 1 Assessor or higher
- Assessors must at a minimum record assessment judgements as entries in the online mark book on the INGOTs.org certification site.
- Routine evidence of work used for judging assessment outcomes in the candidates' records of their day to day work will be available from their e-portfolios and online work. Assessors should ensure that relevant web pages are available to their Account Manager on request by supply of the URL.
- When the candidate provides evidence of matching all the criteria to the specification, subject to the guidance below, the assessor can request the award using the link on the certification site. The Account Manager will request a random sample of evidence from candidates' work that verifies the assessor's judgement.
- When the Account Manager is satisfied that the evidence is sufficient to safely make an award, the candidate's success will

be confirmed and the unit certificate will be printable from the web site.

- Each unit at Level 1 has recommended 40 guided learning hours based on time required to complete by an average learner.

Assessment Method

Assessors can score each of the criteria N, L, S or H. N indicates no evidence and it is the default setting. L indicates some capability but some help still required to meet the standard. S indicates that the candidate can match the criterion to its required specification in keeping with the overall level descriptor. H indicates performance that goes beyond the expected in at least some aspects. Candidates are required to achieve at least S on all the criteria to achieve the full unit award. Once the candidate has satisfied all the criteria by demonstrating practical competence in realistic contexts they achieve the unit certificate.

Expansion of the assessment criteria

1. Relate a product design to its manufacture

1.1 I can check quality in a design in preparation for manufacture.

Candidates should check their design for possible quality issues prior to manufacture.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be guided systematically to check the design for any quality issues that will affect the manufacture. This could be related to precision, choice of materials, suitability for files used to automate manufacture, finish or any other attributes that need transfer from the design to manufacture.

1.2 I can use scale and dimensions to associate plans with manufacture.

Candidates should appreciate the link between scale and dimensions in their plans and how these translate to the manufacture of the product.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be able to work with simple scale multiples transferring dimensions from their plans to materials in order to manufacture the product.

1.3 I can prepare and document files to support the process of moving from design to manufacture.

Candidates should prepare any information needed for supporting the manufacturing process and organise it appropriately.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be able to document the process of translating designs to products so that other people can follow the process. At Level 1 it is reasonable to provide direction and structure for the candidate and the process can be illustrated by technical drawings, photographs or diagrams.

1.4 I can make adjustments to a design as a result of feedback from the manufacturing process.

Candidates should be prepared to learn from experience and make adjustments accordingly.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should understand the concept of feedback as a positive mechanism for improvement. Finding out what works and what doesn't should be used usefully to inform the current and future design projects.

2. Use tools and information to support the manufacturing process.

2.1 I can select the tools needed for manufacture.

The candidate will find suitable tools to manufacture the product using the specification for the design.

Evidence: From portfolios, assessor observations.

Additional information and guidance: Candidates should become familiar with a range of tools so that they can choose appropriately and based on rationale evidence. This implies significant opportunities for practice.

2.2 I can prepare information to manufacture a product.

The candidate will prepare the information to guide the manufacturing process.

Evidence: portfolio content and assessor observations.

Additional information and guidance: At Level 1 this will be a fairly straight forward product and candidates need to be.g.in to appreciate that to manufacture complex objects, good referral information is likely to make the task easier and more reliable. They need to prepare information ahead of manufacturing the product, such as creating and gathering a list of materials needed for manufacture. Candidates might attempt more than one project in order to provide a broader range of experience in preparing the information for manufacture. A lot will depend on complexity and issues arising along the way. At level 1 learners may be guided in the range of materials but they should have opportunity to prepare as much of the information necessary for their own project as possible in order to identify and appreciate the complexities.

2.3I can use manufacturing tools with appropriate precision and attention to safety.

The candidate will use a range of appropriate tools to the appropriate precision under guidance.

Evidence: Photographs of products, portfolio content and assessor observations.

Additional information and guidance: The appropriate precision will depend on the particular tools and circumstances and in keeping with the Level 1 global criteria assessors should provide reasonable guidance and sufficient time for candidates to practice skills. Candidates should appreciate the meaning of the word precision and that nothing is absolutely precise. The degree of precision will depend on the needs of the task and the tools available. Safety should always be considered and acted upon. At Level 1 close supervision should be applied where there are any significant risks. Candidates should accept this gracefully and be guided through a risk assessment where this is relevant. They should be familiar with the concept of a risk assessment.

2.4 I can fabricate a product using appropriate materials and settings.

The candidate will end up with a product or prototype that is in keeping with the design brief.

Evidence: Series of photographs showing the steps in the manufacturing process in portfolio, assessor observations.

Additional information and guidance: Candidates will build their products and record the evidence photographically. The crucial learning is that which comes from physically manufacturing a design. At one level a student can evolve the design through identifying and eliminating errors between digital to physical modelling techniques, at a more advanced level students can use information from the physical modelling process to evolve the actual design. At Level 1 this will be a fairly straight forward product and candidates need to begin to appreciate that a high level of skill and knowledge is required to manufacture complex objects even using a CNC device. Candidates might attempt more than one project in order to provide a broader range

of experience. A lot will depend on complexity and issues arising along the way.

2.5 I can finish or assemble parts and components.

Candidates can add finish and refinements to components, prototype or product.

Evidence: Photographs of the final finished digital prototype, assessor observations, work log in portfolio.

Additional information and guidance: Physical components may need to be post processed for example sanded, painted or fixed using appropriate hand tools, fixtures and fittings as necessary. Candidates should pay particular attention to small delicate components. Final assembly might need manipulation of components. Some of these finishing techniques are likely to require practice and candidates should be given sufficient time to develop these practical skills with due emphasis on safety.

2.6 I can identify and correct errors to make improvements to my work.

Candidates can make adjustments that improve their work.

Evidence: Photographs illustrating changes, assessor observations, work log in portfolio.

Additional information and guidance: Candidates should appreciate that while it is a good idea to eliminate as much risk and uncertainty before manufacture it is inevitable that adjustments might be needed. They should have enough opportunities either in making a range of components or other products/parts to be able to demonstrate evidence of improving their work as needs arise.

3. Present evaluations of manufacturing processes.

3.1 I can collect evidence for presenting the manufacturing process.

The candidate will prepare their presentation using the evidence gathered and collected in their portfolio.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates will gather the information they need to make their presentation. This will most likely be an on-going process throughout a project or projects. Level 1 candidates should be able to gather information but they will need help with structure and organisation. Use of digital photographs and video should be encouraged.

3.2 I can present strengths and weaknesses in the manufacturing process.

The candidate will identify a range of strengths and weaknesses in the manufacturing process.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should be taught to be critical of their work and to classify strengths and weaknesses both from their perspective and through peer review and asking others. Particular attention should be given to any health and safety issues arising. At Level 1 structured support and guidance will be needed in keeping with the level descriptor.

3.3 I can use appropriate digital and/or physical drawings or models to support a presentation of the manufacturing process.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Manufacture requires candidates to understand sequences and use of tools and this should be reflected in their presentation. Candidates should be aware that the first way to evaluate their final product is against the specification in the design brief taking account of any changes that have been made. Their digital and physical models should be used to demonstrate how manufacture builds on the design process and can feedback into it. If things have changed they should be able to say why. At Level 1 they

will need support in providing structure and cohesion to their presentation. Being able to do this with minimal support is a characteristic of Level 2.

3.4 I can receive feedback from presenting a manufacturing process.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should receive feedback graciously from any source and should consider it objectively. At Level 1 this might need support and time for them to gain control over emotions and part of the purpose is to achieve a mature response to criticism even where it appears to be unjustified. This might take some repetition and practice in some cases and peer review can be used as a means of providing this efficiently.

3.5 I can act on feedback to improve a design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should show evidence of acting on feedback even if it is in the end to do nothing because they have considered the evidence and make a judgement that any changes will be detrimental or inappropriate. In most cases some changes will be needed to a manufacturing process in hindsight and acting on this could be to record what to do if such circumstances arise again if it is at the end of the project and too later to make any direct changes to the product this time.

Level 1 Smart Product Design
Unit 3: Smart Electronics
5 credits (40 GLH)

1. understand analogue circuits.	**2. understand digital control.**	**3. combine analogue and digital systems.**
1.1 identify circuit components and symbols.	2.1 identify digital circuit components.	3.1 identify a trigger point in a changing voltage.
1.2 identify valid circuits.	2.2 identify program elements that control physical components.	3.2 follow instructions to build a Smart system.
1.3 set up a physical analogue circuit for a purpose.	2.3 debug a control program to get it working.	3.3 use a program to control a physical system.
1.4 distinguish between analogue and digital products.	2.4 use switches to control actions.	3.4 combine Smart technology in a design to improve the user experience.

Assessor's guide to interpreting the criteria

General Information

RQF general description for Level 1 qualifications

- RQF general description for Level 1 qualifications
- Achievement at RQF level 1 (EQF Level 2) reflects the ability to use relevant knowledge, skills and procedures to complete routine tasks. It includes responsibility for completing tasks and procedures subject to direction or guidance.
- Use knowledge of facts, procedures and ideas to complete well-defined, routine tasks. Be aware of information relevant to the area of study or work
- Complete well-defined routine tasks. Use relevant skills and procedures. Select and use relevant information. Identify whether actions have been effective.
- Take responsibility for completing tasks and procedures subject to direction or guidance as needed

Requirements

- Standards must be confirmed by a trained Level 1 Assessor or higher
- Assessors must at a minimum record assessment judgements as entries in the online mark book on the INGOTs.org certification site.
- Routine evidence of work used for judging assessment outcomes in the candidates' records of their day to day work will be available from their e-portfolios and online work. Assessors should ensure that relevant web pages are available to their Account Manager on request by supply of the URL.
- When the candidate provides evidence of matching all the criteria to the specification, subject to the guidance below, the assessor can request the award using the link on the certification site. The Account Manager will request a random sample of evidence from candidates' work that verifies the assessor's judgement.

- When the Account Manager is satisfied that the evidence is sufficient to safely make an award, the candidate's success will be confirmed and the unit certificate will be printable from the web site.
- Each unit at Level 1 has recommended 40 guided learning hours based on time required to complete by an average learner.

Assessment Method

Assessors can score each of the criteria N, L, S or H. N indicates no evidence and it is the default setting. L indicates some capability but some help still required to meet the standard. S indicates that the candidate can match the criterion to its required specification in keeping with the overall level descriptor. H indicates performance that goes beyond the expected in at least some aspects. Candidates are required to achieve at least S on all the criteria to achieve the full unit award. Once the candidate has satisfied all the criteria by demonstrating practical competence in realistic contexts they achieve the unit certificate.

Expansion of the assessment criteria

1. Understand analogue circuits.

1.1 I can identify circuit components and symbols.

The candidate will identify a range of common circuit components either from their circuit symbols or from photographs.

Evidence: From portfolios, internal testing, assessor observations

Additional information and guidance: The components can include power supply (AC and DC), resistor, potentiometer, switch, diode, LED, LDR, variable resistor, bulb/lamp, voltmeter, ammeter, transformer, capacitor, motor, thermistor, loudspeaker, buzzer, motor, transistor, integrated circuit, micro-controller. Make links to work in the core science curriculum and use real and practical applications as illustrations.

1.2 I can identify valid circuits.

The candidate will be able to identify simple circuits that will function as intended.

Evidence: From portfolios, internal testing, assessor observations.

Additional information and guidance Candidates should be able to identify simple circuits that will work and ones that will not. e.g. identify a short circuit and a broken circuit. In most cases these are the reasons why a circuit will not work. An inappropriately high series resistor will effectively be like a broken circuit.

1.3 I can set up a physical analogue circuit for a purpose

The candidate should be able to set up simple working circuits and test them.

Evidence: From portfolios, internal testing, assessor observations

Additional information and guidance Candidates will need practice setting up circuits to learn the effects of combining different components and systematically checking connections to find faults and check working. They need to appreciate that short circuits can generate heat very quickly and that mismatching components can damage them. They can be taught to solder and techniques for achieving neat joints.

1.4 I can distinguish between analogue and digital products.

The candidate should know the meaning of the terms analogue and digital and they should be able to identify examples.

Evidence: From portfolios, internal testing and/or assessor observations.

Additional information and guidance Candidates should understand that analogue signals are continuous whereas digital data representing a continuous signal is made of separate or discrete numbers. A variable resistor in a circuit is a good example of an analogue device and a

switch is a good example of a digital device. Candidates should be familiar with relays or transistors as switches that can be controlled.

2. Understand digital control.

2.1 I can identify digital circuit components.

The candidate will identify switches, and micro-controllers as digital devices.

Evidence: From portfolios, internal testing and/or assessor observations.

Additional information and guidance: At Level 1 it is enough to be able to identify the devices and recognise simple situations where they might be included a circuit. Electromagnetic switches is a good introduction in understanding basic principles, such as in stepper motors, which are very common electro-mechanical devices in Smart applications.

2.2 I can identify program elements that control physical components.

The candidate should be able to identify code that has been written to control a physical component.

Evidence: Internal testing, assessor observations.

Additional information and guidance: In general commented code in any language is reasonable. e.g. in Arduino LED 1 on for 100 microseconds, off for 50 microseconds. Logo forward 100: Left 90 to drive a floor turtle or write a value of 255 to a byte controlling 8 digital lines to make them all +5 volts.

2.3 I can debug a control program to get it working.

Candidates should be able to find simple faults in code controlling devices.

Evidence: Portfolios, assessor observations.

Additional information and guidance: Any control programming language can be used. At Level 1 Arduino, Logo, Scratch or similar languages can be used. Any questions set in the grading exam will use a generic pseudo-code with sufficiently clear structure to work out what is happening without a knowledge of the specific syntax.

2.4 I can use switches to control actions.

Candidates should use a range of switches for control in circuits

Evidence: Portfolios, assessor observations.

Additional information and guidance: The simplest switch is simply switching a circuit on and off e.g. a LED. Candidates should appreciate that this is a binary operation as there are only 2 possibilities, on or off. Switches can be used to represent binary numbers. 7 switches attached to a 7 segment display can make the numbers from 0 to 9. These are typical simple cases appropriate for Level 1.

3. Combine analogue and digital systems.

3.1 I can identify a trigger point in a changing voltage.

Candidates should know that a changing voltage can cause a particular action when the voltage gets to a particular level.

Evidence: Portfolios, assessor observations.

Additional information and guidance: A good example is to use a LDR (Light dependent resistor) as a switch to turn lights on when it gets dark using a transistor switch. The voltage across the LDR will change continuously as the light level falls but at a particular point it will cause the transistor to switch and the light to go on. For Level 1 it is sufficient to have experienced the principle and to know that a particular point can be used to switch things on in a continuously changing property of the environment as this is common to sensors used as switches.

3.2 I can follow instructions to build a Smart system.

The candidate should be able to follow directions to build a working Smart system that incorporates electronic control.

Additional information and guidance: In general at Level 1 Candidates will be becoming more self-sufficient but they will still need significant guidance and support with all but the simplest systems. If they can self-sufficiently build practical electronic controlling circuits that integrate with wider projects it is a good indication that they are operating at Level 2. Level 1 Candidates should be able to follow clear instructions and work with occasional help to get straightforward systems working.

3.3 I can use a program to control a physical system.

Candidates can use a program to control physical systems relevant to their projects.

Evidence: Portfolios, assessor observations.

Additional information and guidance At Level 1 they should know how to get a program set up and working even if they did not write the program themselves. They should be given the opportunity to experiment with the source code and explore the effects of changing different parameters. If they can originate programs self-sufficiently and debug them themselves it is an indication of Level 2 work.

3.4 I can combine Smart technology in a design to improve the user experience.

Candidates will use an electronic component or components in their project(s) in order to provide a degree of functionality or user experience that would not otherwise be possible.

Evidence: Portfolios, assessor observations.

Additional information and guidance An example might be to build an interactive LED display into a model of an eco-house control panel that tells you the amount of energy a house is consuming. Another example might be a window display that contains moving components controlled by simple motors. The exact methods are less important than making the product responsive to the purpose of the project by using a

control and/or processing aspect related to digital electronics. It is likely that substantial practice with learning about digital electronics projects will be needed before inte.g.rating electronics into wider project briefs that include manufacturing outside the electronics field. At Level 1 Candidates can follow guidance to build a solution using Smart electronics.

Moderation/verification

The assessor should keep a record of assessment judgements made for each candidate and make notes of any significant issues for any candidate. They must be prepared to enter into dialogue with their Account Manager and provide their assessment records to the Account Manager through the online mark book. They should be prepared to provide evidence as a basis for their judgements through reference to candidate e-portfolios and any other sources e.g. through signed witness statements associated with the criteria matching marks in the online mark book or internal controlled testing. Before authorizing certification, the Account Manager must be satisfied that the assessors judgements are sound.

Annexe D - Level 2 Units
Level 2 Smart Product Design and Manufacture
Unit 1: Product Design and Visualisation
5 credits (40 GLH)

1. Relate opportunities and constraints to a product design.	**2. Visualise product solutions to meet identified needs.**	**3. Present evaluations of designs.**
1.1 describe opportunities for a product or solution.	2.1 explain key aspects in a design brief.	3.1 organise evidence for presenting the design.
1.2 describe constraints on a product or solution.	2.2 gather information to develop a solution.	3.2 explain strengths and weaknesses in a visual prototype.
1.3 explain commercial sustainability of a product or solution.	2.3 design and test sketches and models to visualise a solution.	3.3 use appropriate digital and/or physical models to support presenting a design.
	2.4 use appropriate digital and physical media to design a product.	3.4 receive feedback from presenting a design.
	2.5 prepare a visual prototype of the solution.	3.5 act on feedback to improve a design.

Assessor's guide to interpreting the criteria

General Information

RQF general description for Level 2 qualifications

- RQF general description for Level 2 qualifications
- Achievement at RQF Level 2 (EQF Level 3) reflects the ability to select and use relevant knowledge, ideas, skills and procedures to complete well-defined tasks and address straight-forward problems. It includes taking responsibility for completing tasks and procedures and exercising autonomy and judgement subject to overall direction or guidance.
- Use understanding of facts, procedures and ideas to complete well-defined tasks and address straightforward problems. Interpret relevant information and ideas. Be aware of the types of information that are relevant to the area of study or work.
- Complete well-defined generally routine tasks and address straight-forward problems. Select and use relevant skills and procedures. Identify, gather and use relevant information to inform actions. Identify how effective actions have been.
- Take responsibility for completing tasks and procedures.
- Exercise autonomy and judgement subject to overall direction or guidance.

Requirements

- Standards must be confirmed by a trained Level 2 Assessor or higher
- Assessors must at a minimum record assessment judgements as entries in the online mark book on the INGOTs.org certification site.
- Routine evidence of work used for judging assessment outcomes in the candidates' records of their day to day work will be available from their e-portfolios and online work. Assessors should ensure that relevant web pages are available to their Account Manager on request by supply of the URL.

- When the candidate provides evidence of matching all the criteria to the specification, subject to the guidance below, the assessor can request the award using the link on the certification site. The Account Manager will request a random sample of evidence from candidates' work that verifies the assessor's judgement.
- When the Account Manager is satisfied that the evidence is sufficient to safely make an award, the candidate's success will be confirmed and the unit certificate will be printable from the web site.
- Each unit at Level 2 has recommended 40 guided learning hours based on time required to complete by an average learner.

Assessment Method

Assessors can score each of the criteria N, L, S or H. N indicates no evidence and it is the default setting. L indicates some capability but some help still required to meet the standard. S indicates that the candidate can match the criterion to its required specification in keeping with the overall level descriptor. H indicates performance that goes beyond the expected in at least some aspects. Candidates are required to achieve at least S on all the criteria to achieve the full unit award. Once the candidate has satisfied all the criteria by demonstrating practical competence in realistic contexts they achieve the unit certificate.

Expansion of the assessment criteria

Level 2 Smart Product Design and Manufacture

Unit 1: Product Design and Visualisation

5 credits (40 GLH)

1. Relate opportunities and constraints to a product design.

1.1 I can describe opportunities for a product or solution.

Candidates should be able to make connections between the opportunities presented and the product proposal, describing them.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: At level 2, some market research should be evident and an ability to link research findings to the product proposal. They should be able to describe the opportunities they find and say why they think they might be important.

1.2 I can describe the constraints on a product or solution.

Candidates should be able to describe possible constraints on the proposed product.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be able to appreciate that any proposal will have constraints and describe the constraints and put them into simple classifications. These can include environment, cost-benefit, social/political and/or practical issues.

1.3 I can explain commercial sustainability of a product or solution.

The candidate will explain the conditions for achieving commercial sustainability for a prototyped product and explain their conclusions.

Evidence: From portfolios, assessor observations.

A**dditional information and guidance:** Candidates consider the conditions necessary for a commercial product. Cost of materials, cost of manufacture, cost of distribution and advertising. Environmental issues such as disposal and energy generation in the manufacturing process, health and safety, intellectual property. How would they go about getting a patent? Would an open source hardware route be better? At level 2 they should be able to explain themselves. Evidence of explanations could be text but audio and video is also acceptable.

2. Visualise product solutions to meet identified needs.

2.1 I can explain the key aspects in a design brief.

The candidate will be able to take a design brief and explain the key aspects in order to consider their approach.

Evidence: From portfolios, local testing, assessor observations.

Additional information and guidance: Candidates should be presented with several design briefs and demonstrate the capacity to explain specific requirements that might be needed for each key aspect. At Level 2 the design briefs should be structured but with prompts such as What does it cost? Is it available? What are the critical functions? The key point of this criterion is getting candidates to focus on the priorities for research and planning demonstrating that they are reasonably self-sufficient in the process.

2.2 I can gather information to develop a solution.

The candidate will be able to gather information from several sources in order to develop their design.

Evidence: From portfolios, assessor observations.

Additional information and guidance: Candidates should be able to use the key facts identified in the design brief to consider design parameters such as size, form, materials, or constraints such as having to fit and accommodate existing or external systems, environmental impact and other factors within their own knowledge base and then use research from books, the internet and people to support their own ideas. Level 2 Candidates should document their findings and organise the information they gather largely self-sufficiently.

2.3 I can design and test sketches and models to visualise a solution.

The candidate will be able to create and test ideas through visual means.

Evidence: From portfolios, assessor observations.

Additional information and guidance: Candidates will produce a range of visual evidence of their approach to the problem demonstrating the evolution of their thinking. This will include for example, mind-maps, sketches, collages, computer drawings, and might be supplemented with written or audio supporting commentary. There should be clear evidence of how their research helped them develop their ideas beyond what they already knew themselves. At Level 2 some broad guidance and pointers will need to be given but then the candidate will achieve rich outcomes mostly self-sufficiently.

2.4 I can use appropriate digital and physical media to design a product.

The candidate will use a range of media to contribute to product design.

Evidence: From portfolios, the visual prototype, assessor observations.

Additional information and guidance: The design tools will include software with an increasing understanding of software principles used in design and any other appropriate modelling materials such as paper, plasticine, plastic etc. Level 2 candidates will demonstrate a broader range and variety than at Level 1.

2.5 I can prepare a visual prototype of a product.

The candidate will produce a visual prototype of a product.

Evidence: Portfolio images of the digital prototype at various stages, assessor observations.

Additional information and guidance: Candidates will produce a visual prototype through the input of information and data into suitable software and media to realise their visual prototype. This could be 2D or 3D models in CAD, computer based drawing and design tools. Any information and data required to create a suitable digital model of a project can be accepted as long as it clearly meets the project brief or solution. Candidates' briefs should include the need for at least one Smart technology or element that invites user and environment interaction. For example a learner could use Computer Aided Design to

design the external form of a Smart weather sensor. This would involve drawing on a computer and contributing documentation of simple code in an integrated development environment to design sensor functionality and feedback. At this stage it is a visual prototype and so the key priority is to be able to show sufficient detail of what the product might look like given the functional needs required from it. Project design should take into account any physical products or systems which it may need to reasonably accommodate within the project. Level 2 candidates will be increasingly self-sufficient in this process.

3. Present evaluations of designs.

3.1 I can organise evidence for presenting the design.

The candidate will prepare their presentation using the evidence gathered and collected in their portfolio.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates will gather the information they need to make their presentation. Level 2 candidates should be able to gather and organise the information with only occasional prompts. They should prioritise what to present on its importance and work out a reasonable time schedule.

3.2 I can explain strengths and weaknesses in a visual prototype.

The candidate should explain a range of strengths and weaknesses in the visual prototype of the design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should be taught to be critical of their work and to classify strengths and weaknesses both from their perspective and through peer review and asking others. At level 2 they should be able to explain the causes of strengths and weaknesses and how they affect the work.

3.3 I can use appropriate digital and/or physical models to support a presentation of the design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Level 2 candidates should produce and use visual, audio and tactile aids as appropriate to support their presentations. Designing for products require understanding of manufacture and candidates should be aware of a number of external product requirements including designing for assembly, clearances and tolerances, regulatory requirements for specific types of products or specific uses. Candidates should be aware that the first way to evaluate their final product is against the specification in the design brief and any visual prototypes should relate strongly to the brief. Their digital and physical models should be used to demonstrate this. If things have changed they should be able to say why. At level 1 they will need support in explaining and communicating the reasons but they should demonstrate that they can identify them. Being able to describe and explain them is a characteristic of Level 2.

3.4 I can receive feedback from presenting a design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should receive feedback graciously from any source and should consider it objectively. At level 2 control of emotions and ability to achieve a mature response to criticism even where it appears to be unjustified is expected.

3.5 I can act on feedback to improve a design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should show evidence of acting on feedback even if it is in the end to do nothing because they have considered the evidence and make a judgement that any changes will be detrimental. In most cases some changes will be needed to the design before it is used to start producing the product or in retrospect informed by the production process. These changes could be in structure, colour, functional aspects or aesthetics. At level 2 the proposed actions should be plausible for improvement and actions carried out with minimal support. Candidates should not be constrained

in making improvements by assessment procedures or teaching order. All they need is to demonstrate actions on feedback that affect their designs.

Unit 2: Product Manufacture
5 credits (40 GLH)

1. Relate a product design to its manufacture.	**2. Use tools and information to support the manufacturing process.**	**3. Present evaluations of manufacturing processes.**
1.1 check quality in a design in preparation for manufacture.	2.1 select the tools needed for manufacture.	3.1 organise evidence for presenting the manufacturing process.
1.2 work with scales and dimensions when associating plans with manufacture.	2.2 plan and prepare information for the manufacture process	3.2 explain strengths and weaknesses in the manufacturing process
1.3 prepare and document files to support the process of moving from design to manufacture.	2.3 use manufacturing tools with appropriate precision and safety.	3.3 use appropriate digital and/or physical models to support a presentation of the manufacturing process.
1.4 make adjustments to a design as a result of feedback from the manufacturing process.	2.4 fabricate a product using appropriate materials and settings.	3.4 receive feedback from presenting the manufacturing process.
	2.5 finish or assemble parts and components.	3.5 act on feedback to improve my work.
	2.6 explain how to correct errors and make improvements to my work.	

Assessor's guide to interpreting the criteria.

General Information

RQF general description for Level 2 qualifications

- RQF general description for Level 2 qualifications
- Achievement at RQF Level 2 (EQF Level 3) reflects the ability to select and use relevant knowledge, ideas, skills and procedures to complete well-defined tasks and address straight-forward problems. It includes taking responsibility for completing tasks and procedures and exercising autonomy and judgement subject to overall direction or guidance.
- Use understanding of facts, procedures and ideas to complete well-defined tasks and address straightforward problems. Interpret relevant information and ideas. Be aware of the types of information that are relevant to the area of study or work.
- Complete well-defined generally routine tasks and address straight-forward problems. Select and use relevant skills and procedures. Identify, gather and use relevant information to inform actions. Identify how effective actions have been.
- Take responsibility for completing tasks and procedures.
- Exercise autonomy and judgement subject to overall direction or guidance.

Requirements

- Standards must be confirmed by a trained Level 2 Assessor or higher
- Assessors must at a minimum record assessment judgements as entries in the online mark book on the INGOTs.org certification site.
- Routine evidence of work used for judging assessment outcomes in the candidates' records of their day to day work will be available from their e-portfolios and online work. Assessors should ensure that relevant web pages are available to their Account Manager on request by supply of the URL.

- When the candidate provides evidence of matching all the criteria to the specification, subject to the guidance below, the assessor can request the award using the link on the certification site. The Account Manager will request a random sample of evidence from candidates' work that verifies the assessor's judgement.
- When the Account Manager is satisfied that the evidence is sufficient to safely make an award, the candidate's success will be confirmed and the unit certificate will be printable from the web site.
- Each unit at Level 2 has recommended 40 guided learning hours based on time required to complete by an average learner.

Assessment Method

Assessors can score each of the criteria N, L, S or H. N indicates no evidence and it is the default setting. L indicates some capability but some help still required to meet the standard. S indicates that the candidate can match the criterion to its required specification in keeping with the overall level descriptor. H indicates performance that goes beyond the expected in at least some aspects. Candidates are required to achieve at least S on all the criteria to achieve the full unit award. Once the candidate has satisfied all the criteria by demonstrating practical competence in realistic contexts they achieve the unit certificate.

Expansion of the assessment criteria

1. Relate a product design to its manufacture.

1.1 I can check quality in a design in preparation for manufacture

Candidates should check their design for possible quality issues prior to manufacture.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be able to check the design systematically for any quality issues that will affect

the manufacture. A manufacturing brief should contain at least some constraints that will require learners to be resourceful in their approach, for example certain number of manufactured items against a cost, fixed number of parts, material constraints, performance and technical tolerances. These constraints should give students an opportunity to carefully consider their design and manufacture process. Learners can be given a choice of briefs and constraints and allowed to explore solutions individually or through teamwork. This could be related to precision; choice of materials; method of assembly including considerations such as components or flat pack assembly; suitability for files used to automate manufacture, finish or any other attributes that need transfer from the design to manufacture.

1.2 I can work with scales and dimensions when associating plans with manufacture.

Candidates should be able to work with scales and dimensions in translating plans to the manufacture of the product.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be able to work with scales and dimensions taken from their plans. Precision should be appropriate to the manufacture of the product. For Level 2 candidates the mathematical demand in terms of shape space and measure should be broadly in line with Level 2 expectations in mathematics. Reference the NC in mathematics and typical questions in GCSE and functional skills at Level 2.

1.3 I can prepare and document files to support the process of moving from design to manufacture.

Candidates should prepare any information needed for supporting the manufacturing process and organise them appropriately.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should be able to document the process of translating designs to products so that other

people can follow the process. At Level 2 the candidate should be largely self-sufficient illustrating the process by technical drawings, diagrams, text or photographs.

1.4 I can make adjustments to a design as a result of feedback from the manufacturing process.

Candidates should make adjustments according to needs.

Evidence: Documentation in portfolios, assessor observations.

Additional information and guidance: The candidate should actively look for opportunities for improvement based on the evidence they have gleaned from implementing the design. Finding out what works and what doesn't should be used usefully to inform the current and future design projects.

2. Use tools and information to support the manufacturing process.

2.1 I can select the tools needed for manufacture.

The candidate will find suitable tools to manufacture the product using the specification for the design.

Evidence: From portfolios, assessor observations.

Additional information and guidance: Candidates should become familiar with a range of tools so that they can choose appropriately and based on rationale evidence. This implies significant opportunities for practice. At Level 2 they will be able to justify their choices using rationale explanation.

2.2 I can plan and prepare information for the manufacture process

The candidate will plan and prepare the information to guide the manufacturing process.

Evidence: portfolio content and assessor observations.

Additional information and guidance: At Level 2 products will have multiple components and candidates will appreciate that to manufacture

complex objects, good referral information makes the task easier and more reliable. Learners should be aware that part of manufacture requires planning ahead, for example by producing a bill of materials and identifying lead times. They can also be set tasks to work in groups to introduce real complexities faced in the manufacture workflow when trying to manage lead times and work across more than one person or team.

2.3I can use manufacturing tools with appropriate precision and safety.

The candidate will use a range of appropriate tools to the appropriate precision under guidance.

Evidence: Photographs of products, portfolio content and assessor observations.

Additional information and guidance: The appropriate precision will depend on the particular tools and circumstances and Level 2 candidates will work to a precision that is derived from the design drawings and/or planning and the tolerances of the tools they are using. They will appreciate that nothing is absolutely precise. They will use mathematics and skills in keeping with the level.

2.4 I can fabricate a product using appropriate materials and settings.

The candidate will end up with a product or prototype that is in keeping with the design brief.

Evidence: Series of photographs showing the steps in the manufacturing process in portfolio, assessor observations.

Additional information and guidance: Candidates will build their products and record the evidence photographically. The crucial learning is that achieved by physically manufacturing a design. At one level a student can evolve the design through identifying and eliminating errors between digital to physical modelling techniques, at a more advanced level students can use information from the physical modelling process

to evolve the actual design. At Level 2 the product will involve several different skills including software design and CNC manufacture.

2.5 I can finish or assemble parts and components.

Candidates can add finish and refinements to components, prototype or product.

Evidence: Photographs of the final finished digital prototype, assessor observations, work log in portfolio.

Additional information and guidance: Physical components may need to be post processed for example sanded, painted or fixed using appropriate hand tools, fixtures and fittings as necessary. Candidates should pay particular attention to small delicate components. Final assembly might need manipulation of components. Some of these finishing techniques are likely to require practice and candidates should be given sufficient time to develop these practical skills. Level 2 candidates will demonstrate perseverance to achieve good standards of finish and precision.

2.6 I can explain how to correct errors and make improvements to my work.

Candidates can explain how they made adjustments that improved their work.

Evidence: Photographs illustrating changes, assessor observations, work log in portfolio.

Additional information and guidance: Candidates will explain how they planned to eliminate as much risk and uncertainty before manufacture as possible and then how they identified and fixed errors in the manufacturing process. In Smart manufacture with agile techniques flexibility needs to be recognised as a key aspect to the approach. This does not mean laissez-faire but continuous consideration of the cost-benefit of any actions in terms of getting the job done. Over-planning is counter-productive as is under-planning. Rigour is about optimisation of

the process to get something fit for purpose, not about over-elaborate bureaucratic procedures.

3. Present evaluations of manufacturing processes.

3.1 I can organise evidence for presenting the manufacturing process.

The candidate will prepare their presentation using the evidence gathered and collected in their portfolio.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates will gather the information they need to make their presentation. This will most likely be an on-going process throughout a project or projects. Level 2 candidates should be able to organise their information with only occasional prompts. Use of digital photographs and video should be encouraged.

3.2 I can explain strengths and weaknesses in the manufacturing process.

The candidate will explain a range of strengths and weaknesses in the manufacturing process.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should be taught to be critical of their work and to classify strengths and weaknesses both from their perspective and through peer review and asking others. In Smart Manufacture, candidates should also be taught the economic factors behind a manufacturing process. For example 3D printing would be a cost efficient way to manufacture low volume or highly customised projects, whereas it would still be more cost effective to mass manufacture many everyday items through injection moulding. Candidates should be aware of how their particular manufacturing method or process is beneficial or applicable to their project brief or outcome. Particular attention should be given to any health and safety

issues arising. Level 2 candidates should be able to explain themselves clearly through rehearsal and input from peer review.

3.3 I can use appropriate digital and/or physical drawings or models to support a presentation of the manufacturing process.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Level 2 candidates should construct their own presentation aids. Manufacture requires candidates to understand sequences and use of tools. Candidates should be aware that the first way to evaluate their final product is against the specification in the design brief taking account of any changes that have been made. Their digital and physical models should be used to demonstrate how manufacture builds on the design process and can feedback into it. If things have changed they should be able to say why. At Level 1 they will need support in providing structure and cohesion to their presentation. Being able to do this with minimal support is a characteristic of Level 2.

3.4 I can receive feedback from presenting a manufacturing process.

Candidates should seek and receive feedback graciously.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should receive feedback graciously from any source and should consider it objectively. At level 1 this might need support and time for them to gain control over emotions and part of the purpose is to achieve a mature response to criticism even where it appears to be unjustified. Level 2 candidates should be able to control emotional responses with composure.

3.5 I can act on feedback to improve a design.

Evidence: Portfolios, presentations, assessor observations.

Additional information and guidance: Candidates should show evidence of acting on feedback even if it is in the end to do nothing because they

have considered the evidence and make a judgement that any changes will be detrimental. In most cases some changes will be needed to a manufacturing process in hindsight and acting on this could be to record what to do if such circumstances arise again if it is at the end of the project and too late to make any direct changes to the product this time. At level 2 the proposed actions should be plausible for improvement and actions carried out with minimal support. The important thing is for candidates to demonstrate that they have thought about the feedback and used it to improve their work.

Level 2 Smart Product Design and Manufacture
Unit 3: Smart Electronics
4 credits (30 GLH)

1. understand analogue circuits.	**2. understand digital control.**	**3. combine analogue and digital systems.**
1.1 describe the purpose of circuit components and symbols.	2.1 describe the purpose of digital circuit components.	3.1 describe the process of analogue to digital conversion.
1.2 build valid circuits.	2.2 create program elements that control physical components.	3.2 build a Smart system.
1.3 set up and debug a physical analogue circuit for a purpose.	2.3 explain bugs in a control program and get it working.	3.3 explain how to use a program to control a physical system.
1.4 explain the difference between analogue and digital products.	2.4 use logic to control actions.	3.4 combine Smart technology in a design to improve the user experience.

Assessor's guide to interpreting the criteria

General Information

RQF general description for Level 2 qualifications

- RQF general description for Level 2 qualifications
- Achievement at RQF Level 2 (EQF Level 3) reflects the ability to select and use relevant knowledge, ideas, skills and procedures to complete well-defined tasks and address straight-forward problems. It includes taking responsibility for completing tasks and procedures and exercising autonomy and judgement subject to overall direction or guidance.
- Use understanding of facts, procedures and ideas to complete well-defined tasks and address straightforward problems. Interpret relevant information and ideas. Be aware of the types of information that are relevant to the area of study or work.
- Complete well-defined generally routine tasks and address straight-forward problems. Select and use relevant skills and procedures. Identify, gather and use relevant information to inform actions. Identify how effective actions have been.
- Take responsibility for completing tasks and procedures.
- Exercise autonomy and judgement subject to overall direction or guidance.

Requirements

- Standards must be confirmed by a trained Level 2 Assessor or higher
- Assessors must at a minimum record assessment judgements as entries in the online mark book on the INGOTs.org certification site.
- Routine evidence of work used for judging assessment outcomes in the candidates' records of their day to day work will be available from their e-portfolios and online work. Assessors should ensure that relevant web pages are available to their Account Manager on request by supply of the URL.

- When the candidate provides evidence of matching all the criteria to the specification, subject to the guidance below, the assessor can request the award using the link on the certification site. The Account Manager will request a random sample of evidence from candidates' work that verifies the assessor's judgement.
- When the Account Manager is satisfied that the evidence is sufficient to safely make an award, the candidate's success will be confirmed and the unit certificate will be printable from the web site.
- Each unit at Level 2 has recommended 40 guided learning hours based on time required to complete by an average learner.

Assessment Method

Assessors can score each of the criteria N, L, S or H. N indicates no evidence and it is the default setting. L indicates some capability but some help still required to meet the standard. S indicates that the candidate can match the criterion to its required specification in keeping with the overall level descriptor. H indicates performance that goes beyond the expected in at least some aspects. Candidates are required to achieve at least S on all the criteria to achieve the full unit award. Once the candidate has satisfied all the criteria by demonstrating practical competence in realistic contexts they achieve the unit certificate.

Expansion of the assessment criteria

1. Understand analogue circuits.

1.1 I can describe the purpose of circuit components and symbols.

The candidate can describe the purpose of a range of common circuit components either from their names, circuit symbols or from photographs.

Evidence: From portfolios, internal testing, assessor observations.

Additional information and guidance: The components can include power supply (AC and DC), resistor, potentiometer, switch, diode, LED, LDR, variable resistor, bulb/lamp, voltmeter, ammeter, transformer, capacitor, motor, thermistor, loudspeaker, buzzer, motor, transistor, integrated circuit, micro-controller. The Level 2 candidate should be able to describe these components referring to their purpose and common properties. Make links to work in the core science curriculum and use real and practical applications as illustrations.

1.2 I can build valid circuits.

The candidate will be able to build simple circuits that will function as intended.

Evidence: From portfolios, internal testing, assessor observations.

Additional information and guidance Candidates should be able to build simple circuits that will work. Using a prototyping system such as breadboards or kits for practice is recommended. Candidates should appreciating that sinking or sourcing high current from some devices is likely to damage them so care needs to be exercised even if it is simply at this stage asking for advice. Soldering or etching techniques can also be introduced where appropriate to extend learner knowledge of circuit board design and manufacture.

1.3 I can set up and debug a physical analogue circuit for a purpose

The candidate should be able to set up simple working circuits and test them.

Evidence: From portfolios, internal testing, assessor observations

Additional information and guidance Candidates will need practice setting up circuits to learn the effects of combining different components and systematically checking connections to find faults and check working. They need to appreciate that short circuits can generate heat very quickly and that mismatching components can damage them. They could be taught to solder and techniques for achieving neat joints

or practice building circuits using breadboards. At Level 1 they will need close supervision and guidance whereas at Level 2 they will be becoming largely self-sufficient and trusted to work safely using common components such as resistors, bulbs, motors, simple sensors and transistors. Attention to safety should be appreciated at all times.

1.4 I can explain the difference between analogue and digital products.

The candidate should know the meaning of the terms analogue and digital and they should be able to explain some simple examples.

Evidence: From portfolios, internal testing and/or assessor observations.

Additional information and guidance Candidates should understand that analogue signals are continuous whereas digital data representing a continuous signal is made of separate or discrete numbers. A variable resistor in a circuit is a good example of an analogue device and a switch is a good example of a digital device. Level 2 candidates should be able to describe an analogue watch, for example, as an analogue device because the hands move continuously whereas a digital watch or clock changes in steps of e.g. 1 second or 100th of a second not every division in between. Alternating current in a circuit is analogue, variations in temperature, pressure, brightness, and position in nature and so most sensors are analogue. Most digital devices are dependent on buttons or switches, e.g. a numeric number pad on a telephone where there are discrete buttons to press. Analogue systems are not less accurate than digital, they are more accurate in that in principle they can measure every point in their range. The problem is they might not in practical terms have the precision to pick out points close together as distinct from one another and they also lack any means of clearing out noise from the main signal. Digital systems can enable the signal to be processed removing any unwanted components or indeed adding desirable information so they are much more versatile.

2. Understand digital control.

2.1 I can describe the purpose of digital circuit components.

The candidate can describe the purpose of switches and micro-controllers as digital devices.

Evidence: From portfolios, internal testing and/or assessor observations.

Additional information and guidance: At Level 2 candidates should be able to describe simple switches, relays, transistor switch, AND, NAND, NOT, OR, EOR and NOR gates. It is enough to be able to identify the circuit symbols and describe the purpose of the component. In the case of micro-controllers, include any device e.g. an Arduino that can perform Smart functions in software and interface with external circuits to control things.

2.2 I can create program elements that control physical components.

The candidate should be able to write code to control a physical component.

Evidence: Internal testing, assessor observations.

Additional information and guidance: In general commented code in any language is reasonable. The code should include at least some conditionality e.g. IF <condition> THEN <action>. For products to be "Smart" requires some form of decision making which implies input from a sensor and output to a physical device.

2.3 I can explain bugs in a control program to get it working.

Candidates should be able to find simple faults in code controlling devices and explain how to fix them.

Evidence: Portfolios, assessor observations.

Additional information and guidance: Any control programming language can be used. At level 1 Arduino, Scratch or similar languages can be used. Any questions set in the grading exam will use a generic pseudocode with sufficiently clear structure to work out what is

happening without a knowledge of the specific syntax. Level 2 candidates should be able to not only identify the fault but explain what action should be taken to fix it.

2.4 I can use logic to control actions.

Candidates should use a range of logic for control in circuits.

Evidence: Portfolios, assessor observations.

Additional information and guidance: Two switches in series makes an AND gate because the circuit will only work if switch one AND switch 2 are closed. Using a relay to open a switch is a NOT gate because switching the relay on causes it to open the switch which then breaks the second circuit. The second circuit only works if the relay is not switched on. If there are two wires connecting a device to a power source a switch in both wires means either of them being switched on will switch the device on. This is an OR gate because either switch one OR switch two will switch on the device. Level 2 candidates should build on these ideas to become familiar with logic gates and get some practical hands on experience with them. They should appreciate that using software is quicker and more versatile than "hard wiring" logic gates but it requires a more expensive general purpose device to run the software. This might not be justified if the logic is dedicated to a single simple task. For rapid prototyping using a micro-controller or computer might be much quicker and more convenient but for mass production it could be too expensive. In summary, they should get hands on experience of using control logic but the exact method is left to the centre. Nevertheless they need familiarity with a range of ways of doing it.

3. Combine analogue and digital systems.

3.1 I can describe the process of analogue to digital conversion.

Candidates should be able to describe how sampling an analogue signal can produce digital data.

Evidence: Portfolios, assessor observations.

Additional information and guidance: A good example making a digital thermometer. Putting a thermistor in melting ice and then into water and heating it up to boiling point will produce a continually changing resistance as the device warms up. This in turn varies the voltage across the device. If we sample the value of the voltage in the melting ice it corresponds to zero degrees and in the boiling water 100 degrees. Divide the interval into 100 parts and they have a working thermometer (link to science as they are likely to have put a scale on a thermometer in a similar way) This is an analogue scale because it changes continually. If we now take measurements of the voltage at say 100 points along the scale and store the numbers we have a digital scale with 100 points. Sample 255 points and we can better precision. 64000 points better still and so on. This is a digital thermometer but the same principle applies to any measuring device. The greater the number of samples along the scale the more precise the measurements. The device that does the sampling is called an analogue to digital converter ADC. It converts changing voltages into digital data. This could be the voltage from a microphone which is then converting an analogue sound wave into digital audio. The number of samples depends on the ADC resolution. 8 bit can sample 255 levels, 12 bit, 2048 16 bit about 65,535 and 32 bit about 4.3 billion. The other key factor in changing signals like sound waves is the sample rate. A slow sample rate won't matter measuring temperature which changes slowly, but a sound wave can change 20,000 times a second. To sample its shape in 2048 levels would need a 12 bit ADC and to get a lot of samples in one 20,000th of a second would need a sample rate a lot faster than 20,000 a second. Once the digital data has been sampled it can be transferred to computer memory and then software can operate on the data.

The opposite of ADC is DAC Digital to analogue conversion. This is reconstructing the analogue signal from the digital data. The DAC device works like the ADC but in reverse. A DAC can reconstruct a sound wave from data. These devices are so fast now that you can sample live music through the ADC, process it in software and convert it

back to the sound wave without anyone noticing. This is called real time processing. Level 2 candidates might or might not need ADC/DAC in their projects but they should be taught about the principles. There is a clear need here to be familiar with the National Curriculum Science requirements for the end of KS3 as Level 2 work should reinforce and build on it.

3.2 I can build a Smart system.

The candidate should be able to build a working Smart system that incorporates electronic control largely self-sufficiently.

Additional information and guidance Level 2 Candidates will be becoming more self-sufficient. If they can self-sufficiently build practical electronic controlling circuits that integrate with wider projects with occasional prompts and advice they are at level 2. In contrast, Level 1 Candidates should be able to follow clear instructions and work with occasional help to get straightforward systems working.

3.3 I can explain how to use a program to control a physical system.

Candidates can explain how to use a program to control physical systems relevant to their project(s).

Evidence: Portfolios, assessor observations.

Additional information and guidance If they can originate programs largely self-sufficiently, debug them and explain them it is a good indication of Level 2 work. Relate this work to National Curriculum Computing in KS3 and KS4.

3.4 I can combine Smart technology in a design to improve the user experience.

Candidates can use an electronic component or components in their project(s) in order to provide a degree of functionality or user experience that would not otherwise be possible.

Evidence: Portfolios, assessor observations.

Additional information and guidance An example might be a window display that contains moving components controlled by simple motors. Another example might be to build temperature and light sensing into a model of an eco-house so that temperatures and light levels could be automated to save energy. The exact methods are less important than making the product responsive to the purpose of the project by using a control and/or processing aspect related to digital electronics. It is likely that substantial practice with learning about digital electronics projects will be needed before integrating electronics into wider project briefs that include manufacturing outside the electronics field. At Level 1 Candidates can follow detailed guidance to build a solution using Smart electronics. At Level 2 they will need some prompts and support but they will be largely self-sufficient.

Moderation/verification

The assessor should keep a record of assessment judgements made for each candidate and make notes of any significant issues for any candidate. They must be prepared to enter into dialogue with their Account Manager and provide their assessment records to the Account Manager through the online mark book. They should be prepared to provide evidence as a basis for their judgements through reference to candidate e-portfolios and any other sources e.g. through signed witness statements associated with the criteria matching marks in the online mark book or internal controlled testing. Before authorizing certification, the Account Manager must be satisfied that the assessors judgements are sound.

Annexe E – Summary of the units and their assessment.

Level 1

Unit 1 – Product Design and Visualisation	- 5 credits - 40 GLH
Unit 2 – Product Manufacture	- 5 credits - 40 GLH
Unit 3 – Smart Electronics	- 5 credits - 40 GLH

120 GLH in total for the full certificate. Units can be assessed concurrently or consecutively enabling the school to decide how to organise teaching.

There is a unit certificate available for each unit and all units must be assessed as satisfactory through coursework at Level 1 or higher for a Level 1 pass and before and exam entry is permitted. The exam will then differentiate pass with merit, pass with distinction and pass with distinction*.

Level 2

Unit 1 – Product Design and Visualisation	- 5 credits - 40 GLH
Unit 2 – Product Manufacture	- 5 credits - 40 GLH
Unit 3 – Smart Electronics	- 5 credits - 40 GLH

120 GLH in total for the full certificate. Units can be assessed concurrently or consecutively enabling the school to decide how to organise teaching. The exam covers all unit and the 120 GLH content.

There is a unit certificate available for each unit and all units must be assessed as satisfactory through coursework at Level 2 or higher before an exam entry is permitted. The exam will then differentiate grades A*, A, B, C.

Annexe F - Useful links and supporting information

The INGOT community learning site www.theINGOTs.org has a wealth of supporting information and practical tools for managing evidence, progress tracking and reporting. These are all free for participating schools. Contact TLM for further details or training if required. We will update and add to supporting materials as time goes on.

The INGOT web site supports multiple languages and it is not very difficult to provide new translations. If you want to teach in the context of a modern foreign language it is possible and we will provide support where we can.

Making the transition from existing qualifications

It is rarely necessary to abandon all of the course-ware of existing courses. The flexibility of the TLM approach means that most centres find they can map a great deal of their current learning to the assessment criteria and avoid major upheaval. This means that you can start gently and at more or less any time in the year. All we are interested in is the assessment outcome, the process to get there is up to the Principal Assessor and colleague assessors in the centre. So we can start by using evidence already available or in existing systems and you can decide for yourself how quickly you transition to TLM's evidence management if at all. We are not a software company trying to sell you technology, we are simply providing tools to make administration of our quality assurance service more convenient to users. If you think a different system is better for you, you are free to use it. All we need is ready access to evidence supporting the assessment criteria.

Annexe G - Coursework assessment flowchart