Leaving Certificate Computer Science

Guidelines for completing the coursework assessment

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NCCA
An Chomhairle Náisiúnta Curaclaim agus Measúnachta
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Contents

Introduction

This document, *Leaving Certificate Computer Science: Guidelines for completing the coursework assessment*, provides:

- a general overview of assessment in Leaving Certificate Computer Science as described in the Leaving Certificate Computer Science curriculum specification
- details of the coursework assessment
- the process for completing and presenting coursework
- quality descriptors for coursework assessment
- information on the role of schools and teachers in supporting students with the coursework assessment.

These guidelines should be used in conjunction with the curriculum specification for Leaving Certificate Computer Science, which can be accessed at https://curriculumonline.ie/Senior-cycle/Senior-Cycle-Subjects/Computer-Science.

Assessment for certification in computer science

Assessment of the Leaving Certificate Computer Science (LCCS) course is based on the aims, objectives, and learning outcomes of the LCCS specification. Differentiation at the point of assessment is achieved through the end-of-course examination at two levels – Ordinary level and Higher level. For the coursework assessment, students at Higher and Ordinary level will respond to the same project brief. Differentiation between the levels will be applied to the coursework afterwards, as part of the process used when the work is assessed.

Assessment components

There are two assessment components:

(i) an end-of-course computer-based examination (70%)

(ii) coursework assessment in the final year of the course (30%).

Both components reflect the relationship between the application of skills and the theoretical content of the specification, and combine to assess the extent to which students:

- understand how computing technology presents new ways to address problems
- use computational thinking to analyse problems, and to design, develop and evaluate solutions
- can read, write, test and modify computer programs
- understand how computers work and the component parts of computer systems and how they interrelate, including software, data, hardware, communications, and users
- understand the evolution of computing technology and appreciate the ethical and social implications of the use of computing technology in contemporary and future social issues
- work independently, communicate effectively, and understand the factors that influence collaboration and teamwork
- are responsible, competent, confident, reflective and creative users of computing technology.

Coursework assessment overview

The coursework assessment in the final year of the course will require students to create an innovative computational artefact. The coursework brief will be issued by the State Examinations Commission (SEC) and will be a common thematic brief for both Ordinary and Higher level. This accounts for the fact that at the time of undertaking the coursework assessment students may not yet have decided what level of end-of-course assessment they will take.

Students will be required to submit to the SEC a digital coursework portfolio in response to the brief. The students will be required to report on the design and development process of creating their artefact and the technologies employed. The coursework assessment will require students to demonstrate proficiency in applying course content and skills from across all three strands of the specification. Student work for the coursework assessment will be submitted electronically and will be marked by the State Examinations Commission (SEC).

Coursework assessment process

Timeframe

The coursework brief will be issued in the first school week of January in the second year of the course. It is anticipated there will be a period of eight school weeks for completion of the coursework assignment. At the end of this period, students will submit their final coursework digital portfolio to the SEC. The exact timeframe will be fully laid out by the SEC, including deadlines for submission of the coursework digital portfolio.

The coursework brief

The coursework brief issued by the SEC will define the context of the assignment and the task required of the student. It is anticipated that the brief issued by the SEC will indicate a set of basic and advanced requirements of the task. This is a means to allow for adequate differentiation among students. The brief will use a practical situation to assess how students might design data structures and develop algorithms, simulate a natural occurrence, integrate ideas, test hypotheses, or explore new ways to address practical problems. The nature of the brief will be similar to the structure of the strand 3 applied learning tasks (ALTs) that students complete during the two years of the course. The four ALTs that comprise strand 3 are:

- Interactive information systems
- Analytics
- Modelling and simulation
- Embedded systems.

Coursework digital portfolio

Based on the task given in the brief, students will construct a **coursework digital portfolio**.

The key components of the coursework digital portfolio are:

- The digital components of the computational artefact, including all relevant programs in the prescribed languages.
- A coursework report, including a video presentation.

The design and development of the artefact should show evidence of an iterative design approach, in line with the process shown in Figure 1. The structure of the coursework report should document and reflect this iterative design process.

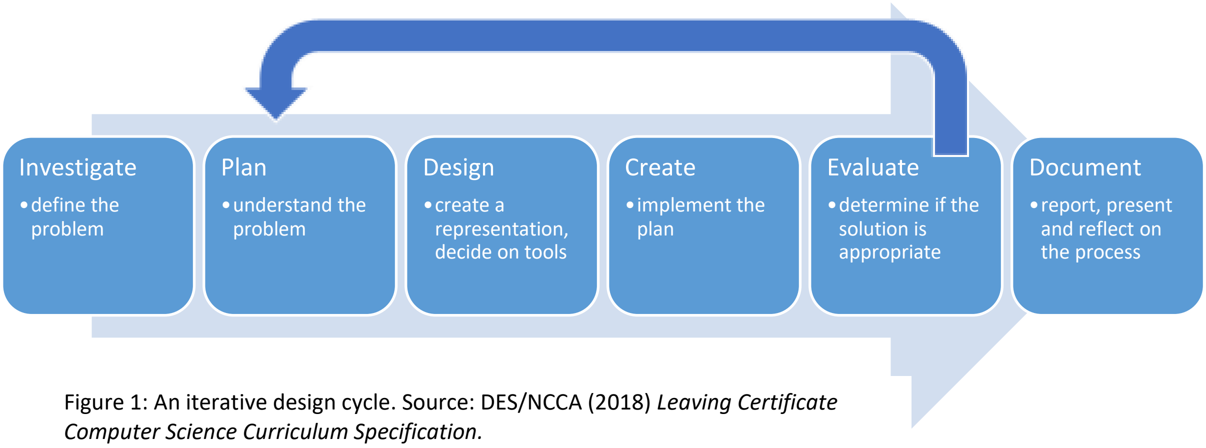

Figure 1: An iterative design cycle. Source: DES/NCCA (2018) *Leaving Certificate Computer Science Curriculum Specification.*

This portfolio will comprise a report in HTML format, including video evidence of the final artefact in operation, and the digital components of the final artefact. In the case where the final artefact incorporates both digital and physical elements, the student will submit the digital element of the final artefact. The required structure for the report will be specified in the SEC brief. It will be broadly in line with report structure described below. The SEC may include other sub-headings deemed necessary for students to fulfil the brief. A breakdown of the marks available for each section will accompany the coursework brief.

Unlike the work for ALTs, students will not be permitted to submit work in groups for the coursework assessment. The coursework must be carried out **individually**. The coursework digital portfolio must be the work and responsibility of the individual student and must be authenticated by the computer science teacher.

Coursework report

One of the key components of the coursework digital portfolio is the coursework report. The key sections of the coursework report are:

1. A rationale for the approach to the brief
2. The final artefact in operation
3. Design and development of the artefact

4. Evaluation of the final artefact

The sub-headings, given below in bold, indicate the aspects that need to be addressed within those sections.

Section 1: A rationale for the approach to the brief

Research

Students will be expected to show evidence of research on the thematic brief, including research on existing solutions or ideas aligned to the brief. They will also be expected to research the background and context of the thematic brief. The SEC brief will supply a sample selection of websites or references to assist the student with ideas and research. The sample selection will be neither an exclusive nor exhaustive list.

Response to the brief

The envisaged end user(s) should be identified. For example, students may be prompted into designing an artefact for a very specific personal purpose, such as a family relation or friend who could be in need of an artefact described in the brief. Alternatively, they may be inspired to develop a product for the enjoyment and amusement of their peers, that is also aligned to the theme of the assignment brief. In the context of the brief and of user-centred design, students could also engage with possible users. Based on their personal response to the brief and the envisaged end user, students should give reasons for specifying their initial design parameters. For example, why one form of user interface is more suitable to meet the needs of their end user or how the design accommodates some special needs of potential users. Students could also be encouraged to outline any of their other alternative responses to the brief. It should be noted that it may be permissible for aspects of this section of the work to take place outside of supervised class time. The SEC will clarify such arrangements within each assignment.

Section 2: The final artefact in operation

As a key component of the report students must embed a video presentation showing the final artefact in operation.

In deciding on the content of the video presentation, students should refer to the description of the task in the coursework assignment. Their presentation should demonstrate clearly which key features of the task they have accomplished.

For example, the presentation could show how the final artefact meets the needs of an envisaged end user. It could demonstrate the robustness of a digital simulation or physical model by showing how it works under a wider variety of operational environments. It could also demonstrate the quality of the user interface design. In particular, the presentation could highlight how the principles of good UI design are evident in their final artefact. In the case of an interactive system, the presentation could show the artefact being used and the system response to the user's inputs.

It will be important for the student to ensure that the video presentation displays all of the features of the artefact to good effect, as this presentation will be one of the key pieces of evidence used to assess the final artefact.

The capture of images either in video or photographs must be in full adherence with all requirements associated with the school's Acceptable Use Policy (AUP), data protection protocols and GDPR. It should also be completed in compliance with the requirements as set down by the SEC. Editing and publishing of the video is conducted in school under the supervision of the computer science teacher and will be subject to the protocols of the school's Acceptable Use Policy outlining the safe, ethical and responsible use of digital technology.

Section 3: Design and development of the artefact

The iterative design process

Students must show evidence of some form of an iterative design approach that reflects the process described in the LCCS specification (see Figure 1). Students should explain the rationale behind any adaptations to their design approach. The key stages in each iteration of their design process, for example Plan-Design-Create-Evaluate, should be clearly explained. There should be a concise description of how the artefact evolved through the iterative design approach. For example, students may have done one major iteration of the entire design cycle in Figure 1, but may have developed their artefact through various sub-process iterations, such as the Create-Evaluate element of the design process.

Students should report how they managed their project, including a design timeline, indicating where key decisions were made in the creation of the artefact. The report should justify these key decisions.

Development of the final artefact

There should be a clear description of how the operation of the artefact was developed to meet the brief and to work well in an overall design sense. This section should be closely aligned to, and consistent with, the video presentation of the final artefact in operation. Students should highlight the degree to which the core concepts that are relevant to the design brief are addressed. The five core concepts are Abstraction, Algorithms, Computer systems, Data, and Evaluation and testing. The SEC brief may stipulate at this point additional sub-sections that are particularly relevant to the requirements of the brief. For example, the level of robustness within the artefact to handle, where relevant, a variety of operational environments and inputs. This will be reflected in an effective UI design and an artefact that has been efficiently tested and evaluated.

In this section of the report, students should be aware of the key areas of assessment that are addressed by the quality descriptors. Therefore, during the construction of their coursework digital portfolio, students should be encouraged to consider how to report on the key criteria contained in the quality descriptors. The key areas of assessment addressed by the quality descriptors are as follows:

- Design and development
- Computational thinking
- Computer programming
- Problem solving
- Appropriate use of computing technologies
- Awareness of potential social impacts

The criteria for each of these key areas is described below in *Quality descriptors for coursework assessment.*

Section 4: Evaluation of the final artefact

Reflection on meeting the brief

Students should evaluate their final artefact in relation to the context and requirements of the brief. They should examine each of the requirements they have undertaken and explain how their artefact fulfils these requirements. If a requirement or an element of the task is not fully achieved, students should explain the reasons why it was not achieved. Students should evaluate the final artefact in relation to the needs of the end users they have identified for their product.

Future development of the final artefact

- Students should suggest, with justification, how the artefact could be modified or improved in future iterations of the design cycle.
- Students could place their concept in the context of emerging trends in computing technology. They could also identify possible applications for their artefact, both in terms of the design ambition and also potential adaptations of their design.

Format and presentation of the report

Students should present their report in a structured and coherent fashion. They will be required to present their report in a coursework report folder. The required folder structure will be specified by the SEC. This will include the report in the form of a HTML file (webpage), with an embedded video presentation. Students must acknowledge the source of any research or the use of the work of others. The report may also incorporate images. The HTML file (webpage) will be required to run on commonly-available web browsers. Students are advised to test their webpages on commonly-available web browsers prior to submission, and should indicate the browsers they have used to open and test their HTML file. The report of the completed coursework must be presented in the HTML format specified by the SEC. Other constraints, such as the maximum number of words in the report, will be specified in the brief. It is envisaged that the coursework report will not exceed 2000 words.

A video presentation will be an integral part of the report and must show the artefact in operation. The video should be 3-5 minutes in length. The purpose of the video will be to demonstrate the operation of the final artefact in such a way as to illustrate all of the features that the student wishes to highlight. This section of the report will therefore have comparatively little text, although the video may incorporate voiceover or some overlaid text to help highlight some of the artefact's features, if desired.

Quality descriptors for coursework assessment

The coursework digital portfolio will be assessed in line with quality descriptors. The quality descriptors below are based on the coursework assessment criteria set out in the LCCS specification (DES/NCCA, 2018, Table 5, p.27). Although each of the competencies that underlie the criteria represent a continuum of achievement, they are described at three levels of achievement: high, moderate and low. In some cases the criteria is expanded or developed for greater clarity and to give more helpful indicators of quality in coursework submitted by students. One additional criterion has been included, which is the student's capacity to read, write, test and modify computer programs in the prescribed languages for assessment. The key areas in which the quality of a student's coursework digital portfolio will be assessed by the SEC are as follows:

- **Design and development**
  Show evidence of design and development skills, including the creative use of an iterative design cycle (investigate, plan, design, create, evaluate and document) in all development work.
- **Computational thinking**
  Show evidence of computational thinking (CT) skills such as abstraction, decomposition, generalisation, testing and evaluation, algorithmic thinking, pattern recognition and so forth.
- **Computer programming**
  Demonstrate the ability to read, write, test and modify computer programs in the prescribed languages for assessment.
- **Problem solving**
  Demonstrate the ability to systematically address and solve problems thrown up in the implementation of their design.
- **Appropriate use of computing technologies**
  Demonstrate a knowledge of how computing technologies operate, within the context of computer science.
- **Awareness of potential social impacts**
  An appreciation of the issues around automation that are relevant to the brief, including, where relevant, adaptive technology.

Quality descriptors for coursework assessment			
	High level	**Moderate level**	**Low level**
Design and development	iteratively designs, models, tests, debugs and evaluates solutions (using a development plan and data where appropriate). chooses appropriate ways to represent and evaluate solutions and final products. shows considerable evidence of research into a rationale for approaching the brief; evaluates the performance and potential of the final artefact.	iteratively develops, tests, and debugs solutions. chooses limited ways to represent and evaluate solutions and final products. shows evidence of research into a rationale for approaching the brief; evaluates the performance of the final artefact.	does not iterate significantly upon solutions or the final product. tests, debugs and refines solutions in a linear fashion, lacking iterative processes. shows limited evidence of research into a rationale for approaching the brief; lacks meaningful evaluation of the final artefact.
Computational thinking	systematically breaks down and solves problems and processes. shows considerable evidence of CT skills in the design and development process and can explain the processes involved. uses innovative thinking in design and development.	identifies problems and processes that can be solved. shows evidence of CT skills in the design and development processes. uses some innovative thinking in design and development.	engages with limited aspects of the problem. shows limited evidence of CT skills in the design and development process. shows limited use of innovative thinking and tends to avoid challenges that have multiple steps or parts to them.
Computer programming	shows considerable evidence of appropriate use of high level data structures. implements a modular approach extensively and maximises opportunities to create well-structured code. minimises duplication and enhances readability with informative, well-placed comments has fully tested and evaluated their programs for robustness, correct logic, functionality and good UI design.	shows some evidence of appropriate use of high level data structures. implements a limited modular approach and avails of opportunities to create well-structured code. minimises duplication and enhances readability with well-placed comments. has partially tested and evaluated their programs for robustness, correct logic, functionality and good UI design.	shows limited or no evidence of appropriate use of high level data structures. does not implement a modular approach nor attempts to make programs more structured. duplicates code and does not use comments in an informative way. has not tested nor evaluated their programs, to any meaningful level, for robustness, correct logic, functionality and UI design.

Quality descriptors for coursework assessment			
	High level	**Moderate level**	**Low level**
Problem solving	independently identifies and acts on patterns in problems and solutions. seeks out pre-existing solutions, evaluating ideas and/or solutions from one problem context to another.	adapts existing knowledge or solutions to solve new problems. evaluates outcomes systematically from different ideas and solutions.	shows limited application of previous learning to new problems. demonstrates a limited systematic approach to solving problems.
Appropriate use of computing technologies	consistently displays curiosity and perseverance to investigate and analyse a spectrum of appropriate automated solutions. demonstrates an ability to apply heuristics and workarounds.	investigates a narrow spectrum of alternative automated solutions. displays a tendency to stick with a solution, with limited application of heuristics.	does not deviate from an original plan to use a particular automated solution. displays no evidence of workarounds or application of heuristics when faced with problems.
Awareness of potential social impacts	celebrates ambiguity and having different interpretations. as a creator of artefacts, shows a sensitivity to ethical and adaptive considerations, where appropriate. is aware of the potential social impact of automation in areas aligned to the brief.	shows an ability to tolerate ambiguity. as a creator of artefacts, demonstrates limited understanding around the ethical or adaptive implications of automation, where appropriate. is aware, in a limited fashion, of the potential social impact of automation in areas aligned to the brief.	has difficulty accepting ambiguity in situations. shows little or no evidence of ethical or adaptive considerations. is largely unaware of the potential social impact of automation in areas aligned to the brief.

The process of creating the computational artefact, including the rationale for the design and a reflection on the final artefact, will be assessed through the coursework report. The quality of the final artefact itself, including its operation as demonstrated through the video presentation, will be assessed according to the coursework quality descriptors. Usually the assessment of coursework that involves a report is based almost exclusively on the *content* of the report. However, in the case of the coursework in computer science, the report itself is an opportunity for the SEC to seek evidence of the student's capacity to create an appropriately designed HTML webpage to present their content. Marks will therefore also be allocated to the effectiveness with which this is done, through appropriate structuring of the webpage, the separation of content from presentational elements (through the use of CSS or otherwise), dealing with accessibility issues through appropriate tagging, and so on. The content of the report is still the primary element assessed. The technical skills displayed in the creation of the format of the report are a secondary element of the assessment. Thus the majority of marks for the report will still be allocated to its content rather than the technical construction of the presentation.

The teacher's role

The teacher has an important role to play in supporting and supervising the student. The most crucial role a teacher can play in preparation for the coursework assessment is to ensure that students are facilitated in realising the learning outcomes of all three strands. This should be done in as many contexts as possible over the course of the two years. Student engagement with the practices and principles of strand 1 and the ALTs of strand 3 is pivotal to students' readiness to carry out the coursework assignment.

The teacher's role supporting formative assessment in the classroom

Computer science in practice (strand 3) provides multiple opportunities for students to apply the practices and principles and the core concepts of the specification. Students work collaboratively to carry out four applied learning tasks over the duration of the course, each of which results in the creation of a physical or digital computational artefact. A computational artefact is anything created by a human using a computer. Examples of computational artefacts include programs, games, web pages, simulations, visualisations, digital animations, robotic systems or apps.

The ALTs explore the following four contexts: Interactive information systems, Analytics, Modelling and simulation, and Embedded systems. They provide opportunities for students to develop their theoretical and procedural understanding as they grapple with computer science practices, principles and core concepts in increasingly sophisticated applications.

The teacher should ensure, as part of the formative assessment within the classroom, that a computational artefact is designed for each ALT and a concise report outlining its development. Each student's work on ALTs will then be evaluated by the teacher, and at times collaboratively evaluated by both the teacher and peers. The focus of feedback should be on the quality of the work, how the needs of the end user are met by the artefact, and how effectively the learner has engaged with and applied the design process. Evaluation should be specific to what students did well and also how they could improve their design and development skills. ALTs, and other learning experiences in the classroom, provide both the time and the opportunities over the course of the two years for students to develop and improve their computer science skills. Initial reports on ALTs could be in the form of structured presentations to the whole class. As students progress, reports should become more detailed and individual. These reports are collected in personal portfolios, along with evidence of the design and development of the associated computational artefacts.

The NCCA link to Support for Teaching and Learning contains support material for teachers and students in all three strands, including support in each of the four ALTs. For example, depending on the theme of the brief, there may be a need to emphasise the principles of effective UI design. The NCCA further resources section links to Nielsen's effective UI design and guidance on usability heuristics. The resources, where appropriate, are designed to encourage student reflection and to enable students to build personal digital portfolios of their learning and progress. Some of the resources are cross-curricular, include a wide variety of student-generated examples, and can also be adapted by teachers and students to become part of the student's digital portfolio. Various communities of practice, such as the PDST site compsci.ie, have teaching and learning resources which can be used to support the specification. These resources are categorised under the headings contained within all three strands of the specification. The digital technologies used by the students should be those most appropriate to their needs and that can be supported within the context of the classroom.

The teacher's role supporting students with the coursework assessment

The coursework assessment will assess learning outcomes from across all three strands. Students will be required to submit, to the SEC, a coursework digital portfolio, comprising a report and the artefact. The structure of the report should reflect the iterative design process shown in Figure 1. The submission of the coursework report in HTML format is a very specific requirement of computer science students. As previously explained, marks will be awarded by the SEC for both the quality of the presentation of the report and also for the demonstration of fundamental programming skills in designing the HTML file (webpage). The student's ability to design their own webpage using their own code will be assessed. The student is not being assessed on their ability to use a website builder. It is therefore in the interest of the students to be encouraged by the teacher to design their own webpage in this manner, demonstrating some of the key skills from across the three strands.

Specifically in relation to the fulfilling the coursework brief, some of the ways teachers can assist their students are as follows:

- Be familiar with what is required in the coursework brief issued by the SEC and clarify key concerns or questions students may have.
- Prompt the learner's critical thinking in relation to the design and development of the artefact, including their own evaluation of their product. For example, the following prompts could be used:
  - Which key computational thinking skills and techniques did you apply to create your artefact?
  - Is your artefact different to how you imagined it was going to be at the beginning? If so, in what way is it different?
  - If you chose a random person in your class to use your artefact, what do you think would be their feedback?
  - How can you showcase the development and operation of your artefact in the best possible way?
  - If you were to start again, how would you improve the design and development of your artefact?
- Facilitate and support the student with the appropriate access to digital technologies.
- Ensure the students are aware of the quality descriptors.
- Oversee that their approach to the brief is related to the strands of the specification (see Appendix A).

- Supervise and monitor the work to ensure that it is possible to authenticate all the work as that of the individual student. It should be noted that some aspects of the work related to the rationale section of the report may be permitted to take place outside of class time.
- Provide appropriate access arrangements for students with SEN (see *Inclusive practice and access arrangements*).
- Ensure the student complies with the parameters and regulations laid down by the State Examinations Commission. The teacher should also ensure that there is adherence to all requirements associated with the school's AUP, data protection protocols and GDPR. To facilitate authentication of the video presentation as the student's own work, editing and publishing must be conducted in the school setting monitored by the teacher.

Each student must complete and submit an individual report, which has been authenticated by the teacher. Note that only work which is the student's own can be accepted for submission to the State Examinations Commission. It is not envisaged that the level of support involved requires teachers to edit draft reports, or to provide model reports.

Submitting the coursework digital portfolio

The coursework digital portfolio is completed by the student using the reporting structure and file format instructions specified by the SEC. The completed coursework digital portfolio will comprise all of the following:

- The digital components of the computational artefact, including all relevant programs in the prescribed languages.
- A coursework report which follows the SEC structure and adheres to the parameters set out in the assignment brief.
- As part of the coursework report, a video showing the final artefact in operation.

It is anticipated there will be a period of eight school weeks for completion of the coursework assignment. The exact timeframe will be fully laid out by the SEC, including deadlines for submission of the coursework digital portfolio.

All images must be captured, edited and published in accordance with the requirements of the school's AUP and Data Protection Policy, and GDPR. Once completed, students will transmit the digital portfolio by the deadline date in a manner specified by the SEC brief.

Backing up the digital portfolio

Appropriate back-up should be maintained by the students while their work is in preparation. The SEC will specify any back-up arrangements that are to be put in place on submission of the work in order to mitigate risks of data loss or corruption of data. This will require copies of the digital portfolios being retained by the school until the examinations process is complete, including the completion of the appeals process.

Inclusive practice and access arrangements

Leaving Certificate Computer Science is designed to be accessible to every student. Any access arrangements that a school considers necessary in order for a particular student to carry out the course work component should be processed between the school and State Examinations Commission as early as possible. These are known as *reasonable accommodations*. They are designed to enable the student to show what they know and what they can do without changing the demands of the assessment. It is important that, in order to make an informed decision before undertaking the course, any prospective learner who has a disability that might affect their capacity to engage with the standard assessment arrangements be made aware of the accommodations that are possible. Equally important is that the learner be made aware, where relevant, of those access arrangements that are *not* possible. Further details and the kinds of arrangements that are possible are available on the SEC's website, www.examinations.ie, or available from the Reasonable Accommodations Section of the SEC directly.

The intention behind any assessment access arrangement is to meet the particular needs of an individual student with a disability, without affecting the integrity of the assessment. Reasonable accommodations are necessary where a person with a disability would be at a substantial disadvantage in undertaking the assessment as outlined in the specification.

Leaving Certificate grading

Leaving Certificate Computer Science will be graded using an 8-point grading scale at both Ordinary level and Higher level. The highest grade is a Grade 1, the lowest grade a Grade 8. The highest seven grades 1-7 divide the range of marks from 100% to 30% into seven equal grade bands 10% wide, with a Grade 8 being awarded for percentage marks of less than 30%. As shown in Figure 2, the grades at Higher level and Ordinary level are distinguished informally by prefixing the grade with H or O respectively, giving H1-H8 at Higher level, and O1-O8 at Ordinary level.

Grade	% Marks
H1/O1	90-100
H2/O2	80<90
H3/O3	70<80
H4/O4	60<70
H5/O5	50<60
H6/O6	40<50
H7/O7	30<40
H8/O8	<30

Figure 2: Leaving Certificate grading scale.

Appendix A : How the strands can weave through the design cycle

'Assessment of Leaving Certificate Computer Science will be based on the learning outcomes in the specification.' (DES/NCCA, 2018, *Leaving Certificate Computer Science Curriculum Specification,* p. 17). Throughout the two years of the course students will show evidence of the skills, values and knowledge learned in the computer science classroom. The quality descriptors give details on the set of competencies students should display and the assessment criteria by which their digital coursework portfolio is assessed. The quality descriptors will provide guidance and certainty to students regarding the standard of their work. Students can gain further confidence and assurance in their work by seeing how the three strands of the LCCS specification can weave their way through each stage of the design cycle. For example:

- Before designing the solution, the student should define the typical end user for the product they are creating by considering differing perspectives of possible end users or stakeholders (LO 1.21). Students may then define the needs and requirements of that end user (LO 3.1).
- As students begin to design a solution, they will inevitably consider several designs before deciding on the system that best meets the requirement of the brief. In doing this they are, for example, evaluating alternative solutions to computational problems (LO 1.5) or looking at different perspectives (LO 1.21), or they are developing algorithms to implement chosen solutions (LO 1.7). Also they could be describing and explaining how computing enables different solutions to problems (LO 1.2).
- As they begin to implement their solution, and engage with an iterative design cycle, the core concepts of strand 2 and the associated learning outcomes will become more relevant. For example, as students begin to develop their system and to write code, they will be reading, writing, testing and modifying their computer programs (LO 1.22), solving problems by deconstructing them into smaller units (LO 1.3), debugging and commenting their code (LO 2.20), managing data (LO 2.16, 2.18) and they will be using a variety of programming concepts in their solutions (for example LO 2.6, 2.7, 2.9).
- As students evaluate their artefact they will reflect on the whole process of creating the artefact (LO 1.23) and identify its strengths and weaknesses, including possible improvements for future iterations of the design cycle (LO 2.21).

These are examples of how the student, with the guidance of the teacher, could map their design and development processes to the learning outcomes in the three strands. This form of reflection will help develop the metacognitive skills involved in being an active and reflective creator of their artefact. It will also help to reassure the student that their work is situated within the context of the LCCS specification.

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