Item types and demand

What is the impact on demand of manipulating item types in Computer Science GCSE and IGCSE?

Research Report

Clare Green and Sarah Hughes for the Digital High Stakes Assessment Programme

February 2022

Author contact details:

Clare Green and Sarah Hughes

sarah.hughes@cambridge.org
https://www.cambridge.org/

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How to cite this publication:

Green, C. & Hughes, S. (2022). *Item types and demand: What is the impact on demand of manipulating item types in Computer Science GCSE and IGCSE?* Cambridge University Press & Assessment.

Contents

1 Summary

1.1 Background

The Digital High Stakes Assessment Programme in Cambridge University Press & Assessment is developing digital assessments for UK and global teachers and learners. In one development, the team are making decisions about the assessment models to use to assess computing systems knowledge and understanding. This research took place as part of the evidence gathering to inform decisions about the assessment model. One option would be to use objective questions in an online test which could be auto-marked using pattern-matching. The auto-marking would require a change in some item types.
This piece of responsive research aimed to provide empirical evidence to the assessment developers quickly.

1.2 Research questions

The key questions for the study were:

- *If exam questions were manipulated to be objective questions, can the demand be maintained?*
- *If so, how can the demand be maintained in terms of which item types could be used?*

1.3 Method

The CRAS scale of demand[1] was chosen as the analysis tool; the five dimensions of the scale are:

- Complexity - The number of components or operations or ideas and the links between them
- Resources - The use of data and information
- Abstraction - The extent to which the student deals with ideas rather than concrete objects or phenomena
- Task strategy - The extent to which the student devises (or selects) and maintains a strategy for tackling the questions
- Response Strategy - The extent to which students have to organise their own response

The CRAS framework enabled the analysis to reveal where demand[2] might be affected should questions be rewritten for auto-marking. All items in the Computer Science (Computer Systems components) GCSE and IGCSE were investigated.

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[1] Johnson, M. & Mehta, S. (2011). Evaluating the CRAS framework; development and recommendations. Research Matters: A Cambridge Assessment publication.

[2] Demand concerns the skills designed into an exam task that can determine its relative difficulty. Intended difficulty can be defined by the target grade for an item whereas empirical difficulty is measured after an exam is sat, for example, using facility values.

1.4 Findings

Table 1: Consequences of manipulating question parts to make them objective questions (and so auto-markable)

Consequence	Number of question parts (total 60)	Percentage of question parts
Minimal changes required	16	27%
Changes required but demand maintained	8	13%
Decrease in demand if rewritten	35	58%
Not able to be rewritten for auto-marking	1	2%

- 16 of the 60 question parts needed minimal changes so that they could be auto-marked, for example, tick box questions could be rewritten as inline choice (see glossary).
- 8 question parts could be rewritten as objective questions whilst maintaining their demand and subsequently could be auto-marked, for example, short answer questions being rewritten as multiple-choice questions (MCQs).
- The demand of most of the question parts (35 of the 60 question parts) was judged to decrease if rewritten as an objective question.
- There was one question which could not be rewritten as an objective question, as the specification stated that one question will assess '*the ability to construct and develop a sustained line of reasoning*'.
- The least likely areas of demand to be affected by rewriting the question parts were Resources (the use of data and information) and Abstraction (the extent to which the student deals with ideas rather than concrete objects or phenomena). Overall, the demand of Complexity (the number of components or operations or ideas and the links between them) could be maintained.
- If the items were rewritten as objective questions, demand would be most affected in the Strategies, particularly in the Response Strategy (the extent to which students have to organise their own responses), but also in the Task Strategy (the extent to which the student devises, or selects, and maintains a strategy for tackling the questions). For example, the use of MCQs in place of a short answer question may affect the Task Strategy due to the different approach candidates might take when answering, and, with the nature of objective question responses being closed, this would then impact the Response Strategy as it eliminates the need to organise or communicate a response.
- When considering how existing items could be rewritten, possible alternative item types were determined; these were chosen from those available on the test platform currently in use. Multiple choice questions were the most useful, particularly when

replacing more open response item types. True / false, text entry and inline choice[3] were all frequently identified as suitable types.

1.5 Discussion

There was an expectation before this study (given professional knowledge and experience) that making questions more structured would lower their demand. The analyses have shown this to be true for the expert judgements' perceived demand of the responses using CRAS and particularly in relation to the dimension Strategy. This prompts debate around the value of constructed responses (as compared to closed responses). The Assessment Objectives (AOs) examined in the Computer Science papers include demonstrating knowledge and understanding, and applying knowledge and understanding. Findings suggest that these parts of the AOs could be assessed using objective question types that can be auto-marked.

However, the specifications also describe the command words (and their definitions) used in the assessments and relate to the learning outcomes. These command words influenced the decisions about whether questions could be recreated as objective items. Several of the command words encompassed skills that are more readily assessed with open response items, for example, 'describe' and 'explain'. It may be that assessments require a mixture of auto-marked items and manually marked items to allow these learning objectives to be met.

Other studies have likewise concluded that, rather than rewriting existing questions, it may be more appropriate to write a new question so that an assessment can be at the appropriate level of demand and cover the right AO and Learning Outcomes defined in the exam specifications. There are a range of MCQ types that can be utilised when re-writing questions addressing higher order thinking skills, for example, complex recall, applying reasoning, showing understanding, two-tier, assertion-reasoning.

1.6 Conclusion

If we manipulate exam questions to be objective questions, can the demand be maintained?

Yes, for certain question parts the demand could be maintained, but not for all question parts or item types. Demand across three of the CRAS dimensions could be maintained for the majority of question parts (Complexity, Resources and Abstraction), but the demand in the Strategies (Response and Task) would most frequently decrease due to the closed nature of the types of responses available with auto-marking.

How can the demand be maintained in terms of which item types could be used?

For questions where demand could be maintained, the most likely item types to be used (based on those available in the platform being used) would be MCQs (of various designs), true / false, text entry, and inline choice. Other item types identified in this study would be multiple response, inline gap match, matching, graphic gap match, drag and drop, and numeric entry (see glossary).

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[3] See Appendix 7.1 for a description of these items types

2 Background

The Digital High Stakes Assessment Programme in Cambridge University Press & Assessment is developing digital assessments for UK and global teachers and learners. One development in the programme is that of a digital computing qualification. In this development, the team are making decisions about the best assessment models to use to assess Computing knowledge. This research took place as part of the evidence gathering to inform decisions about the assessment model. One option would be to use objective questions in an online test which could be auto-marked. As the papers incorporate some longer, free response questions, changes would be required for these question types.

The assumption was made that the online test would be delivered in a test platform which includes an auto-marking function within the platform. The test platform uses pattern-based auto-marking – possible correct answers are determined using the mark scheme, then the bank of possible correct answers is searched to determine what mark should be awarded[4]. Pattern matching used in the platform requires that questions are short objective items rather than longer, free response questions. Consequently, throughout the report, when we refer to 'objective questions' we mean an item which can be auto-marked in the platform using one of the objective item types. A list of these can be found in Appendix 7.6.

The assessment developers were making decisions about whether and how auto-marking could be used in the assessment of Computer Science for GCSE and IGCSE. The existing items needed investigating to see if they could be rewritten as objective questions while retaining their demand[5].

3 Research Questions

The key questions for the study were:

- *If we manipulate exam questions to be objective questions, can the demand be maintained?*
- *If so, how can the demand be maintained in terms of which item types could be used?*

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[4] Machine learning is a different approach; machine learning requires a large dataset of example answers and marks which is used to train models. The models "learn" from the example data to determine how marks should be allocated without being explicitly told. The intention is that the models generalise well enough that they can be used on new responses to produce accurate marks.

[5] Pollitt, Ahmed & Crisp (2007) defined demands as "…separable, but not wholly discrete skills or skill sets that are presumed to determine the relative difficulty of examination tasks and are intentionally included in examinations" and they can be used to compare examination questions and papers. Demands differ from intended difficulty (target grade) and empirical difficulty (e.g. facility value which can be measured after an examination has been sat). Pollitt, A., Ahmed, A., & Crisp, V. (2007). The demands of examinations syllabuses and question papers. In P. E. Newton, J. Baird, H. Goldstein, H.Patrick & P. Tymms (Eds.), Techniques for monitoring the comparability of examination standards.London: Qualifications and Curriculum Authority

4 Method

The two components analysed were the OCR GCSE Computer Science and Cambridge Assessment International Education IGCSE Computer Science assessments of Computer Systems.

The CRAS framework of scales of demand (Appendix 7.1) was chosen as the analysis tool for exploring the demand of the items as it provided a structure for detailed analysis due to the five dimensions in the framework:

1. Complexity - The number of components or operations or ideas and the links between them
2. Resources - The use of data and information
3. Abstraction - The extent to which the student deals with ideas rather than concrete objects or phenomena
4. Task strategy - The extent to which the student devises (or selects) and maintains a strategy for tackling the questions
5. Response Strategy - The extent to which students have to organise their own response

Judgements were made across each dimension from level 1 to level 5; descriptors are given for levels 2 and 4 in the CRAS framework.

CRAS judgements were captured alongside other information about the questions (Appendix 7.2), including:

- the Assessment Objectives (Appendix 7.3),
- the levels of intended difficulty detailed in the examination specifications,
- the existing item type,
- the manipulated, objective item type, and
- comments about how demand might be affected by manipulation.

Question parts were coded green if they could be manipulated for auto-marking with minimal changes required, for example, responses that were text or numeric entry, or an existing objective question involving a tick box being rewritten as a matching question. The remaining question parts were judged against the CRAS framework and assigned scores across its 5 dimensions. They were further analysed to see if demand could be maintained if they were to be re-written for auto-marking; this necessitated considering what objective question types could replace the existing ones. The research question did not necessitate the actual re-writing of items, solely the consideration of possibilities; for many of the question parts there was more than one option for the item type that could work with auto-marking.

Following this initial analysis, the CRAS framework was embellished (Appendix 7.1.1) to include specific features found in the Computer Science specifications and mark schemes. These further influences included whether responding involved addressing facts, concepts, principles, or procedures and whether it required students to understand, apply or evaluate. In the first analysis, judgements were made for each question part across all five dimensions, whereas in the second analysis judgements were made for one dimension at a time across all question parts. This more customised framework was used to verify the judgements of demand in a more subject-specific way and also functioned as a check for internal consistency of the findings.

Where there was judged to be a change in demand with the manipulated, objective question, a positive (+1) point was assigned for each dimension for which an increase in demand was predicted and a negative (-1) point where there was a predicted decrease in demand. These points were totalled to give an indication of the magnitude of any overall change in demand for each question part. The CRAS scale was not designed for the purpose of aggregating scores across the 5 dimensions as it was intended to gauge demand rather than give a precise measure of it. In this instance, totals gave an indication of the degree and direction of change so that emerging patterns could be described. Patterns across individual dimensions were also analysed.

5 Findings

Table 1: Consequences of manipulating question parts to make them objective questions (and so auto-markable)

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Not able to be rewritten for auto-marking	1	2%

The analyses revealed that:

- 16 of the 60 question parts would need minimal or no changes to make them objective questions,
- 8 question parts would need manipulating for auto-marking, but their demand could be maintained,
- most of the question parts (35) would have a predicted decrease in demand if rewritten as objective questions,
- one question could not be rewritten due to its specific description in the Computer Science specification being an extended response question, and
- there were no question parts where there was a predicted increase in demand should they be manipulated for auto-marking.

The demands in the Resources and Abstraction dimensions were judged to be easy to maintain following manipulation, as the Resources (data and information) in a new question could be similar, or easily altered, to preserve demand and the Abstraction was more related to the content in the question context which could remain the same, for example, if the student was dealing with facts, procedures or concepts.

The main impact on demand came with the Strategies; both the Task and the Response Strategies were most often affected by manipulation due to the influences on tackling questions and the more closed nature of communicating a response to an objective question. Complexity in an item was less likely to be affected when elements of the question stem were preserved.

Question types needing minimal changes in order to be auto-marked included, for example, tick box questions being rewritten as matching. Question types which could be rewritten as objective assessments for auto-marking included, for example, short answer questions being rewritten as MCQs. Items coded as requiring minimal changes were most often those targeting the lower grades.

When considering how existing items could be rewritten, possible manipulated item types were determined. If existing questions were rewritten using item types available on the platform, the analyses determined that the most likely item types to be of use would be MCQs (assessing recall, complex recall, for example, definitions, understanding of meaning, applying reasoning and showing understanding), true / false, text entry, and inline choice, with MCQs being the most common type. Other types identified in this study (though less frequently) would be multiple response, inline gap match, matching, graphic gap match, drag and drop, and numeric entry.

6 Discussion

6.1 Caveats

- CRAS was not ever intended to provide an aggregated measure of overall demand, so although positive and negative 'points' were awarded to questions to indicate the direction and magnitude of predicted changes in demand, these are not taken as hard and fast measures, instead they were reported in findings as an indication of change in demand.
- Whether demand can be maintained or not will depend on how the new questions are written. Much of the reduction in demand stems from open response questions requiring students to organise their responses. With certain manipulations, an increase in demand could be designed into, for example, the Complexity of a question to balance a decrease in demand in the Response Strategy, but this would change the pattern of demand within the question, so this type of 'compensation' is not necessarily desirable.

6.2 Findings

- There was an expectation before this study (given professional knowledge and experience) that making questions more structured would lower their demand. This seems to be the case in this context and the lowering of demand across the question parts was mainly related to the Strategies, particularly with respect to the Response Strategy which decreases with more structured, closed response types.
- A few question parts may not be as easy to manipulate as it may first appear, for example, a text entry question which has many possible correct answers would be difficult to auto-mark using pattern-matching auto-marking. An example of this from the papers analysed is: *Identify three devices, other than a Sat Nav, which contain embedded systems.* The mark scheme gives 5 possible correct answers

(*dishwasher, MP3 player, washing machine, mobile phone, manufacturing equipment*), but also states that *there are many other examples of devices with embedded systems which may be acceptable*.

- Where a learning objective requires students to 'describe' or 'explain' these are currently assessed using open ended questions with multiple marks. Certain 'explain' questions could be assessed using complex multiple-choice questions, for example, with cause-and-effect scenarios[6]. In the IGCSE syllabus[7] the command word 'describe' is defined as 'state the points of a topic / give characteristics and main features'; when broken down in this way, it is clearer how these extended response items could be split into a series of objective items. The issue would remain as to whether the skill of writing without the scaffolding or prompts afforded in a more structured item response is valued or necessary when assessing Computer Science.
- Of the ten command words used across the two papers, the following easily lend themselves to objective items: choose, draw, identify, list, and state. A further two are less clear but could arguably be assessed using cleverly designed MCQs: give (for example, give two reasons) and suggest. That leaves three command words, describe, discuss, and explain, that do not lend themselves to pattern-matching auto-marking. The issue centres on whether the skills of describing, discussing and explaining are considered central to demonstrating attainment in the subject and, as such, assessed in the examinations. The GCSE specification, in the detail about the forms of assessment, states how question paper 1 will consist of short and medium answer questions; these could arguably be rewritten as objective questions. However, the specification also states that:

  'there will also be one 8-mark extended response question. This question will enable students to demonstrate the ability to construct and develop a sustained line of reasoning'.

  This precludes the re-writing of this question into an objective item. It also demonstrates how this skill is valued in this paper.
- Certain findings could be generalised for use with other subjects, for example, how the level of demand of the Abstraction dimension was unlikely to be affected by question manipulation, and how command words have an impact on the ability to manipulate a question for auto-marking.

7 Conclusion

27% of the question parts investigated needed no or minimal changes so that they could be auto-marked using pattern matching. Only 1 question part could not be rewritten for this type of auto-marking. The Assessment Objectives suggested that all of the specification examined in the exam papers assessing Computer Systems could be examined using objective questions. However, the command words detailed in the specifications (alongside

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[6] the definition of explain in the GCSE specification is 'give a detailed account including reasons or causes' GCSE (9-1) Computer Science J277 Specification (ocr.org.uk).

[7] In the Cambridge International IGCSE syllabus https://www.cambridgeinternational.org/Images/595424-2023-2025-syllabus.pdf command words used in the exams and their meanings can be found on p.47.

the detail in the Learning Objectives) suggested that other skills were valued, and it was these skills that were less easily tested using objective questions, for example, ‘describe’ and ‘explain’. If the ability to describe and explain in writing is key to success in Computer Science for 14- to 16-year-olds, then questions assessing these skills could be human marked. Perhaps we could question whether the skills of writing descriptions and explanations are a valid part of success in Computer Science. If these were not considered valid, then it is possible that these could either not be assessed or be assessed in other ways, for example, orally or through presentation.

The consideration of which item types could be auto-marked was defined by the testing platform being considered. Certain existing, more open question parts could be replaced by MCQs. The skills needed to write simple recall or understanding MCQs differ from those needed to address higher order thinking skills which require more complex stems and distractors. A number of characteristics of MCQs can be adjusted to influence the demand, including the familiarity of the context, the topic, the question task, the cognitive processes involved, the number of operations or links, and the need to apply reasoning or show understanding of meaning. MCQs are not as effective at measuring a candidate’s ability to articulate explanations, display thought processes, organise and communicate information or produce original ideas - all of which were required in the Computer Science papers.

The CRAS framework was an appropriate tool to use for these analyses; the addition of subject-specific details to the framework, and the second analysis, verified the judgements. The use of the framework enabled results to be generalised across question parts and made patterns of demand more evident by exposing where the effects of item manipulation lay.

If we manipulate exam questions to be objective questions, can the demand be maintained?

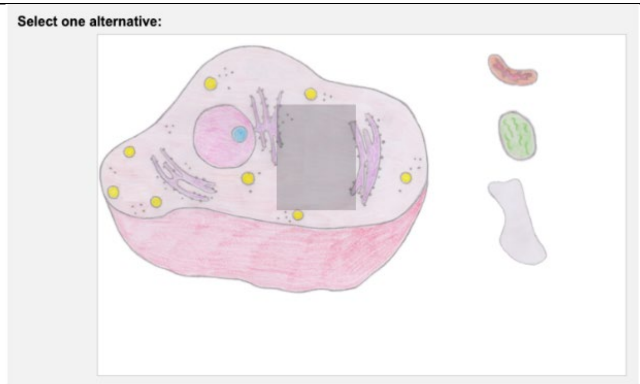
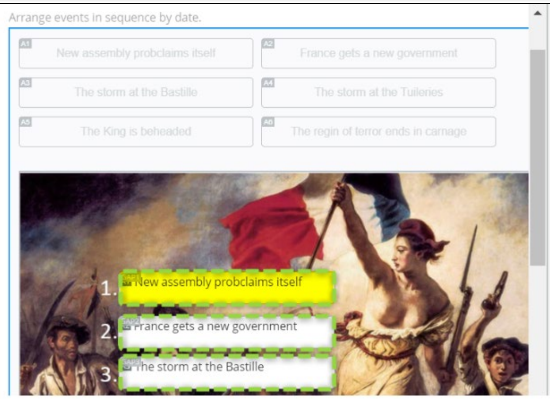
Yes, for certain question parts the demand could be maintained, but not for all question parts or item types. Demand across three of the CRAS dimensions could be maintained for the majority of question parts (Complexity, Resources and Abstraction), but the demand in the Strategies (Response and Task) would most frequently decrease due to the closed nature of the types of responses available with auto-marking.

How can the demand be maintained in terms of which item types could be used?

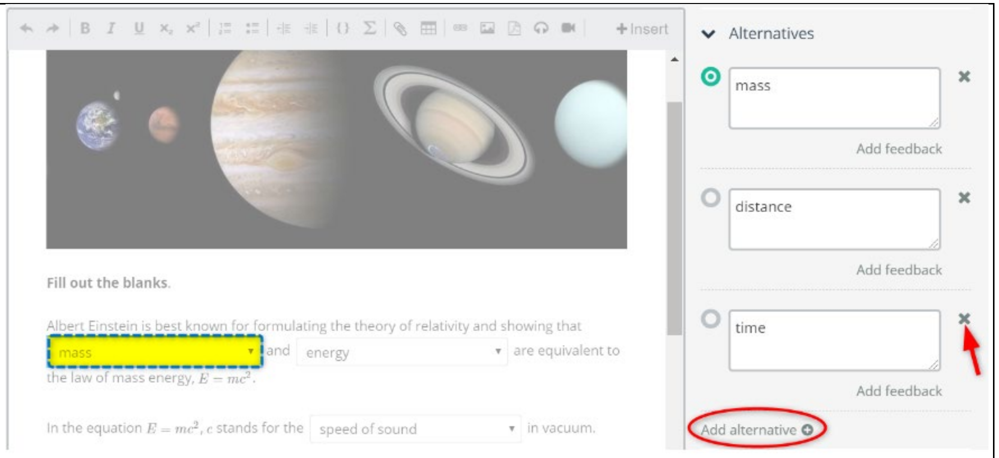
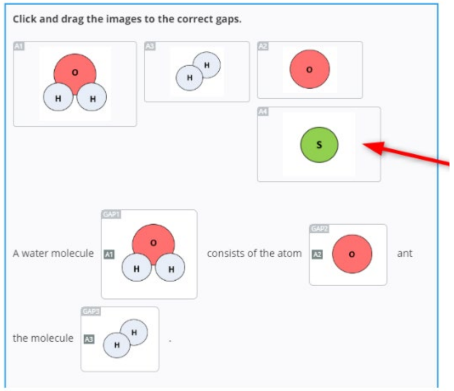
For questions where demand could be maintained, the most likely item types to be used (based on those available in the platform being used) would be MCQs (of various designs), true / false, text entry, and inline choice. Other item types identified in this study would be multiple response, inline gap match, matching, graphic gap match, drag and drop, and numeric entry.

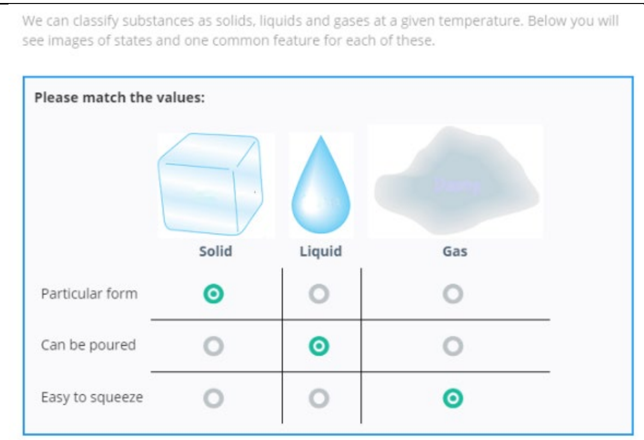
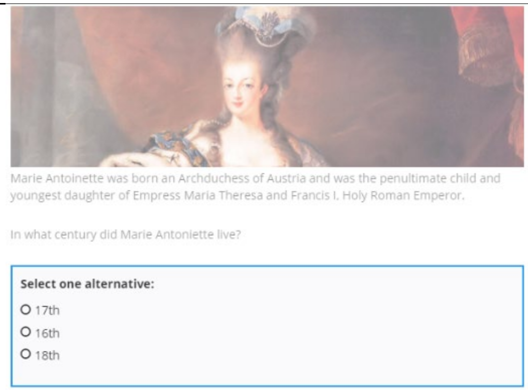
8 Appendices

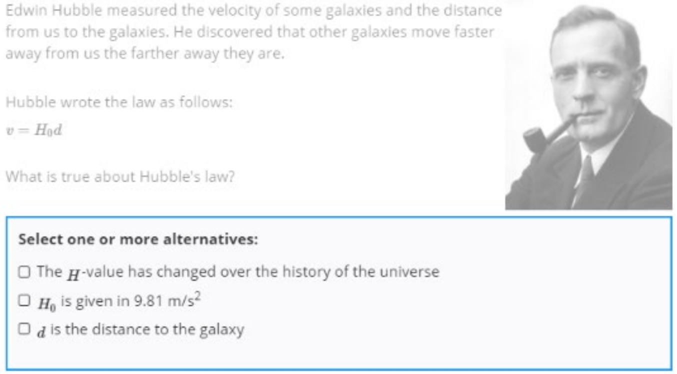
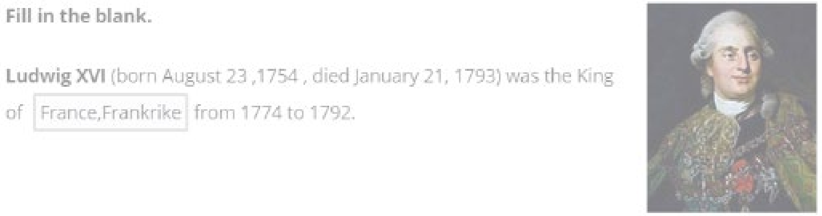
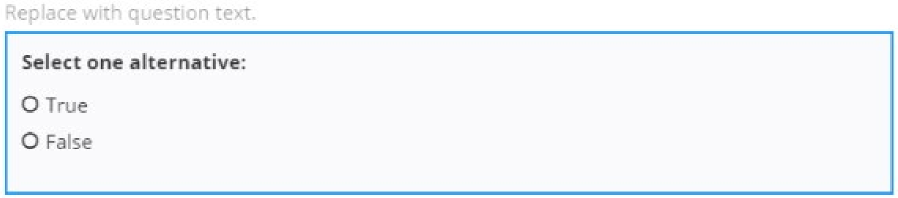
8.1 Glossary of item types with examples [8]

Drag and drop Drag and drop is a question type where a number of drag objects are to be dragged over predefined drop areas. The drag objects can be images and / or text. The drop areas are added on an image background, or, alternatively, just as a field.	
Graphic gap match Graphic Gap Match is a question type where a number of elements are to be dragged over to predefined drop areas on an image.	

[8] Taken from https://support.inspera.com/hc/en-us/sections/4564122809245-Question-types-Automatically-marked

<table>
<tr>
<td>In-line choice
Inline Choice is a question type where the candidates can answer the question by selecting a value from alternatives in a drop-down list.</td>
<td>
</td>
</tr>
<tr>
<td>In-line gap match
Inline Gap Match is a question type where a number of drag elements (tokens) are to be dragged over to predefined drop areas (gaps) in a text. The question is answered by the candidates dragging the elements to selected drop areas in the text.</td>
<td>
</td>
</tr>
</table>

<table>
<tr>
<td>Matching / pairing
Matching or pairing is answered by matching values in rows or columns. The question can also be in the form of a check table.</td>
<td>
</td>
</tr>
<tr>
<td>Multiple-choice question
Multiple Choice is a question type where the candidates will answer the question by selecting one correct answer from multiple alternatives. The alternatives can be text, sound or images.</td>
<td>
</td>
</tr>
</table>

Multiple response Multiple Response is a question type where candidates will answer the question by selecting one or more alternatives. The alternatives can be text, sound or images.	
Numeric entry Numeric entry is a question type where the question is answered by typing a numeric value.	
Text entry Text Entry is a question type where the candidates can answer the question by filling in a word or a short sentence in a blank field.	
True / False True / false is a question type where candidates answer the question by selecting one of the alternatives: True or False. It is possible to change the names of the alternatives, such as boy / girl.	

8.2 CRAS Scales of demand

Dimension	←→ *Levels*	*1*	*2*	*3*	*4*	*5*
Complexity	The number of components or operations or ideas and the links between them		Mostly single ideas or simple steps. Little comprehension, except that required for natural language. Few links between operations.		Synthesis or evaluation is required. Need for technical comprehension. Make links between cognitive operations.	
Resources	The use of data and information		More or less all and only the data / information needed are given.		Students must generate or select the necessary data / information.	
Abstraction	The extent to which the student deals with ideas rather than concrete objects or phenomena		Mostly deals with concrete objects.		Mostly abstract.	
Strategy – task	The extent to which the student devises (or selects) and maintains a strategy for tackling the questions		Strategy is given. Little or no need to monitor strategy. Little selection of information required.		Students need to devise their own strategy. Students must monitor the application of their strategy.	
Strategy – response	The extent to which students have to organise their own response		Organisation of response hardly required.		Must select answer content from a larger pool of possibilities. Must organise how to communicate response.	

8.3 CRAS Scales of Demand with Computer Science, subject-specific additions from the specifications and mark schemes shown in purple

Dimension	⟵⟶ *Levels*	*1*	*2*	*3*	*4*	*5*
Complexity	The number of components or operations or ideas and the links between them. The number of steps in the solution.		Mostly single ideas or simple steps. Little comprehension, except that required for natural language. Few links between operations. Understand the components / characteristics that make up digital systems.	Combine knowledge from more than one element. Understand how component parts of systems interrelate. Apply basic analytical and logical computational thinking to problems.	Synthesis or evaluation is required. Need for technical comprehension. Make links between cognitive operations. Combine elements that are rarely combined. Use analytical, logical, and evaluative computational thinking to problems.	Appreciation of questions from a range of different perspectives. Use sustained analytical, logical, and evaluative computational thinking to complex problems.
Resources**	The use of data and information. The inclusion of a diagram, graph, table, context. Using or generating information.		More or less all and only the data / information needed are given.		Students must generate or select the necessary data / information / text / stimulus.	
Abstraction	The extent to which the student deals with ideas rather than concrete objects or phenomena.		Mostly deals with concrete objects. Facts.	Procedures.	Mostly abstract. Concepts / principles.	
Strategy – task	The extent to which the student devises (or selects) and maintains a strategy for tackling the questions. Given / apply / devise strategy.		Strategy is given. Little or no need to monitor strategy. Little selection of information required.	Apply understanding of key concepts in a sustained way. Use principles of solving problems using computers.	Students need to devise their own strategy. Students must monitor the application of their strategy. Builds arguments and uses examples to enhance it.	Develop and refine a solution of a substantial problem.
Strategy – response***	The extent to which students have to organise their own response. Degree of scaffolding given for a response.		Organisation of response hardly required.	Candidates using their own words. Produce a working solution.	Must select answer content from a larger pool of possibilities. Must organise how to communicate response.	

8.4 Grid headings for analysing the item type and demand of the GCSE and IGCSE Computer Science question parts

					CRAS dimensions						Impact on demand: 1 point for each CRAS dimension / U = unable to rewrite			
Item ID	AO	Level of difficulty in specification: Low - Medium - High	Original item type	Details: include command words and number of expected responses	Complexity	Resources	Abstractness	Task strategy	Response strategy	New item type	-	0	+	Comments on overall impact across CRAS dimensions

8.5 Assessment Objectives for GCSE and IGCSE Computer Science

GCSE Assessment Objectives		
AO1	Demonstrate knowledge and understanding of the key concepts and principles of Computer Science.	AO1 1a: Demonstrate knowledge of the key concepts and principles of computer science.
		AO2 1b: Demonstrate understanding of the key concepts and principles of computer science.
AO2	Apply knowledge and understanding of key concepts and principles of Computer Science.	AO2 1a: Apply knowledge of key concepts and principles of computer science
		AO2 1b: Apply understanding of key concepts and principles of computer science
AO3	Analyse problems in computational terms: • To make reasoned judgements • To design, program, evaluate and refine solutions.	

IGCSE Assessment Objectives	
AO1	Demonstrate knowledge and understanding of the principles and concepts of computer science.
AO2	Apply knowledge and understanding of the principles and concepts of computer science to a given context, including the analysis and design of computational or programming problems.
AO3	Provide solutions to problems by: • Evaluating computer systems • Making reasoned judgements • Presenting conclusions.

8.6 Item types identified in the analyses

Item types available in the testing platform
Multiple-choice - recall
Multiple-choice - complex recall e.g., definitions
Multiple-choice – understanding of meaning
Multiple-choice – applying reasoning
Multiple-choice – showing understanding
Multiple response
Numeric Entry
Math entry
Text entry
Inline choice
True / False
Matching / pairing
Drag and drop
Hotspot
Code compile
Graphic gap match
Inline gap match
Ordering
Slider – fixed dot

Additional item types not currently available in the testing platform
Short answer text
Tick box
Word Problem (mathematical)
Comparison
Computational (perform calculation)
Extended response / essay
Draw a diagram
Choice