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A LEVEL
Transition Guide

COMPUTER SCIENCE

H446
For first teaching in 2015

KS4–KS5 Focus
Binary

Version 2

www.ocr.org.uk/computerscience

A LEVEL
COMPUTER SCIENCE

Key Stage 4 to 5 Transition guides focus on how a particular topic is covered at the different key stages and provide information on:

- Differences in the demand and approach at the different levels;
- Useful ways to think about the content at Key Stage 4 which will help prepare students for progression to Key Stage 5;
- Common student misconceptions in this topic.

Transition guides also contain links to a range of teaching activities that can be used to deliver the content at Key Stage 4 and 5 and are designed to be of use to teachers of both key stages. Central to the transition guide is a Checkpoint task which is specifically designed to help teachers determine whether students have developed deep conceptual understanding of the topic at Key Stage 4 and assess their 'readiness for progression' to Key Stage 5 content on this topic. This checkpoint task can be used as a summative assessment at the end of Key Stage 4 teaching of the topic or by Key Stage 5 teachers to establish their students' conceptual starting point.

Key Stage 4 to 5 Transition Guides are written by experts with experience of teaching at both key stages.

Key Stage 4 Content

OCR GCSE Computing Specification Content*

(e) understand and produce simple logic diagrams using the operations NOT, AND and OR

(f) produce a truth table from a given logic diagram.

Key Stage 5 Content

A Level Computer Science Criteria Content*

- Understand and produce logic diagrams using AND, OR, XOR and NOT
- Produce a truth table for a given logic diagram or expression
- Simplify a logical expression using AND, OR, XOR and NOT

Comment

At key stage 4 students are expected to know about three logic gates, AND, OR and NOT and should be able to produce truth tables for simple logic circuits with up to three gates. At this key stage students will need to know the symbols for and the truth tables associated with each of the three gates identified. They are also expected to be able to use the output from one gate as an input for another to calculate the overall truth table for a simple two or three gate circuit.

For example ((A AND B) OR C)

At key stage 5 the student also needs to understand the XOR gate and be able to produce logic diagrams for more complex expressions. The use of Venn diagrams to represent Boolean expressions within set theory is an additional skill as is the requirement to apply Boolean logic to the simplification of logical expressions.

Key concepts:

- Symbols and truth tables for each of AND, OR, XOR and NOT gates
- Truth tables for complex logic circuits using these gates by decomposing the problem into simpler units
- Venn diagrams to represent Boolean expressions as
  - AND set intersection
  - NOT set exclusion
  - OR set union
  - XOR exclusive OR
- Use of Venn diagrams to represent complex Boolean expressions
- The use of Venn diagrams to simplify complex Boolean expression
- De Morgan's laws :
  - NOT (A AND B) = (NOT A) OR (NOT B)
  - NOT (A OR B) = (NOT A) AND (NOT B)

Students need to be aware of the link between Boolean logic and computer electronic circuits and how logic gates can control the flow of data through a circuit.

Students need to appreciate the link between Boolean logic and conditional statements used in programs to control the flow of the program.

Students also need to be aware of the link to search criteria used for web searching and within all database searching, for example within structured query languages in general.

Venn diagrams are not part of the GCSE content but provide an excellent way to demonstrate these functions. Introducing the students to the concept of Venn diagrams at GCSE will help them appreciate the function of AND OR and NOT and will prepare them for A level more effectively.

The link between the Venn diagram with 1 inside the set and 0 outside the set and the values shown in the truth tables for the various operators can be quite illuminating for students. Relating the concepts to less abstract ideas such as cows and four legged animals can provide insight for students who find the topic difficult, from the concrete example to the abstract concept.

At GCSE the XOR gate is not required and it is common for students to confuse the inclusive OR with the common usage of or in the English language ('either or' or exclusive OR). While not required at GCSE introducing the difference between OR and XOR will aid understanding considerably.

Activities

Logic gates, circuits and truth tables

Students need to know the standard symbols for AND, OR and NOT. Students need to know the standard truth tables for AND, OR and NOT.

Basic logic tutorials from Cambridge Assessment

Useful resources for teaching about logic circuits and truth tables are available from Cambridgegcsecomputing.org

http://www.cambridgegcsecomputing.org/computing-hardware-main

These are basic tutorials that explain the principles for the main logic gates, these can be used before asking students to try the practical activities such as:

Logic simulator

Once the basic concepts are identified students can experiment with logic gates using a suitable simulator:

Useful free logic gate simulator is available for Windows operating systems from Steve Kollmansberger at South Puget College: http://www.kolls.net/gatesim/

Physical models for logic circuits

1. An excellent demonstration of physical models for this can be found in the youtube video http://www.youtube.com/watch?v=H-53TVR9EOw

Typically students can watch the video and create their own versions of these logic 'machines' with lego, plastic track and marbles or use the domino based demonstrations.

2. It is relatively straightforward to appreciate the AND and NOT statements from these but OR is often used as an exclusive 'either or' construct and using the dominoes demonstration for the OR gate may help to show what OR means in Boolean logic. http://www.youtube.com/watch?v=SudixyugiX4 (Neil Fraser)

When working with truth tables for logic circuits students should be taught to decompose the problem into the separate units, processing the output from each logic gate to create the input for the next gate.

For example (A AND B) OR C

Process A AND B to get an output R (for example)

A	B	C	R=(A AND B)	R OR C
0	0	0	0	0
0	0	1	0	1
0	1	0	0	0
0	1	1	0	1
1	0	0	0	0
1	0	1	0	1
1	1	0	1	1
1	1	1	1	1

Now use the values in the table for R as the inputs to the truth table for R OR C

Practical experience with logic gates and wires will benefit students, but failing that there are many free logic gate simulators available on the web.

Checkpoint Task

To assess the understanding from key stage 4 before starting key stage 5 typical questions that should be straightforward to answer are simple three gate logic circuit truth tables and the ability to recognise the pattern in the answers to the following:

Write out the truth tables for the expressions

NOT (A AND B) and ((NOT A) OR (NOT B))

What do you notice?

Students should notice the truth tables are the same and should be encouraged to deduce that NOT (A AND B) is the same as ((NOT A) OR (NOT B)) (De Morgan's law). They should be encouraged to look at NOT (A OR B) and suggest what the answer might be before checking their prediction. This demonstrates their ability to generalise, a fundamental computational thinking skill.

It is important the knowledge can be applied so it is important they recognise what form the output from this will take and what the actual value returned is.

What is the result returned by the condition in the following statement and what are the values of a, b and c after the program code has been executed.

When a = 5, b = 3 and c = 4

IF (a < b) OR (b < c) THEN a = b

Students should be encouraged to generalise from this result and write a simple program to check their predictions for a range of numerical values.
This will demonstrate their ability to apply computational thinking skills to solving problems.

The activity sheet and teacher guidance for this checkpoint task can be accessed via the links on the left.

Teacher Instructions:
www.ocr.org.uk/Images/163714-binary-truth-tables-checkpoint-task-teacher-instructions-.pdf

Learner Activity:
www.ocr.org.uk/Images/163715-binary-truth-tables-checkpoint-task.doc

Activities

Boolean logic and set theory

At key stage 5 students need a deeper appreciation of Boolean logic and how it applies to computer science. Initial activities can include those for key stage 4 but these are only a starting point.

The XOR (exclusive OR) gate needs to be introduced. To do this the concept of the Venn diagram may be a useful starting point. Venn diagrams demonstrating AND and OR should be used to illustrate the concept adding the XOR gate to show the exclusivity of this type of the XOR gate. Use simple Boolean expressions to illustrate the use of Venn diagrams to describe the logical expression. Venn diagrams can be used to demonstrate De Morgan's laws effectively.

Once the basic concepts are introduced more complex logical expressions can be simplified using these tools. It is important the students are introduced to the use of logic circuitry within the electronic circuitry of the computer, for example showing how a simple logic circuit can be used to store data. It is also important to appreciate how Boolean logic is used to evaluate the outcome of an expression in a conditional statement or the results of a search within a database

Wikipedia has many useful resources, including http://en.wikipedia.org/wiki/Boolean_algebra

Boolean logic challenge

The University of Surrey on-line resources and 'quiz' on Boolean algebra.

Read the material, look at the examples, complete the problems then take the on-line quiz.

Note AND is represented by . and OR by +. Venn diagrams will help to understand each of these rules.

http://www.ee.surrey.ac.uk/Projects/Labview/boolalgebra/

Wolfram demonstrations project

There is a downloadable utility to control a series of interactive demonstrations including several for Venn diagrams.

For example, for simple two variable logic:
http://demonstrations.wolfram.com/VennDiagramsForTwoVariableBooleanLogicCircuits/

The site also has useful resources to support the teaching of truth tables:
http://demonstrations.wolfram.com/TruthTables/

From this page there are a range of appropriate demonstrations that can illustrate the use of logic using Venn diagrams, for example http://demonstrations.wolfram.com/VennDiagrams/ can be used to look at all possibilities for three sets and could form the basis for a lesson identifying the appropriate logic for selected illustrations using Venn diagrams.

DFStermole

Provides a good tutorial on logic circuits, truth tables and the use of Venn diagrams. The page also has links to a range of articles, tutorials and questions that can be used at various stages and with varying ability students.

http://www.dfstermole.net/TEJ2O/logicgates/introduction.php

DFStermole

Has a range of activities on his website that support work with logic gates from A level standard to university standard:

http://www.dfstermole.net/TEJ2O/logicgates/introduction.php

Wolfram demonstrations

include a wide range of activities in this and other areas of Mathematics and computer science at all levels, by exploring the site various topics and various levels can be identified to support and extend learning in this subject.

The section on mathematical logic contains some useful material:
http://demonstrations.wolfram.com/topic.html?topic=Mathematical+Logic&limit=20

Resources, links and support

Find resources and qualification information through our Computing page:
http://www.ocr.org.uk/qualifications/as-a-level-gce-computing

Contact the team: ICT&Computing@ocr.org.uk

Continue the discussion on the Computing community forum: http://social.ocr.org.uk/

To find out more about GCSE and A Level reform please visit:
http://www.ocr.org.uk/qualifications/gcse-and-a-level-reform

The small print

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