Educational Assessment Australia

Assessing higher-order thinking (HOT) skills in ICAS tests

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‘The imparting of knowledge (content) and the development of thinking skills are accepted today as primary purposes of education.’

Source: ACARA Australian Curriculum Assessment and Reporting Authority
‘A good teacher makes you think even when you don’t want to.’

Defining higher-order thinking (HOT)

‘Students engage in purposeful, extended lines of thought during which they:

- Identify the task or problem type.
- Define and classify essential elements and terms.
- Judge and connect relevant information.
- Evaluate the adequacy of information and procedures for drawing conclusions or solving problems.’
Defining higher-order thinking (HOT) (contd 2)

‘In addition, students become

- self-conscious about their thinking and

- develop self-monitoring problem-solving strategies.’
Defining higher-order thinking (HOT) (contd 3)

‘Commonly specified higher-order reasoning processes are

1. Cognitive
   Analyse
   Compare
   Infer/Interpret
   Evaluate

2. Metacognitive
   Plan
   Monitor
   Review / Revise.’

Bloom’s (revised) taxonomy

Creating
Evaluating
Analyzing
Applying
Understanding
Remembering

Bloom’s (revised) taxonomy: HOT and LOT skills

- Remembering
- Understanding
- Applying
- Analyzing
- Evaluating
- Creating

{ HIGHER-ORDER THINKING }

{ LOWER-ORDER THINKING }

UNSW Global
THE UNIVERSITY OF NEW SOUTH WALES
Bloom’s (revised) taxonomy: Cognitive skills at each level

- Remembering: Recall factual information
- Understanding: Explain ideas or concepts
- Applying: Use information in new contexts
- Analyzing: Break information into parts
- Evaluating: Make judgements
- Creating: Generate new ideas or concepts
Bloom’s (revised) taxonomy:
Some instructional verbs at each level

- **Remembering**
  - Define, describe, find, identify, label, locate, list, memorise, name, recognise, recite, retrieve, state

- **Understanding**
  - Defend, explain, express, extend, give examples, interpret, interrelate, illustrate, match, paraphrase, restate, rewrite, summarise

- **Applying**
  - Apply, carry out, choose, dramatise, draw, execute, generalise, implement, organise, paint, prepare, produce, show, sketch, use

- **Analyzing**
  - Analyse, classify, compare, deconstruct, differentiate, distinguish, find, infer, interrogate, organise, point out, prioritise, subdivide, survey

- **Evaluating**
  - Appraise, check, compare, criticise, critique, evaluate, experiment, judge, recommend, relate, support

- **Creating**
  - Compose, construct, design, develop, hypothesise, invent, plan, produce
HOT skills are NOT about

- Rote learning
- Recalling facts
- Remembering information, and
- Answering ‘yes’ / ‘no’ or ‘right’ / ‘wrong’
What are HOT skills?

- Creative thinking
- Critical thinking
- Logical thinking
- Reflective thinking
- Metacognitive thinking (thinking about the thinking involved in learning)
Where are HOT skills used?

- Where thought processes are needed to solve problems and make decisions in everyday life, and
- Where mental processes are needed to benefit from instruction, including comparing, evaluating, justifying and making inferences.

Why develop HOT skills?

- Increase student achievement
- Increase student motivation
- Challenge students to meet the rapidly changing needs of the 21\textsuperscript{st} century
  - Greater depth of knowledge
  - Wider range of skills
  - Broader grasp of processes
  - Increased adaptability and flexibility
‘Higher-order thinking increases students’ sense of control over ideas. Thinking is much more fun than memorizing.’

Source: S M Brookhart (2010), How to Assess Higher-Order Thinking Skills in Your Classroom, ASCD, Alexandria, Virginia
Prerequisites for HOT skills

- HOT skills are not actually distinct or separate from other thinking skills, but form part of a continuum of thinking.

- Mastery of content and LOT skills are important and necessary prerequisites for HOT skills.

- If students do not have a solid foundation of basic skills and knowledge, they cannot function at the higher levels.
Prerequisites for HOT skills (contd 2)

- Students must **not** have learned a previous response.

- The context must also be as authentic as possible.
HOT skills and student learning

- HOT skills engage, encourage and challenge students to
  - create new learning environments
  - generate new ideas, and
  - analyse and manage multiple, nuanced solutions.
HOT skills and student ability

- HOT skills can be taught to students of all ability levels.

- HOT skills are not the exclusive domain of high-ability students.

- Teaching and learning HOT skills takes time, because they involve more complex thinking processes.
Case study: HOT skills and disadvantaged students

Pogrow’s 25-year-old Higher Order Thinking Skills (HOTS) program for disadvantaged (low income) students in the USA focuses on four kinds of thinking skills to accelerate educational achievement after the third grade:

(1) metacognition (the ability to think about thinking)
(2) making inferences
(3) transfer (generalising ideas across contexts), and
(4) synthesizing information.
Case study: Results of Pogrow’s HOTS program

Pogrow’s Higher Order Thinking Skills (HOTS) program increased performances of educationally disadvantaged (low income) US students in

- State and national tests
- Measures of metacognition
- Writing
- Problem solving, and
- Grade point average.

Source: S Pogrow (2005), *HOTS revisited: A thinking development approach to reducing the learning gap after grade 3*, Phi Delta Kappan, Vol 87, pp 64–75
HOT skills can be taught

- Asking effective HOT questions increases student engagement and achievement.
  - They are not spontaneous (off the cuff) questions.
  - They are not content-driven or short response questions.
  - Teachers need to carefully plan HOT questions and include some in each lesson.
  - Students need time to answer HOT questions properly.
Examples of challenging HOT questions

✓ ‘What argument would you use to convince …’
✓ ‘How would you evaluate …’
✓ ‘What would happen if …’
✓ ‘How would you develop an effective strategy to …’
✓ ‘Why is it important to consider different viewpoints in a balanced critique of …’
HOT skills can be learned

Positive student attributes also facilitate the growth of HOT skills. These include

- Persistence
- Self-monitoring
- Open-mindedness, and
- Flexibility.

Source: FJ King, L Goodson & F Rohani, Higher Order Thinking Skills, CALA, Florida State University, p. 1
http://www.cala.fsu.edu/files/higher_order_thinking_skills.pdf
HOT skills are transferable

Once students successfully apply HOT skills to solve a problem, these skills can be transferred to new situations and contexts.
How are HOT skills developed?

HOT skills develop in response to

- Uncertainty
- Unfamiliar problems, questions or dilemmas
- Apparent disorder
# Development of HOT skills

- **Situations**
  - situations of multiple categories, for which the student has not learned answers, preferably real-life context
  - ambiguities
  - challenges
  - confusions
  - dilemmas
  - discrepancies
  - doubt
  - obstacles
  - paradoxes
  - problems
  - puzzles
  - questions
  - uncertainties

- **Skills**
  - multidimensional skills of applying more than one rule or transforming known concepts or rules to fit the situation
  - complex analysis
  - creative thinking
  - critical thinking
  - decision making
  - evaluation
  - logical thinking
  - metacognitive thinking
  - problem solving
  - reflective thinking
  - scientific experimentation
  - scientific inquiry
  - synthesis
  - systems analysis

- **Outcomes**
  - outcomes that are created through thinking processes, not generated from rote responses of prior learning experiences
  - arguments
  - compositions
  - conclusions
  - confirmations
  - decisions
  - discoveries
  - estimates
  - explanations
  - hypotheses
  - insights
  - inventions
  - judgments
  - performances
  - plans
  - predictions
  - priorities
  - probabilities
  - problems
  - products
  - recommendations
  - representations
  - resolutions
  - results
  - solutions

HOT skills and 21\textsuperscript{st} century learning theories

‘Twenty-first century learning theories emphasise the importance of

1. supporting authentic and ubiquitous (anywhere, anyhow) learning, and

2. providing students with opportunities, resources and spaces to develop their creative and critical thinking skills.’

Source: ACARA Australian Curriculum Assessment and Reporting Authority
‘Learners need to develop the skills to analyse and respond to authentic situations through inquiry, imagination and innovation.’

Source: ACARA Australian Curriculum Assessment and Reporting Authority
HOT skills and Howard Gardner’s *5 Minds for the Future*

1. The disciplined mind
2. The synthesising mind
3. The creating mind
4. The respectful mind, and
5. The ethical mind

These ‘minds’ provide a useful starting place for teaching, learning and assessment.

Applying HOT skills to the classroom

‘The philosophical inquiry model, first applied to school education by Lipman, Sharp and Oscanyan (1980), has two major elements:

- critical and creative thinking, and
- forming a classroom environment called a ‘community of inquiry’, to support the development of thinking and discussion skills.

This model places emphasis on possibilities and meanings, wondering, reasoning, rigour, logic, and using criteria for measuring the quality of thinking.’

Source: ACARA Australian Curriculum Assessment and Reporting Authority
Applying HOT skills to the classroom (contd 2)

‘… critical and creative thinking are fundamental to students becoming successful learners.’

‘Thinking that is productive, purposeful and intentional is at the centre of effective learning.’

HOT skills and the Australian F–10 curriculum

‘The explicit teaching and embedding of critical and creative thinking throughout the learning areas encourages students to engage in higher order thinking.

… students are increasingly able to select from a range of thinking strategies and employ them selectively and spontaneously in an increasing range of learning contexts.’

Source: ACARA Australian Curriculum Assessment and Reporting Authority
HOT skills and the Australian F–10 curriculum
(contd 2)

‘… students develop capability in critical and creative thinking as they learn to generate and evaluate knowledge, clarify concepts and ideas, seek possibilities, consider alternatives and solve problems.’

Source: ACARA Australian Curriculum Assessment and Reporting Authority
Tasks that foster HOT skills

- include both independent and collaborative tasks
- entail some sort of transition or tension between ways of thinking
- should be challenging and engaging
- should contain approaches that are within the ability range of the learners, and
- should challenge learners to think logically, reason, be open-minded, seek alternatives, tolerate ambiguity, inquire into possibilities, be innovative risk-takers and use their imagination.

Source: ACARA Australian Curriculum Assessment and Reporting Authority
HOT skills and international assessment

‘Higher order literacy and numeracy skills are now adopted as the starting point in most international assessment programs.’

Source: Margaret Forster (2004), Higher Order Thinking Skills, Research Developments, Vol II, Article 1
Assessing higher-order thinking (HOT) skills

Three assessment item/task formats are useful in measuring HOT skills:

- **Selection** – includes multiple-choice, matching and rank-order items
- **Generation** – includes short-answer, essay, and performance items or tasks
- **Explanation** – involves giving reasons for the selection or generation of responses.

Examples of HOT items in ICAS English

Q18, Paper A, 2013
Imagine the story in the poem appeared in a newspaper. Which newspaper headline matches the story?
(A) Friendly monster comes to town
(B) Children run away from monster
(C) Monster afraid of children
(D) Monster comes out to play

Q6, Paper B, 2013
This story is a folktale. Folktales are spoken stories that are passed on from one person to another.
To keep the same message, which part of a spoken folktale should NOT be changed when it is retold?
(A) the names of the places in the story
(B) the date that the events took place
(C) the names of the characters
(D) the main plot of the story
Examples of HOT items in ICAS English  (Contd 2)

Q14, Paper C, 2013

Which option is the most likely continuation of the story?
(A) Giles and the girl continue to talk in a friendly way until Giles’s father arrives.
(B) Giles’s father arrives and Giles complains that he had to wait too long for him.
(C) The girl tells Giles that she dislikes him and takes the mandarin from him.
(D) The girl abruptly turns her back on Giles and refuses to talk.

Q32, Paper D, 2013

Brendan’s family motto ‘Harden up’ has two meanings. The first is that the Moonman’s skin hardened as they got older to enable them to work on the Moon. The second is that
(A) they had to be emotionally strong to survive the conditions.
(B) they had to be mean and aggressive in order to be successful.
(C) they must learn to ignore criticism from humans about what they did.
(D) they would become less attached over time to people and other Moonmen.
Examples of HOT items in ICAS English (Contd 3)

Q14, Paper E, 2013

Based on the text, which statement best describes the writer’s attitude towards Reilly?

(A) The writer admires Reilly for his determination to do what he believes in.

(B) The writer dismisses Reilly’s justifications for his unconventional writing style.

(C) The writer is skeptical of Reilly’s ability to differentiate himself from other writers.

(D) The writer regards Reilly’s writing style as commendable and worthy of imitation by others.
Examples of HOT items in ICAS English (Contd 4)

Q55, Paper F, 2013

Both the article *Forum: Crying wolf* on page 14 and the poem *A googled Earth* on page 16 refer to a large mass of waste in the ocean. In which way does the reference to this differ between texts?

<table>
<thead>
<tr>
<th>Article</th>
<th>Poem</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) uses it as an example of inaccurate reporting</td>
<td>uses it to shock</td>
</tr>
<tr>
<td>(B) uses it to illustrate public antipathy towards the environment</td>
<td>uses it to encourage action</td>
</tr>
<tr>
<td>(C) uses it to demonstrate the poor quality of scientific investigation</td>
<td>refers to it in a purely metaphorical sense</td>
</tr>
<tr>
<td>(D) refers to it as a hoax</td>
<td>presents it as an accepted fact</td>
</tr>
</tbody>
</table>
Examples of HOT items in ICAS English (Contd 5)

Q29, Paper G, 2013

This text is intended to
(A) present a satirical description of an awkward meeting.
(B) provide a nostalgic look at the formality of a bygone era.
(C) detail in a mocking way the kind of hotel the affluent frequent.
(D) elaborate on traditional courting rituals.

Q41, Paper I, 2013

Which truism captures Basil’s thoughts about unintelligent people?
(A) Imagination is more important than knowledge.
(B) The fool loses hope, never illusions
(C) A little knowledge is a dangerous thing.
(D) Ignorance is bliss.
Examples of HOT items in ICAS Science
Q 27, Paper B, 2012  (Contd 6)

There are different types of animals.
- Animals that only eat plant materials are called herbivores.
- Animals that only eat other animals are called carnivores.
- Animals that eat both plant materials and other animals are called omnivores.

The diagram shows the food web created when animals were attracted to a garden by a bird feeder.

27. Which of the animals are omnivores?
   (A) kookaburra only
   (B) ant, lorikeet only
   (C) king parrot, mouse, skink only
   (D) ant, king parrot, kookaburra, mouse, skink only
Examples of HOT items in ICAS Science
Q 32, Paper C, 2012  (Contd 7)

Joe carried out an investigation to see whether the material of which gloves are made affects how much water they absorb. He measured the mass of each pair of gloves before placing them in a container of snow. He measured the mass of each pair of gloves again after taking them out of the snow.

Pair W  
Pair X  
Pair Y  
Pair Z

![Images of gloves in water and snow]

32. The table shows the results of Joe’s investigation.

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mass of gloves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before being placed in snow (g)</td>
</tr>
<tr>
<td>W</td>
<td>40.0</td>
</tr>
<tr>
<td>X</td>
<td>60.8</td>
</tr>
<tr>
<td>Y</td>
<td>35.5</td>
</tr>
<tr>
<td>Z</td>
<td>28.8</td>
</tr>
</tbody>
</table>

Joe realised that he had made a mistake during the investigation.

With which pair of gloves did Joe make the mistake, and what is most likely to have made him aware of his mistake?

<table>
<thead>
<tr>
<th>He made the mistake with pair</th>
<th>He realised his mistake because</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) X.</td>
<td>the mass of the gloves did not change.</td>
</tr>
<tr>
<td>(B) X.</td>
<td>the mass of the gloves was too great.</td>
</tr>
<tr>
<td>(C) Y.</td>
<td>the mass of the gloves decreased.</td>
</tr>
<tr>
<td>(D) Y.</td>
<td>the mass of the gloves changed too much.</td>
</tr>
</tbody>
</table>
Examples of HOT items in ICAS Science
Q 13, Paper F, 2012 (Contd 8)

13. High salinity is an environmental issue in many regions. It is often caused by the water table rising, bringing salt to the surface.

The diagram shows the water table of two environments.

Which of the following is an observation from the diagram?

(A) Farm crops do not use as much water as native trees.
(B) Planting farm crops has caused the water table to rise.
(C) The roots of native trees keep the water table lower than the roots of farm crops.
(D) The water table is higher in areas with farm crops than in areas with native trees.
For questions 22 and 23 use the information below.

Objects that have a density greater than that of water sink in water. Objects that have a density less than that of water float on water. The lower the density of the material, the higher it will float.

Sam had four solid spheres, each one made from a different type of wood. She placed the wooden spheres into a container with water.

The table shows the density of each type of wood. The density of water is 1.0 g/cm³.

The diagram shows what she observed.

<table>
<thead>
<tr>
<th>Type of wood</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>balsa</td>
<td>0.14</td>
</tr>
<tr>
<td>box</td>
<td>1.10</td>
</tr>
<tr>
<td>gum</td>
<td>0.95</td>
</tr>
<tr>
<td>maple</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Sam made a new solid sphere, T, using the same type of wood as sphere Z, but with a diameter twice as large as the diameter of Z.

She placed sphere T into another container of water.

Which diagram correctly shows what she observed?

(A)  
(B)  
(C)  
(D)
36. Joe wants to check his body mass regularly and as accurately as possible as part of his fitness program. He thought that his old bathroom scales were no longer accurate so he bought new scales.

How can he check if his new bathroom scales are accurate?

(A) weigh his family members on the new scales and see if they agree with the readings
(B) weigh himself on the old scales and compare the result with that shown on the new scales
(C) weigh a 10 kg bag of rice on the new scales and compare the result with the mass shown on the rice bag
(D) weigh a 100 g tin of baked beans on the new scales and compare the result with the mass shown on the tin
Examples of HOT items in ICAS Science
Q 23, Paper H, 2013  (Contd 11)

Cocoa butter is an important ingredient in making chocolate. When it cools down, it can take one of six different forms. Each form is called a polymorph.

The table lists some information about each polymorph of cocoa butter.

<table>
<thead>
<tr>
<th>Polymorph</th>
<th>Key step in preparation</th>
<th>Melting point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form I</td>
<td>rapidly cool the cocoa butter</td>
<td>17.3</td>
</tr>
<tr>
<td>Form II</td>
<td>cool the cocoa butter at a rate of 2 °C/min</td>
<td>23.3</td>
</tr>
<tr>
<td>Form III</td>
<td>cool the cocoa butter in a container with a temperature of 5-10 °C</td>
<td>25.5</td>
</tr>
<tr>
<td>Form IV</td>
<td>cool the molten cocoa butter in a container with a temperature of 16-21 °C</td>
<td>27.3</td>
</tr>
<tr>
<td>Form V</td>
<td>cool the molten cocoa butter at a rate of 1 °C/min while stirring; keep it at 22 °C, then reheat the cocoa butter gradually to 31 °C</td>
<td>33.8</td>
</tr>
<tr>
<td>Form VI</td>
<td>leave Form V at 25 °C for four months or longer</td>
<td>36.3</td>
</tr>
</tbody>
</table>

The chocolate that is sold for consumption has to contain cocoa butter of Form V, as it has the texture and appearance that people prefer.

23. From the information in the table, what aspect of the preparation needs to be controlled most carefully to produce this form of cocoa butter in the chocolate?

(A) the heating rate  (B) the cooling rate
(C) the initial temperature  (D) the final temperature
Examples of HOT items in ICAS Maths
Q 35, Paper D, 2011  (Contd 12)

35. \(4! = 4 \times 3 \times 2 \times 1\)
\(5! = 5 \times 4 \times 3 \times 2 \times 1\)

Jess wrote the expression \(20! - 19!\) on the board.

Which of the following has the same value as this expression?

(A) \(1!\)
(B) \(20\)
(C) \(19 \times 19!\)
(D) \(20 \times 19!\)
Examples of HOT items in ICAS Maths
Q 37, Paper D, 2011  (Contd 13)

37. Jess and Yara are walking laps around a park.

Jess completes each lap in 10 minutes and then rests for 1 minute before starting the next lap.

Yara completes each lap in 13 minutes and then rests for 2 minutes before starting the next lap.

Jess and Yara start walking together in the same direction.

How many minutes will it be until they both meet together again?
Final perspective on HOT skills

‘Higher level thinking is virtually impossible without a foundation of automaticity of basic skills and knowledge. In other words, students can’t do higher-level thinking unless basic-level thinking has become automatic.’

Source: Ellen Hoerle (14 Feb 2004), New schools can be held more accountable, Minneapolis Star Tribune