Diagnostic assessments are used by teachers to check students’ knowledge and skill levels, identify student misconceptions, and profile the cognitive skills or bodies of knowledge that learners might lack (Popham, 2009). This form of assessment must be linked to further follow-up by students and teachers in order to tackle the learning difficulties identified. Diagnostic assessment can also be regarded as a form of formative assessment.

ToKToL is one example of an adaptive learning and diagnostic system that attempts to assess students’ learning progress. It promotes independent learning in the N(A), O and / or A-Level Science and Mathematics syllabus.

Funded by the Infocomm Development Authority (IDA) EdVantage initiative, this diagnostic assessment system was first piloted at the School of Science and Technology, Singapore. Subsequently, it was scaled to be trialled in four other schools - Manjusri Secondary School, Ngee Ann Secondary School, Tanglin Secondary School and Yishun Junior College.

Through the adaptive learning and diagnostic assessment platform, students attempt a series of multiple-choice questions on pre-determined subject topics (e.g. Acids and Bases in Chemistry). Based on their answers, the diagnostic algorithm adjusts the difficulty of subsequent questions to ensure that students are adequately challenged. With every response, explanations are provided to help students develop conceptual understanding and mastery. Further elaboration is also provided for higher order thinking questions, which may include more than one selected response. The design requiring multiple responses also makes questions more difficult.

This diagnostic assessment system supports assessment for learning and assessment as learning. It provides teachers with diagnostic information to enhance instruction and learning both in class and out of class. Students learn and revise concepts using the resource materials provided within the system after each response to the Multiple Choice Questions (MCQs).

The system also informs teachers about the mastery level of each student in various subject topics. Instruction can therefore be personalised and tailored by teachers to provide appropriate next steps for learning. With the diagnostic information, students can also identify their areas of weakness and use the system for self-paced learning.
Ownership of learning
• The adaptive system surfaces students’ learning gaps. Resource materials are provided to assist them in their revision when the wrong response option is chosen. Students can address their learning gaps by referring to the resource materials.

Extension of own learning
• The resource materials are not adapted from textbooks and are written for extending students’ learning beyond the textbook. Elaborate explanations are also provided for higher order questions.

Management and monitoring of own learning
• Students will manage and monitor their own learning by revising resource materials about topics in which they are weak. They also have the option of creating their own self-paced learning quizzes.

Effective group processes
• The adaptive learning platform offers an opportunity for the teacher and the student to negotiate and set learning goals. Teacher-student conferencing can be set up for teachers to address areas of weakness in the identified content area and provide individualised coaching support to students. The teacher can also structure for small group remedial amongst students of similar ability.

HOW
The adaptive learning platform is based on the application of Item Response Theory (IRT) in Computerised Adaptive Testing (CAT). IRT is the preferred psychometric model for cognitive assessment and computer based testing such as GMAT, GRE, TOEFL etc. The adaptive platform applies IRT through the following components:

– Adaptive Ability Estimation Algorithm: Estimates the general ability of the student after each item is answered.

– Item Selection Algorithm: Selects the next item depending on the current ability estimate of the student.

– Scoring Algorithm: Estimates the ability of the student with respect to specific cognitive competencies in the subject topic tested.

Question items in the item bank are tagged according to item difficulty. These items are also tagged according to the Revised Bloom’s Taxonomy (RBT), simplified into the following 3 skill levels:

<table>
<thead>
<tr>
<th>Skill Level 1:</th>
<th>Remember</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill Level 2:</td>
<td>Understand, Apply</td>
</tr>
<tr>
<td>Skill Level 3:</td>
<td>Analyse, Evaluate, Create</td>
</tr>
</tbody>
</table>

Table 1: Skill Levels Maped to RBT

The system adaptively generates the appropriate questions for students based on their ability. A description of how the adaptive platform works is described:

1. The teacher or student selects one or several content sections for assessment. The student proceeds with the assessment.
The adaptive ability estimation algorithm starts with an initial estimation of the ability of the student. This could also be based on the student’s previous scores on other sections.

With this estimate of the student’s ability, the item selection algorithm chooses the item that best fits the ability of the student.

Once the student responds to the items, the skill ability of the student is updated. When the student answers the question correctly, his ability estimate is raised. If the student fails to answer the question, his ability estimate is lowered.

The item selection algorithm then selects the next question, based on the updated skill ability of the student.

The item selection algorithm stops when the stopping criteria, such as time limit or the maximum number of test items, has been fulfilled.

The scoring algorithm provides an estimate of the student’s ability based on the student’s responses to the question items. The score is determined from the level of the difficulty of the question items. As a result, while all students may answer the same percentage of questions correctly, students who answered more difficult question items will get a higher score. A report, both for the teacher and student, presents the diagnostic information and mastery level of students in the form of a heat map. (See Figure 2)

It is important to note that no diagnostic test is 100% accurate. As with all systems, there are limitations.

The accuracy of adaptive assessment systems in estimating the ability of students could increase with the number of question items in the item bank. A large question bank also ensures sufficiently many question items of varied difficulty levels for an enriching assessment experience.

The question items are tagged according to item difficulty and the RBT. Before they can be used, it is necessary to calibrate them and this might involve a large sample size of students, up to 1000, depending on the IRT model applied to ensure that the tagging has been estimated accurately. With frequent administration of the test items, the items can be re-calibrated to enhance the system’s accuracy.

![Figure 2: Report produced at the end of assessment test](image)

(The traffic light system is used to indicate the level of mastery i.e. green: proficient mastery, orange: requires support, red: lacks mastery)
TECHNOLOGIES
Adaptive Assessment E-LearningToKToL
https://www.toktol.com

ETD PROJECT SCHOOL
School of Science and Technology, Singapore

IDA CASCADING SCHOOLS
Manjusri Secondary School
Ngee Ann Secondary School
Tanglin Secondary School
Yishun Junior College

RESOURCES


PARTICIPATION
For more information, contact:
Jean_Phua@moe.gov.sg
Kwan_Yew_Meng@moe.gov.sg
Tan_Xiao_Ting@moe.gov.sg
LESSON

Level : Secondary 4
Subject : Chemistry
Unit : Atmosphere – Air

UNIT ENDURING UNDERSTANDINGS
Students will understand that:
• The Earth's atmosphere, land and oceans form part of a finely balanced and complex chemical system.
• Human activity has both a positive and negative impact on the Earth's atmosphere and environment.

START
Before the lesson, the teacher sets up an online test in ToKToL for students on Atmosphere. Teacher monitors the outcome of the test results and uses it in preparing and adjusting lesson instruction.

PEDAGOGICAL DESIGN PRINCIPLE
Reasons for using a pre-test:
• To evaluate the amount of pre-existing knowledge on the topic
• To indicate to the student the learning level of the topic

LESSON 1
LEARNING OUTCOMES:
• Students will formulate generalisations about systems and change.
• Students will understand what atmospheric pollution is and what the undesirable consequences of pollution are.
• Students will be able to describe an experiment to determine the percentage of oxygen in a sample of dry air.
• Students will be able to give the names and formulae of six different atmospheric pollutants.
• Students will be able to recognize signs of pollution in their own surroundings.

INTRODUCTION:
Students are shown photographs of picturesque and unpolluted parts of the world and undesirable polluted parts of the world. Students are asked to comment on what they observe, offering their opinions about what has happened and why it has happened.

DEVELOPMENT:
The teacher introduces students to the concepts of systems and change, giving the students examples (e.g. transport system). Students write down generalisations about systems and change. Students recall the percentage composition of dry air, and discuss an experiment to measure the percentage of oxygen in a sample of dry air, including an explanation of the methodology and variables. Students discuss what pollution is and what the six main atmospheric pollutants are. Outside the classroom, students take photographs of atmospheric pollution / the consequences of atmospheric pollution. The photographs are uploaded and titled in a shared Google document.

CLOSURE:
Applying the think-pair-share strategy, in pairs, students take turns to share one thing that they have learned from the lesson. This process is repeated until they exhaust all of their ideas.
LESSON 2
LEARNING OUTCOME:
1. Students will learn that not all pollution is caused by human activities. Pollution can also be created naturally.
2. Students will learn the origins of different atmospheric pollutants, what problems each atmospheric pollutant causes and how levels of each atmospheric pollutant can be reduced.

INTRODUCTION:
Students use the think-pair-share activity to recall what was covered in the previous lesson.

DEVELOPMENT:
Guided by teacher’s presentation, students discuss the origins, problems and solutions to the six main atmospheric pollutants (CO, NO, O3, SO2, CH4, C8H18). Students use their knowledge to design a gas mask that will remove chemicals from polluted air.

CLOSURE:
Students participate in an activity to summarize the essential information about the six main atmospheric pollutants.

LESSON 3
LEARNING OUTCOME:
• Students will learn about the carbon cycle, understand that ozone is a pollutant at ground level, but an essential component of the upper atmosphere; and understand the origins and consequences of global warming.

INTRODUCTION:
Students navigate to the National Environment Agency’s website and check on the PSI value for the day. Students discuss the origins, consequences and implications of the yearly “haze”.

DEVELOPMENT:
Guided by the teacher’s presentation, students study the carbon cycle, learn about the origin of the ozone layer, the process of destruction of the ozone layer as well as the origins and consequences of global warming.

CLOSURE:
Applying the think-pair-share strategy, in pairs, students take turns to share one thing that they have learned from the lesson. This process is repeated until they exhaust all of their ideas.

END
After the lesson, the teacher sets up an online test in ToKToL for students on Atmosphere. Teacher monitors the outcome of the test results and uses it to decide if remedial action is necessary and how best to tailor the remedial e.g. selected groups of students with targeted focus on areas of weaknesses.

PEDAGOGICAL DESIGN PRINCIPLE
Reasons for using a post-test or formative test:
• To identify the areas of strengths in understanding the topics indicating mastery level
• To identify the areas of weaknesses in understanding the topics for revision

Note:
The questions selected in the pre and post lesson could differ, depending on the questions chosen by the teacher.

Lesson from School of Science & Technology, Singapore