Achieve

Report

International Science

Benchmarking Report

Taking the Lead in Science Education: Forging Next-Generation Science Standards

Appendix

September 2010

APPENDICES

Appendix 1.1: PISA 2006 assessment rankings by country

Country	PISA 2006 Science Literacy Score	PISA 2006 Science Literacy Rank (out of 57)
Canada	534	3
Chinese Taipei	532	4
England[1]	515	14
Finland	563	1
Hong Kong	542	2
Hungary	504	21
Ireland	508	20
Japan	531	5
Korea	522	10
Singapore[2]	N/A	N/A
United States	489	29

Appendix 1.2: Average TIMSS Science Scores of fourth and eighth-grade students, by country, 2007[3]

Country	TIMSS 2007 4th Grade Science Score (avg=500)	TIMSS 2007 4th Grade Science Rank (out of 36)	TIMSS 2007 8th Grade Science Score (avg=500)	TIMSS 2007 8th Grade Science Rank (out of 48)
Canada[4]	N/A	N/A	N/A	N/A
Chinese Taipei	557	2	561	2
England	542	7	542	5
Finland[5]	N/A	N/A	N/A	N/A
Hong Kong	554	3	530	9
Hungary	536	9	539	6
Ireland[6]	N/A	N/A	N/A	N/A
Japan	548	4	554	3
Korea	N/A	N/A	553	4
Singapore	587	1	567	1
United States	539	8	520	11

[1] Participated as "United Kingdom" in PISA.
[2] Singapore did not participate in PISA.
[3] Source: Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., and Brenwald, S. (2008). *Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context* (NCES 2009–001Revised). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington,DC. Table 11 http://nces.ed.gov/pubs2009/2009001.pdf
[4] Canada did not participate as a nation in TIMSS; however, Ontario, British Columbia and Quebec did participate as 'benchmarking participants' and all scored above the TIMSS scale average (scores 526, 526, and 507 respectively).
[5] Finland did not participate in TIMSS.
[6] Ireland did not participate in TIMSS.

Appendix 1.3: Average science content and cognitive domain TIMSS scores of fourth-grade students, by country, 2007 (Scale average =500)[7]

Country	Content Domain			Cognitive Domain		
	Life science	Physical science	Earth science	Knowing	Applying	Reasoning
Canada	*N/A*					
Chinese Taipei	541	559	553	536	556	571
England	532	543	538	543	536	537
Finland	*N/A*					
Hong Kong	532	558	560	546	549	561
Hungary	548	529	517	540	531	529
Ireland	*N/A*					
Japan	530	564	529	528	542	567
Korea	*N/A*					
Singapore	582	585	554	587	579	568
United States	540	534	533	541	533	535

Average score is higher than the U.S. average score ($p < .05$)

Average score is not measurably different from the U.S. average score ($p < .05$)

Average score is lower than the U.S. average score ($p < .05$)

Appendix 1.4: Average science content and cognitive domain scores of TIMSS eighth-grade students, by country, 2007 (Scale average =500)[8]

Country	Content Domain				Cognitive Domain		
	Biology	Chemistry	Physics	Earth Science	Knowing	Applying	Reasoning
Canada	*N/A*						
Chinese Taipei	549	573	554	545	565	560	541
England	541	534	545	529	530	538	547
Finland	*N/A*						
Hong Kong	527	517	528	532	532	522	533
Hungary	534	536	541	531	524	549	530
Ireland	*N/A*						
Japan	553	551	558	533	534	555	560
Korea	548	536	571	538	543	547	558
Singapore	564	560	575	541	554	567	564
United States	530	510	503	525	512	516	529

Average score is higher than the U.S. average score ($p < .05$)

Average score is not measurably different from the U.S. average score ($p < .05$)

[7] Source: Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., and Brenwald, S. (2008). *Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context* (NCES 2009–001Revised). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC. Table 14 http://nces.ed.gov/pubs2009/2009001.pdf

[8] Source: Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., and Brenwald, S. (2008). *Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context* (NCES 2009–001Revised). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC. Table 15 http://nces.ed.gov/pubs2009/2009001.pdf

Appendix 1.5: Average PISA scores of 15-year-old students on combined science literacy scale and science literacy subscales, by jurisdiction, 2006[9]

Country	Science Literacy Subscales		
	Identifying Scientific Issues	Explaining Phenomena Scientifically	Using Scientific Evidence
Canada	532	531	542
Chinese Taipei	509	545	532
England (UK)	514	517	514
Finland	555	566	567
Hong Kong	528	549	542
Hungary	483	518	497
Ireland	516	505	506
Japan	522	527	544
Korea	519	512	538
Singapore	*N/A*		
United States	492	486	489

Average score is higher than the U.S. average

Average score is not measurably different from the U.S. average

Average score is lower than the U.S. average

[9] Baldi, S., Jin, Y., Skemer, M., Green, P.J., and Herget, D. (2007). *Highlights From PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context* (NCES 2008–016). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC. Table 2

Appendix 2: Courses and Levels Included in Analysis

COUNTRY	COURSES AND LEVELS INCLUDED IN ANALYSIS
Ontario, Canada	Primary: The Ontario Curriculum - Grades 1-8 Science and Technology - 2007 Lower Secondary: The Ontario Curriculum - Science Grades 9 & 10 - 2008 • Science, Grade 9, Academic (SNC1D) • Science, Grade 10, Academic (SNC2D) Upper Secondary: The Ontario Curriculum - Grades 11 and 12 Science - 2008 • Biology, Grade 11, University Preparation (SBI3U) • Chemistry, Grade 11, University Preparation (SCH3U) • Physics, Grade 11, University Preparation (SPH3U) • Earth and Space Science, Grade 12, University Preparation (SES4U)
Chinese Taipei	Primary: Learning Areas in Science and Technology 2004 • Stage One (Grade 1-2) • Stage Two (Grade 3-4) • Stage Three (Grade 5-6) Lower Secondary: • Stage Four (Grade 7-9) Upper Secondary: • Biology Basic (required) & Biology (required) • Chemistry Basic (required) & Chemistry (required) • Physics Basic (required) & Physics (required) • Earth Science Basic (required) & Earth and Environmental Science (required)

England	Primary:
	The National Curriculum for England 1999
	• Programme of study for Key Stage 1
	• Programme of study for Key Stage 2
	Lower Secondary:
	The National Curriculum for England 2007
	• Programme of study for Key Stage 3
	• AQA GCSE Science A 4461 2010
	  ○ Biology I, Chemistry I, & Physics I
	Upper Secondary:
	• AQA GCSE Science A 4461 2010
	  ○ Biology I, Chemistry I, & Physics I
	• AQA GCSE Additional Science 4463 2010
	  ○ Biology II, Chemistry II, & Physics II

Finland	National Core Curriculum for Basic Education 2004 Primary: • Environment and Natural Studies: 1-4 • Biology and Geography: 5-6 • Physics and Chemistry: 5-6 Lower Secondary: • Biology

	• Chemistry: 7-9 • Geography: 7-9 Upper Secondary: National Core Curriculum for Upper Secondary Schools 2003 • Biology, Chemistry, Physics
Hong Kong	Primary: Key Learning Area Curriculum Guide 2002 • Science HK Prim Stage 1 • Science HK Prim Stage 2 • Science HK Prim Stage 3 • Science HK Prim Stage 4 Lower Secondary: • Syllabuses for Secondary Schools: Science (Secondary 1-3) 1998 Upper Secondary: Curriculum and Assessment Guide 2007 • Biology (Compulsory Part) Secondary 4-6 • Chemistry (Compulsory Part) Secondary 4-6 • Physics Guide (Compulsory Part) Secondary 4-6
Hungary (No upper secondary courses included in Quantitative Analysis)	Primary: National Core Curriculum 2007 • Man and Nature – Natural Studies Grades 4 & 6 Lower Secondary: National Core Curriculum 2007 • Man and Nature – Biology and Health Studies Grades 8 & 10 • Man and Nature – Chemistry Grades 8 & 10 • Man and Nature – Physics Grades 8 & 10 • Our Earth and Environment – Earth Science Grades 8 & 10
Ireland	Primary: • Primary School Curriculum: Social, Environmental and Scientific Education 1999 Lower Secondary: • Junior Certificate Science Syllabus (Higher Level) 2008 Upper Secondary: • Leaving Certificate (Higher Level): Biology Syllabus (2001), Chemistry Syllabus (1999), and Physics Syllabus (1999)
Japan	The Courses of Study in Japan - October 2004 Primary: • Grades 3, 4, 5, & 6 Lower Secondary: • First and Second Fields • Integrated Science A & B Upper Secondary: • Biology I & II • Chemistry I & II • Physics I & II • Earth science I & II
Korea (No upper secondary courses	Seventh National Curriculum 1998 Primary: • Grades 1, 2, 3, 4, 5, & 6

included in Quantitative Analysis)	Lower Secondary: • Grades 7, 8, 9, & 10
Singapore	Primary: • Science Syllabus Primary P3 , P4, P5, & P6 (Standard) 2008 Lower Secondary: • Lower Secondary Express/Normal (Academic) (2008) Upper Secondary: • Biology Higher 1 (2010) • Chemistry Higher 1 (2010) • Physics Higher 1 (2010)

Appendix 3: Categories and Topics Included in Country Standards by Discipline

In the following Appendix tables 4.1-4.5, the orange highlighted rows represent categories under which related topics were grouped in Achieve's analysis. Each category is followed by a series of rows that represent topics that are grouped within the larger category. The tables are sorted alphabetically by the categories. These data are aggregated across countries, but minimum and maximum values for the data highlight the spread in countries' inclusion of the topics as a percentage of the total number of content standards within their standards documents.

INCLUSION indicates that a country's standards address a category or topic, simply yes or no, in a particular grade span or course without regard for how many times that category or topic is addressed.

- Topic Count provides a count of topics within the framework under each category.
- Topic Hits represents the total number of countries that include at least one content statement on the topic of interest – not all topics or even categories will be included in a particular grade span.

FOR EACH CATEGORY, the following data is provided based on the number of topics addressed per country within each category:

- Average is average of the number of topics addressed per country within each category.
- Min and Max provide the minimum and maximum values for the population (i.e., the number of topics addressed per country within each category).

EMPHASIS indicates the percentage of a country's standards that address a category or topic and the number of times a topic is addressed as a share of the total number of topics in the country's standards in a particular grade span or course.

FOR EACH TOPIC and CATEGORY, the following data is provided based on the percentage of a country's standards that address a particular topic or – in the aggregate – a particular category:

- Average is average of the percentage each country‘s standards that address a topic or category.
- Min and Max provide the minimum and maximum values for the population (i.e., the percentages for country‘s standards that address a topic or category).

Appendix 3.1: Cross-Cutting Content

CROSS-CUTTING CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Interactions of Science, Technology, Math and Society	**25**	**2.5**	1	5	**19%**	**2%**	**30%**
HISTORY OF SCIENCE & TECHNOLOGY	4	.	.	.	<1%	0%	7%
Influence of science, technology on society	8	.	.	.	5%	0%	16%
Influence of society on science, technology	3	.	.	.	<1%	0%	3%
Interactions of Science, Mathematics, & Technology	0	.	.	.	n/a	n/a	n/a
Interactions of Science, Technology and Society	1	.	.	.	<1%	0%	<1%
Mathematics, technology influence on science	0	.	.	.	n/a	n/a	n/a
Science applications in mathematics, technology	9	.	.	.	12%	0%	25%
Nature of Science	**16**	**1.6**	0	2	**38%**	**0%**	**85%**
Nature of Scientific Knowledge	9	.	.	.	31%	0%	79%
The Scientific Enterprise	7	.	.	.	7%	0%	20%
NATURE OF SCIENCE	0	.	.	.	n/a	n/a	n/a
Nature of Technology/Engineering	**9**	**0.9**	0	1	**18%**	**0%**	**43%**
Nature or Conceptions of Technology (identifying needs and opportunities, generating a design, planning and making, evaluating)	9	.	.	.	18%	0%	43%
Sustainability	**37**	**3.7**	1	6	**26%**	**6%**	**52%**
Effects of Natural Disasters	2	.	.	.	<1%	0%	3%
Food Production, Storage	6	.	.	.	5%	0%	20%
Land, Water, Sea Resource Conservation	6	.	.	.	3%	0%	10%
Material & Energy Resource Conservation	7	.	.	.	4%	0%	13%
Pollution - Causes and Treatment	7	.	.	.	6%	0%	29%
World Population	1	.	.	.	<1%	0%	3%
General Sustainability standards	8	.	.	.	6%	0%	12%
Grand Total	**87**	**8.7**	4	14			

CROSS-CUTTING CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Interactions of Science, Technology, Math and Society	**40**	**4.0**	3	5	**38%**	**18%**	**64%**
HISTORY OF SCIENCE & TECHNOLOGY	9	.	.	.	6%	0%	19%
Influence of science, technology on society	10	.	.	.	7%	1%	14%
Influence of society on science, technology	5	.	.	.	3%	0%	11%
Interactions of Science, Mathematics, & Technology	1	.	.	.	<1%	0%	2%
Interactions of Science, Technology and Society	2	.	.	.	<1%	0%	4%
Mathematics, technology influence on science	3	.	.	.	1%	0%	5%
Science applications in mathematics, technology	10	.	.	.	20%	5%	55%
Nature of Science	**18**	**1.8**	1	2	**24%**	**5%**	**52%**
NATURE OF SCIENCE	0	.	.	.	n/a	n/a	n/a
Nature of Scientific Knowledge	9	.	.	.	16%	0%	35%
The Scientific Enterprise	9	.	.	.	7%	0%	20%
Nature of Technology/Engineering	**9**	**0.9**	0	1	**12%**	**0%**	**40%**
Nature or Conceptions of Technology (identifying needs and opportunities, generating a design, planning and making, evaluating)	9	.	.	.	12%	0%	40%
Sustainability	**50**	**5.0**	3	7	**26%**	**11%**	**33%**
Effects of Natural Disasters	4	.	.	.	1%	0%	5%
Food Production, Storage	6	.	.	.	2%	0%	4%
Land, Water, Sea Resource Conservation	10	.	.	.	3%	2%	5%
Material & Energy Resource Conservation	10	.	.	.	7%	2%	15%
Pollution - Causes and Treatment	8	.	.	.	6%	0%	18%
World Population	5	.	.	.	<1%	0%	4%
General Sustainability standards	7	.	.	.	6%	0%	25%
Grand Total	**117**	**11.7**	9	14			

Appendix 3.2: Chemistry

CHEMISTRY CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Atomic Structure	**2**	**0.2**	0	1	**<1%**	**0%**	**5%**
Atoms, ions, molecules	2	.	.	.	<1%	0%	5%
STRUCTURE OF MATTER	0	.	.	.	n/a	n/a	n/a
Oxidation state / Elementary atomic theory	0	.	.	.	n/a	n/a	n/a
Subatomic particles	0	.	.	.	n/a	n/a	n/a
Electrons, protons, neutrons	0	.	.	.	n/a	n/a	n/a
Isotopes	0	.	.	.	n/a	n/a	n/a
Nuclear chemistry	0	.	.	.	n/a	n/a	n/a
Chemical Bonding and Molecular Structure	**3**	**0.3**	0	1	**1%**	**0%**	**7%**
Macromolecules, crystals, amorphous	1	.	.	.	<1%	0%	2%
Formulas, Nomenclature and Word Equations	2	.	.	.	1%	0%	7%
Ionic and covalent compounds	0	.	.	.	n/a	n/a	n/a
Metallic Bonding	0	.	.	.	n/a	n/a	n/a
Ionic and covalent bonding	0	.	.	.	n/a	n/a	n/a
Chemical Periodicity	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Periodicity, Metals and nonmetals	0	.	.	.	n/a	n/a	n/a
Periodic table	0	.	.	.	n/a	n/a	n/a
Electron configuration and periodicity	0	.	.	.	n/a	n/a	n/a
Explanations of chemical changes	0	.	.	.	n/a	n/a	n/a
Ionization energy, Electron affinity, Electronegativity	0	.	.	.	n/a	n/a	n/a
Molecular shape; Periodic trends of reactivity, Electron configurations	0	.	.	.	n/a	n/a	n/a
Chemical Reactions	**18**	**1.8**	1	3	**10%**	**4%**	**19%**
Chemical changes	6	.	.	.	3%	0%	13%
Definition of chemical change, Evidence of chemical change	2	.	.	.	<1%	0%	5%
Electrochemistry	2	.	.	.	1%	0%	7%
Law of Conservation of Matter	2	.	.	.	<1%	0%	4%
Types of reactions	6	.	.	.	4%	0%	14%
Classification of Matter	**13**	**1.3**	0	2	**11%**	**0%**	**20%**
Classification of matter	9	.	.	.	8%	0%	20%
Homogeneous and heterogeneous materials, Elements, Compounds, Mixtures	4	.	.	.	3%	0%	16%
MATTER	0	.	.	.	n/a	n/a	n/a
Energy and Physical/Chemical Change	**27**	**2.7**	1	5	**26%**	**5%**	**64%**
Calorimetry, Exothermic and endothermic reactions	1	.	.	.	<1%	0%	2%
CHEMICAL TRANSFORMATIONS	0	.	.	.	n/a	n/a	n/a
ENERGY & PHYSICAL PROCESSES	0	.	.	.	n/a	n/a	n/a
Energy and chemical change (activation energy)	0	.	.	.	n/a	n/a	n/a

CHEMISTRY CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
First law of thermodynamics, Enthalpy	3	.	.	.	<1%	0%	5%
Heat and energy, changes of state; Thermal expansion; Kinetic-molecular theory, Heat capacity and latent heat	8	.	.	.	10%	0%	24%
Heat and temperature	9	.	.	.	11%	0%	43%
Thermodynamics / Thermal equilibrium [conduction, convection, radiation];	6	.	.	.	5%	0%	14%
Second law of thermodynamics, Entropy	0	.	.	.	n/a	n/a	n/a
Kinetics and Equilibrium	**2**	**0.2**	0	1	**<1%**	**0%**	**5%**
Rate of change and equilibria	2	.	.	.	<1%	0%	5%
Reaction rates and reaction mechanisms	0	.	.	.	n/a	n/a	n/a
Equilibrium expressions, Dynamic equilibrium	0	.	.	.	n/a	n/a	n/a
Organic Chemistry	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Organic & biochemical changes	0	.	.	.	n/a	n/a	n/a
Organic/inorganic	0	.	.	.	n/a	n/a	n/a
Hydrocarbons	0	.	.	.	n/a	n/a	n/a
Isomers	0	.	.	.	n/a	n/a	n/a
Functional groups and properties	0	.	.	.	n/a	n/a	n/a
Types of organic reactions	0	.	.	.	n/a	n/a	n/a
Properties of Matter	**25**	**2.5**	1	4	**24%**	**7%**	**48%**
Acids, Bases, Salts; pH scale	3	.	.	.	1%	0%	6%
Chemical properties	6	.	.	.	7%	0%	28%
Physical properties	9	.	.	.	11%	0%	24%
Weight, Mass, Volume, Density, Hardness, Malleability, Elasticity, Shape, Color	7	.	.	.	5%	0%	12%
Chemical reactivity	0	.	.	.	n/a	n/a	n/a
Materials of high importance in industry	0	.	.	.	n/a	n/a	n/a
Quantum Theory	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Atomic spectra	0	.	.	.	n/a	n/a	n/a
Properties of quantum objects; Quantum numbers and orbital energies; Shapes of orbitals (VSEPR model)	0	.	.	.	n/a	n/a	n/a
Electromagnetic radiation and matter	0	.	.	.	n/a	n/a	n/a
Quantum theory & fundamental particles	0	.	.	.	n/a	n/a	n/a
Quantum nature of light, Photoelectric effect	0	.	.	.	n/a	n/a	n/a
Line spectra, Matter waves, Uncertainty principle	0	.	.	.	n/a	n/a	n/a
Solids, Liquids, Gases (Kinetic-Molecular Theory)	**28**	**2.8**	1	4	**19%**	**10%**	**27%**
Changes in states of matter [gases, liquids, solids], Gas laws, Phase changes and phase diagrams	4	.	.	.	2%	0%	7%
Explanations of physical changes	9	.	.	.	7%	0%	17%
Inter-particle forces, Dispersion and flocculation of colloids	1	.	.	.	<1%	0%	2%
Kinetic-molecular theory	0	.	.	.	n/a	n/a	n/a

CHEMISTRY CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Physical changes	6	.	.	.	4%	0%	20%
PHYSICAL TRANSFORMATIONS	0	.	.	.	n/a	n/a	n/a
States of matter -- gases, liquids, solids	8	.	.	.	6%	0%	12%
Solutions	**10**	**1.0**	0	2	**7%**	**0%**	**27%**
Dynamic equilibrium / Factors affecting solubility	0	.	.	.	n/a	n/a	n/a
Mixing, Solutions, Colligative properties	5	.	.	.	4%	0%	23%
Solutions, Suspensions, Colloids	5	.	.	.	3%	0%	10%
Stoichiometry	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Stoichiometry; Molecular and Formula Weight; Mole Concept; Balancing Equations	0	.	.	.	n/a	n/a	n/a
Grand Total	**128**	**12.8**	7	18			

CHEMISTRY CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Atomic Structure	**35**	**3.5**	2	6	**11%**	**6%**	**19%**
Atoms, ions, molecules	10	.	.	.	6%	<1%	11%
Electrons, protons, neutrons	3	.	.	.	<1%	0%	2%
Isotopes	2	.	.	.	<1%	0%	2%
Nuclear chemistry	5	.	.	.	2%	0%	7%
Oxidation state / Elementary atomic theory	6	.	.	.	1%	0%	3%
STRUCTURE OF MATTER	4	.	.	.	<1%	0%	3%
Subatomic particles	5	.	.	.	1%	0%	5%
Chemical Bonding and Molecular Structure	**27**	**2.7**	1	4	**7%**	**2%**	**13%**
Ionic and covalent bonding	2	.	.	.	<1%	0%	2%
Ionic and covalent compounds	7	.	.	.	1%	0%	4%
Macromolecules, crystals, amorphous	6	.	.	.	2%	0%	8%
Metallic Bonding	3	.	.	.	<1%	0%	2%
Formulas, Nomenclature and Word Equations	9	.	.	.	3%	0%	5%
Chemical Periodicity	**24**	**2.4**	1	5	**6%**	**2%**	**10%**
Electron configuration and periodicity	3	.	.	.	<1%	0%	2%
Explanations of chemical changes	1	.	.	.	<1%	0%	2%
Ionization energy, Electron affinity, Electronegativity	1	.	.	.	<1%	0%	<1%
Molecular shape; Periodic trends of reactivity, Electron configurations	4	.	.	.	<1%	0%	2%
Periodic table	7	.	.	.	1%	0%	4%
Periodicity, Metals and nonmetals	8	.	.	.	3%	0%	7%
Chemical Reactions	**38**	**3.8**	2	5	**13%**	**5%**	**19%**
Chemical changes	7	.	.	.	1%	0%	3%
Definition of chemical change, Evidence of chemical change	7	.	.	.	1%	0%	5%
Electrochemistry	8	.	.	.	3%	0%	9%
Law of Conservation of Matter	6	.	.	.	1%	0%	5%
Types of reactions	10	.	.	.	7%	2%	15%
Classification of Matter	**16**	**1.6**	1	2	**9%**	**1%**	**20%**
Classification of matter	5	.	.	.	2%	0%	7%
Homogeneous and heterogeneous materials, Elements, Compounds, Mixtures	10	.	.	.	7%	1%	15%
MATTER	1	.	.	.	<1%	0%	6%
Energy and Physical/Chemical Change	**45**	**4.5**	2	7	**18%**	**9%**	**34%**
Calorimetry, Exothermic and endothermic reactions	1	.	.	.	<1%	0%	1%
CHEMICAL TRANSFORMATIONS	1	.	.	.	<1%	0%	5%
ENERGY & PHYSICAL PROCESSES	2	.	.	.	2%	0%	15%
Energy and chemical change (activation energy)	3	.	.	.	<1%	0%	2%
First law of thermodynamics, Enthalpy	7	.	.	.	2%	0%	6%
Heat and energy, changes of state; Thermal	10	.	.	.	5%	1%	10%

CHEMISTRY CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
expansion; Kinetic-molecular theory, Heat capacity and latent heat							
Heat and temperature	9	.	.	.	4%	0%	9%
Second law of thermodynamics, Entropy	3	.	.	.	<1%	0%	2%
Thermodynamics / Thermal equilibrium [conduction, convection, radiation];	9	.	.	.	4%	0%	9%
Kinetics and Equilibrium	**9**	**0.9**	0	2	**2%**	**0%**	**7%**
Equilibrium expressions, Dynamic equilibrium	6	.	.	.	<1%	0%	2%
Rate of change and equilibria	0	.	.	.	n/a	n/a	n/a
Reaction rates and reaction mechanisms	3	.	.	.	<1%	0%	4%
Organic Chemistry	**12**	**1.2**	0	4	**3%**	**0%**	**13%**
Organic & biochemical changes	5	.	.	.	2%	0%	8%
Organic/inorganic	1	.	.	.	<1%	0%	1%
Hydrocarbons	3	.	.	.	1%	0%	6%
Types of organic reactions	2	.	.	.	<1%	0%	<1%
Functional groups and properties	1	.	.	.	<1%	0%	1%
Isomers	0	.	.	.	n/a	n/a	n/a
Properties of Matter	**39**	**3.9**	2	6	**16%**	**3%**	**29%**
Acids, Bases, Salts; pH scale	8	.	.	.	3%	0%	13%
Chemical properties	8	.	.	.	3%	0%	9%
Chemical reactivity	4	.	.	.	<1%	0%	3%
Physical properties	9	.	.	.	4%	0%	9%
Weight, Mass, Volume, Density, Hardness, Malleability, Elasticity, Shape, Color	7	.	.	.	4%	0%	9%
Materials of high importance in industry	3	.	.	.	2%	0%	8%
Quantum Theory	**6**	**0.6**	0	3	**2%**	**0%**	**13%**
Atomic spectra	0	.	.	.	n/a	n/a	n/a
Electromagnetic radiation and matter	2	.	.	.	1%	0%	12%
Line spectra, Matter waves, Uncertainty principle	0	.	.	.	n/a	n/a	n/a
Properties of quantum objects; Quantum numbers and orbital energies; Shapes of orbitals (VSEPR model)	0	.	.	.	n/a	n/a	n/a
Quantum nature of light, Photoelectric effect	2	.	.	.	<1%	0%	1%
Quantum theory & fundamental particles	2	.	.	.	<1%	0%	<1%
Solids, Liquids, Gases (Kinetic-Molecular Theory)	**34**	**3.4**	1	6	**7%**	**<1%**	**13%**
Changes in states of matter [gases, liquids, solids], Gas laws, Phase changes and phase diagrams	5	.	.	.	1%	0%	5%
Explanations of physical changes	9	.	.	.	2%	0%	6%
Inter-particle forces, Dispersion and flocculation of colloids	1	.	.	.	<1%	0%	<1%
Kinetic-molecular theory	6	.	.	.	<1%	0%	2%
Physical changes	4	.	.	.	<1%	0%	4%

CHEMISTRY CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
PHYSICAL TRANSFORMATIONS	2	.	.	.	<1%	0%	5%
States of matter -- gases, liquids, solids	7	.	.	.	1%	0%	5%
Solutions	**15**	**1.5**	0	3	**4%**	**0%**	**17%**
Dynamic equilibrium / Factors affecting solubility	3	.	.	.	<1%	0%	2%
Mixing, Solutions, Colligative properties	4	.	.	.	1%	0%	7%
Solutions, Suspensions, Colloids	8	.	.	.	2%	0%	10%
Stoichiometry	**6**	**0.6**	0	1	**2%**	**0%**	**4%**
Stoichiometry; Molecular and Formula Weight; Mole Concept; Balancing Equations	6	.	.	.	2%	0%	4%
Grand Total	**306**	**30.6**	22	53			

CHEMISTRY CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Atomic Structure	**27**	**3.4**	2	5	**5%**	**3%**	**8%**
Atoms, ions, molecules	5	.	.	.	1%	0%	3%
Electrons, protons, neutrons	5	.	.	.	<1%	0%	2%
Isotopes	5	.	.	.	<1%	0%	1%
Nuclear chemistry	4	.	.	.	<1%	0%	1%
Oxidation state / Elementary atomic theory	7	.	.	.	2%	0%	4%
STRUCTURE OF MATTER	1	.	.	.	<1%	0%	3%
Subatomic particles	0	.	.	.	n/a	n/a	n/a
Biology-related Chemistry	**15**	**1.9**	0	5	**2%**	**0%**	**11%**
Biochemistry of systems	1	.	.	.	<1%	0%	1%
Biological organisms are composed primarily of very few elements.	1	.	.	.	<1%	0%	1%
Cells	1	.	.	.	<1%	0%	<1%
Chemistry of cells (enzymes); Cell reproduction; Cell communication and regulation, Cell water relations	3	.	.	.	<1%	0%	4%
Disease and health	1	.	.	.	<1%	0%	<1%
Energy handling	3	.	.	.	<1%	0%	3%
Nutrition	2	.	.	.	<1%	0%	<1%
Prevention of disease, Maintaining good health, Importance of exercise	1	.	.	.	<1%	0%	<1%
Types and causes of disease, Remedies	2	.	.	.	<1%	0%	1%
Chemical Bonding and Molecular Structure	**30**	**3.8**	3	5	**9%**	**4%**	**14%**
Ionic and covalent bonding	3	.	.	.	<1%	0%	1%
Ionic and covalent compounds	8	.	.	.	4%	1%	7%
Macromolecules, crystals, amorphous	8	.	.	.	2%	<1%	6%
Metallic Bonding	5	.	.	.	<1%	0%	2%
Formulas, Nomenclature and Word Equations	6	.	.	.	2%	0%	4%
Chemical Periodicity	**33**	**4.1**	3	5	**7%**	**4%**	**12%**
Electron configuration and periodicity	8	.	.	.	2%	<1%	5%
Ionization energy, Electron affinity, Electronegativity	5	.	.	.	1%	0%	3%
Molecular shape; Periodic trends of reactivity, Electron configurations	5	.	.	.	<1%	0%	2%
Periodic table	7	.	.	.	1%	0%	2%
Periodicity, Metals and nonmetals	8	.	.	.	2%	<1%	5%
Explanations of chemical changes	0	.	.	.	n/a	n/a	n/a
Chemical Reactions	**26**	**3.3**	1	4	**11%**	**3%**	**21%**

CHEMISTRY CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Chemical changes	6	.	.	.	<1%	0%	3%
Definition of chemical change, Evidence of chemical change	3	.	.	.	<1%	0%	1%
Electrochemistry	5	.	.	.	3%	0%	9%
Law of Conservation of Matter	4	.	.	.	<1%	0%	2%
Types of reactions	8	.	.	.	7%	2%	14%
Classification of Matter	**9**	**1.1**	0	2	**2%**	**0%**	**6%**
Classification of matter	1	.	.	.	<1%	0%	1%
Homogeneous and heterogeneous materials, Elements, Compounds, Mixtures	7	.	.	.	2%	0%	4%
MATTER	1	.	.	.	<1%	0%	2%
Earth/Space Science-related Chemistry	**12**	**1.5**	0	4	**1%**	**0%**	**4%**
Atmosphere	5	.	.	.	<1%	0%	2%
Building & breaking	1	.	.	.	<1%	0%	1%
Chemical cycles (nitrogen, carbon, carbon dioxide, oxygen, etc.)	1	.	.	.	<1%	0%	<1%
Earth's composition	2	.	.	.	<1%	0%	<1%
Rock Cycle	0	.	.	.	n/a	n/a	n/a
Rocks, soil	3	.	.	.	<1%	0%	1%
Water Cycle	0	.	.	.	n/a	n/a	n/a
Energy and Physical/Chemical Change	**25**	**3.1**	1	6	**4%**	**<1%**	**8%**
Calorimetry, Exothermic and endothermic reactions	7	.	.	.	1%	0%	3%
CHEMICAL TRANSFORMATIONS	1	.	.	.	<1%	0%	2%
ENERGY & PHYSICAL PROCESSES	1	.	.	.	<1%	0%	2%
Energy and chemical change (activation energy)	5	.	.	.	<1%	0%	3%
First law of thermodynamics, Enthalpy	6	.	.	.	<1%	0%	2%
Heat and energy, changes of state; Thermal expansion; Kinetic-molecular theory, Heat capacity and latent heat	3	.	.	.	<1%	0%	3%
Heat and temperature	0	.	.	.	n/a	n/a	n/a
Second law of thermodynamics, Entropy	1	.	.	.	<1%	0%	<1%
Thermodynamics / Thermal equilibrium [conduction, convection, radiation];	1	.	.	.	<1%	0%	<1%
Interactions of Science, Technology, Math and Society	**19**	**2.4**	0	4	**5%**	**0%**	**10%**
HISTORY OF SCIENCE & TECHNOLOGY	3	.	.	.	<1%	0%	<1%
Influence of science, technology on society	4	.	.	.	<1%	0%	2%
Influence of society on science, technology	1	.	.	.	<1%	0%	<1%
Interactions of Science, Mathematics, & Technology	0	.	.	.	n/a	n/a	n/a

CHEMISTRY CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Interactions of Science, Technology and Society	1	.	.	.	<1%	0%	<1%
Mathematics, technology influence on science	3	.	.	.	<1%	0%	4%
Science applications in mathematics, technology	7	.	.	.	3%	0%	10%
Kinetics and Equilibrium	**19**	**2.4**	1	3	**5%**	**<1%**	**10%**
Equilibrium expressions, Dynamic equilibrium	8	.	.	.	3%	<1%	6%
Rate of change and equilibria	4	.	.	.	<1%	0%	2%
Reaction rates and reaction mechanisms	7	.	.	.	2%	0%	4%
Nature of Science	**9**	**1.1**	0	2	**6%**	**0%**	**19%**
NATURE OF SCIENCE	0	.	.	.	n/a	n/a	n/a
Nature of Scientific Knowledge	6	.	.	.	5%	0%	14%
The Scientific Enterprise	3	.	.	.	1%	0%	9%
Nature of Technology/Engineering	**26**	**3.3**	1	5	**n/a**	**n/a**	**n/a**
Nature or Conceptions of Technology (identifying needs and opportunities, generating a design, planning and making, evaluating)	0	.	.	.	n/a	n/a	n/a
Organic Chemistry	**28**	**3.5**	1	6	**13%**	**<1%**	**32%**
Organic & biochemical changes	6	.	.	.	3%	0%	8%
Organic/inorganic	5	.	.	.	1%	0%	7%
Hydrocarbons	6	.	.	.	3%	0%	9%
Types of organic reactions	5	.	.	.	3%	0%	12%
Functional groups and properties	4	.	.	.	2%	0%	10%
Isomers	2	.	.	.	<1%	0%	2%
Physics-related Chemistry	**1**	**0.1**	0	1	**<1%**	**0%**	**<1%**
Electric charge, Coulomb's law, Conductors, Insulators, Static electricity, Electrical fields, Alternating/direct current	1	.	.	.	<1%	0%	<1%
Time, space and motion	0	.	.	.	n/a	n/a	n/a
PHYSICAL SCIENCES	0	.	.	.	n/a	n/a	n/a
Properties of Matter	**40**	**5.0**	3	6	**11%**	**7%**	**15%**
Acids, Bases, Salts; pH scale	8	.	.	.	3%	<1%	5%
Chemical properties	8	.	.	.	2%	<1%	4%
Chemical reactivity	6	.	.	.	<1%	0%	1%
Materials of high importance in industry	5	.	.	.	1%	0%	5%
Physical properties	8	.	.	.	3%	<1%	5%
Weight, Mass, Volume, Density, Hardness, Malleability, Elasticity, Shape, Color	5	.	.	.	<1%	0%	5%

CHEMISTRY CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Quantum Theory	**8**	**1.0**	0	3	**1%**	**0%**	**3%**
Atomic spectra	1	.	.	.	<1%	0%	<1%
Electromagnetic radiation and matter	0	.	.	.	n/a	n/a	n/a
Line spectra, Matter waves, Uncertainty principle	1	.	.	.	<1%	0%	<1%
Properties of quantum objects; Quantum numbers and orbital energies; Shapes of orbitals (VSEPR model)	6	.	.	.	<1%	0%	2%
Quantum nature of light, Photoelectric effect	0	.	.	.	n/a	n/a	n/a
Quantum theory & fundamental particles	0	.	.	.	n/a	n/a	n/a
Solids, Liquids, Gases (Kinetic-Molecular Theory)	**22**	**2.8**	1	5	**4%**	**1%**	**6%**
Changes in states of matter [gases, liquids, solids], Gas laws, Phase changes and phase diagrams	3	.	.	.	<1%	0%	<1%
Explanations of physical changes	2	.	.	.	<1%	0%	3%
Inter-particle forces, Dispersion and flocculation of colloids	6	.	.	.	<1%	0%	2%
Kinetic-molecular theory	4	.	.	.	<1%	0%	3%
Physical changes	1	.	.	.	<1%	0%	<1%
PHYSICAL TRANSFORMATIONS	1	.	.	.	<1%	0%	2%
States of matter -- gases, liquids, solids	5	.	.	.	<1%	0%	3%
Solutions	**16**	**2.0**	0	3	**3%**	**0%**	**6%**
Dynamic equilibrium / Factors affecting solubility	6	.	.	.	1%	0%	3%
Mixing, Solutions, Colligative properties	4	.	.	.	<1%	0%	1%
Solutions, Suspensions, Colloids	6	.	.	.	<1%	0%	2%
Stoichiometry	**8**	**1.0**	1	1	**7%**	**1%**	**18%**
Stoichiometry; Molecular and Formula Weight; Mole Concept; Balancing Equations	8	.	.	.	7%	1%	18%
Sustainability	**17**	**2.1**	0	3	**4%**	**0%**	**9%**
Effects of Natural Disasters	0	.	.	.	n/a	n/a	n/a
Food Production, Storage	1	.	.	.	<1%	0%	<1%
General Sustainability standards	2	.	.	.	<1%	0%	1%
Land, Water, Sea Resource Conservation	1	.	.	.	<1%	0%	2%
Material & Energy Resource Conservation	6	.	.	.	1%	0%	4%
Pollution - Causes and Treatment	7	.	.	.	2%	0%	6%
World Population	0	.	.	.	n/a	n/a	n/a
Grand Total	**390**	**48.8**	39	61			

Appendix 3.3: Physics

PHYSICS CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Atomic Structure	**2**	**0.2**	0	1	**<1%**	**0%**	**3%**
Atoms, ions, molecules	2	.	.	.	<1%	0%	3%
STRUCTURE OF MATTER	0	.	.	.	n/a	n/a	n/a
Oxidation state / Elementary atomic theory	0	.	.	.	n/a	n/a	n/a
Subatomic particles	0	.	.	.	n/a	n/a	n/a
Electrons, protons, neutrons	0	.	.	.	n/a	n/a	n/a
Isotopes	0	.	.	.	n/a	n/a	n/a
Nuclear chemistry	0	.	.	.	n/a	n/a	n/a
Electrical Phenomena	**22**	**2.2**	0	3	**11%**	**0%**	**21%**
AC/DC circuits, Capacitors, Resistors, Electronics, Semi-conductors, Transformers, Motors, Ohm's Law	8	.	.	.	4%	0%	13%
Electric charge, Coulomb's law, Conductors, Insulators, Static electricity, Electrical fields, Alternating/direct current	6	.	.	.	2%	0%	6%
Electricity (Electrical Phenomena)	8	.	.	.	4%	0%	12%
Electromagnetism	**15**	**1.5**	0	3	**7%**	**0%**	**18%**
Induction, Charges in electric and magnetic fields, Electromagnetism	3	.	.	.	<1%	0%	4%
Electricity (Electromagnetism)	8	.	.	.	4%	0%	12%
Magnetism (Electromagnetism)	4	.	.	.	2%	0%	8%
Energy and Physical/Chemical Change	**27**	**2.7**	1	5	**15%**	**3%**	**29%**
Calorimetry, Exothermic and endothermic reactions	1	.	.	.	<1%	0%	1%
CHEMICAL TRANSFORMATIONS	0	.	.	.	n/a	n/a	n/a
ENERGY & PHYSICAL PROCESSES	0	.	.	.	n/a	n/a	n/a
Energy and chemical change (activation energy)	0	.	.	.	n/a	n/a	n/a
First law of thermodynamics, Enthalpy	3	.	.	.	<1%	0%	3%
Heat and energy, changes of state; Thermal expansion; Kinetic-molecular theory, Heat capacity and latent heat	8	.	.	.	6%	0%	17%
Heat and temperature	9	.	.	.	6%	0%	19%
Thermodynamics / Thermal equilibrium [conduction, convection, radiation];	6	.	.	.	3%	0%	7%
Second law of thermodynamics, Entropy	0	.	.	.	n/a	n/a	n/a
Fluid Mechanics	**5**	**0.5**	0	2	**1%**	**0%**	**4%**
Air / fluid behavior	4	.	.	.	<1%	0%	3%
Types of forces (Fluid Mechanics)	1	.	.	.	<1%	0%	1%
Pressure (Fluid Mechanics)	0	.	.	.	n/a	n/a	n/a
Forces	**20**	**2.0**	0	3	**7%**	**0%**	**13%**
Balanced and unbalanced forces, Buoyancy, Action/reaction	5	.	.	.	1%	0%	5%
Gravitational, Electromagnetic, Frictional, Centripetal, Nuclear	7	.	.	.	3%	0%	10%

PHYSICS CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Static equilibrium	1	.	.	.	<1%	0%	3%
Types of forces	6	.	.	.	2%	0%	5%
Types of forces (Forces)	1	.	.	.	<1%	0%	1%
Pressure (Forces)	0	.	.	.	n/a	n/a	n/a
Light and Optics	**21**	**2.1**	1	4	**9%**	**3%**	**15%**
Light	9	.	.	.	6%	0%	13%
Nature of light, Quantum theory of light, Intensity, Luminosity	4	.	.	.	<1%	0%	2%
Optics	1	.	.	.	<1%	0%	<1%
Reflection, Refraction, Diffraction, Interference	7	.	.	.	2%	0%	5%
Magnetic Phenomena	**10**	**1.0**	0	2	**5%**	**0%**	**12%**
Magnetic materials, Fields, Forces, Properties	6	.	.	.	3%	0%	8%
Magnetism (Magnetic Phenomena)	4	.	.	.	2%	0%	8%
Motion and Newton's Laws	**31**	**3.1**	2	5	**14%**	**6%**	**31%**
Dynamics of motion	9	.	.	.	4%	0%	12%
Frames of reference for motion	2	.	.	.	3%	0%	24%
Laws of motion, Momentum and collisions	6	.	.	.	2%	0%	5%
Measurement of time, space and mass	6	.	.	.	2%	0%	9%
Time, space and motion	3	.	.	.	<1%	0%	3%
Types of motion / Describing motion	5	.	.	.	2%	0%	7%
Quantum Theory	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Atomic spectra	0	.	.	.	n/a	n/a	n/a
Properties of quantum objects; Quantum numbers and orbital energies; Shapes of orbitals (VSEPR model)	0	.	.	.	n/a	n/a	n/a
Electromagnetic radiation and matter	0	.	.	.	n/a	n/a	n/a
Quantum theory & fundamental particles	0	.	.	.	n/a	n/a	n/a
Quantum nature of light, Photoelectric effect	0	.	.	.	n/a	n/a	n/a
Line spectra, Matter waves, Uncertainty principle	0	.	.	.	n/a	n/a	n/a
Relativity	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Relativity theory	0	.	.	.	n/a	n/a	n/a
Speed of light; Relativistic effects at speeds near the speed of light	0	.	.	.	n/a	n/a	n/a
Mass/energy/velocity relationship	0	.	.	.	n/a	n/a	n/a
Solids, Liquids, Gases (Kinetic-Molecular Theory)	**28**	**2.8**	1	4	**11%**	**5%**	**15%**
Changes in states of matter [gases, liquids, solids], Gas laws, Phase changes and phase diagrams	4	.	.	.	1%	0%	6%
Explanations of physical changes	9	.	.	.	4%	0%	11%
Inter-particle forces, Dispersion and flocculation of colloids	1	.	.	.	<1%	0%	1%
Kinetic-molecular theory	0	.	.	.	n/a	n/a	n/a
Physical changes	6	.	.	.	2%	0%	12%

PHYSICS CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
PHYSICAL TRANSFORMATIONS	0	.	.	.	n/a	n/a	n/a
States of matter -- gases, liquids, solids	8	.	.	.	3%	0%	7%
Wave Phenomena	**10**	**1.0**	0	2	**7%**	**0%**	**15%**
Sound & vibration / including standing waves in strings and pipes, Doppler effect	6	.	.	.	6%	0%	13%
Wave phenomena	4	.	.	.	<1%	0%	3%
Work, Energy, Power	**17**	**1.7**	0	2	**14%**	**0%**	**35%**
Energy types / Conversions / Sources	9	.	.	.	9%	0%	27%
Work energy and power, efficiency; Simple machines	8	.	.	.	5%	0%	15%
No Code- Rolled Energy types, conversions, sources into 13312	0	.	.	.	n/a	n/a	n/a
Grand Total	**208**	**20.8**	12	33			

PHYSICS CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Atomic Structure	**35**	**3.5**	2	6	**9%**	**4%**	**14%**
Atoms, ions, molecules	10	.	.	.	4%	<1%	9%
Electrons, protons, neutrons	3	.	.	.	<1%	0%	<1%
Isotopes	2	.	.	.	<1%	0%	1%
Nuclear chemistry	5	.	.	.	2%	0%	7%
Oxidation state / Elementary atomic theory	6	.	.	.	<1%	0%	3%
STRUCTURE OF MATTER	4	.	.	.	<1%	0%	2%
Subatomic particles	5	.	.	.	<1%	0%	3%
Electrical Phenomena	**29**	**2.9**	2	3	**13%**	**5%**	**32%**
AC/DC circuits, Capacitors, Resistors, Electronics, Semi-conductors, Transformers, Motors, Ohm's Law	10	.	.	.	5%	1%	15%
Electric charge, Coulomb's law, Conductors, Insulators, Static electricity, Electrical fields, Alternating/direct current	9	.	.	.	3%	0%	9%
Electricity (Electrical Phenomena)	10	.	.	.	5%	2%	14%
Electromagnetism	**20**	**2.0**	1	3	**7%**	**2%**	**14%**
Induction, Charges in electric and magnetic fields, Electromagnetism	5	.	.	.	1%	0%	5%
Electricity (Electromagnetism)	10	.	.	.	5%	2%	14%
Magnetism (Electromagnetism)	5	.	.	.	<1%	0%	2%
Energy and Physical/Chemical Change	**45**	**4.5**	2	7	**14%**	**5%**	**20%**
Calorimetry, Exothermic and endothermic reactions	1	.	.	.	<1%	0%	1%
CHEMICAL TRANSFORMATIONS	1	.	.	.	<1%	0%	3%
ENERGY & PHYSICAL PROCESSES	2	.	.	.	1%	0%	6%
Energy and chemical change (activation energy)	3	.	.	.	<1%	0%	2%
First law of thermodynamics, Enthalpy	7	.	.	.	1%	0%	4%
Heat and energy, changes of state; Thermal expansion; Kinetic-molecular theory, Heat capacity and latent heat	10	.	.	.	4%	1%	6%
Heat and temperature	9	.	.	.	3%	0%	6%
Second law of thermodynamics, Entropy	3	.	.	.	<1%	0%	<1%
Thermodynamics / Thermal equilibrium [conduction, convection, radiation];	9	.	.	.	3%	0%	9%
Fluid Mechanics	**13**	**1.3**	0	2	**3%**	**0%**	**8%**
Air / fluid behavior	8				2%	0%	5%
Pressure (Fluid Mechanics)	5				1%	0%	4%
Types of forces (Fluid Mechanics)	0				n/a	n/a	n/a
Forces	**25**	**2.5**	0	5	**6%**	**0%**	**12%**
Balanced and unbalanced forces, Buoyancy, Action/reaction	8	.	.	.	2%	0%	4%
Gravitational, Electromagnetic, Frictional, Centripetal, Nuclear	7	.	.	.	2%	0%	7%
Static equilibrium	1	.	.	.	<1%	0%	<1%

PHYSICS CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Types of forces	4	.	.	.	1%	0%	5%
Pressure (Forces)	5	.	.	.	1%	0%	4%
Types of forces (Forces)	0	.	.	.	n/a	n/a	n/a
Light and Optics	**33**	**3.3**	2	4	**12%**	**7%**	**23%**
Light	7	.	.	.	3%	0%	8%
Nature of light, Quantum theory of light, Intensity, Luminosity	7	.	.	.	2%	0%	6%
Optics	10	.	.	.	3%	<1%	10%
Reflection, Refraction, Diffraction, Interference	9	.	.	.	4%	0%	11%
Magnetic Phenomena	**10**	**1.0**	0	2	**2%**	**0%**	**3%**
Magnetic materials, Fields, Forces, Properties	5	.	.	.	<1%	0%	3%
Magnetism (Magnetic Phenomena)	5	.	.	.	<1%	0%	2%
Motion and Newton's Laws	**29**	**2.9**	0	6	**9%**	**0%**	**22%**
Dynamics of motion	8	.	.	.	2%	0%	7%
Frames of reference for motion	2	.	.	.	<1%	0%	1%
Laws of motion, Momentum and collisions	5	.	.	.	2%	0%	5%
Measurement of time, space and mass	3	.	.	.	2%	0%	7%
Time, space and motion	3	.	.	.	1%	0%	6%
Types of motion / Describing motion	8	.	.	.	2%	0%	7%
Quantum Theory	**6**	**0.6**	0	3	**2%**	**0%**	**14%**
Atomic spectra	0	.	.	.	n/a	n/a	n/a
Electromagnetic radiation and matter	2	.	.	.	1%	0%	14%
Line spectra, Matter waves, Uncertainty principle	0	.	.	.	n/a	n/a	n/a
Properties of quantum objects; Quantum numbers and orbital energies; Shapes of orbitals (VSEPR model)	0	.	.	.	n/a	n/a	n/a
Quantum nature of light, Photoelectric effect	2	.	.	.	<1%	0%	<1%
Quantum theory & fundamental particles	2	.	.	.	<1%	0%	<1%
Relativity	**1**	**0.1**	0	1	**<1%**	**0%**	**<1%**
Speed of light; Relativistic effects at speeds near the speed of light	1	.	.	.	<1%	0%	<1%
Mass/energy/velocity relationship	0	.	.	.	n/a	n/a	n/a
Relativity theory	0	.	.	.	n/a	n/a	n/a
Solids, Liquids, Gases (Kinetic-Molecular Theory)	**34**	**3.4**	1	6	**5%**	**<1%**	**12%**
Changes in states of matter [gases, liquids, solids], Gas laws, Phase changes and phase diagrams	5	.	.	.	<1%	0%	3%
Explanations of physical changes	9	.	.	.	2%	0%	6%
Inter-particle forces, Dispersion and flocculation of colloids	1	.	.	.	<1%	0%	<1%
Kinetic-molecular theory	6	.	.	.	<1%	0%	2%
Physical changes	4	.	.	.	<1%	0%	3%

PHYSICS CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
PHYSICAL TRANSFORMATIONS	2	.	.	.	<1%	0%	3%
States of matter -- gases, liquids, solids	7	.	.	.	<1%	0%	3%
Wave Phenomena	**15**	**1.5**	0	2	**6%**	**0%**	**12%**
Sound & vibration / including standing waves in strings and pipes, Doppler effect	8	.	.	.	3%	0%	7%
Wave phenomena	7	.	.	.	3%	0%	11%
Work, Energy, Power	**19**	**1.9**	1	2	**12%**	**4%**	**18%**
Energy types / Conversions / Sources	10	.	.	.	7%	2%	12%
Work energy and power, efficiency; Simple machines	9	.	.	.	5%	0%	12%
No Code- Rolled Energy types, conversions, sources into 13312	0	.	.	.	n/a	n/a	n/a
Grand Total	**314**	**31.4**	23	52			

PHYSICS CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Atomic Structure	**34**	**4.3**	0	6	**6%**	**0%**	**13%**
Atoms, ions, molecules	5	.	.	.	<1%	0%	3%
Electrons, protons, neutrons	7	.	.	.	1%	0%	3%
Isotopes	5	.	.	.	<1%	0%	2%
Nuclear chemistry	6	.	.	.	2%	0%	5%
Oxidation state / Elementary atomic theory	5	.	.	.	<1%	0%	2%
STRUCTURE OF MATTER	0	.	.	.	n/a	n/a	n/a
Subatomic particles	6	.	.	.	1%	0%	3%
Biology-related Physics	**4**	**0.5**	0	2	**<1%**	**0%**	**<1%**
Disease and health	1	.	.	.	<1%	0%	<1%
Organs	1	.	.	.	<1%	0%	<1%
Types and causes of disease, Remedies	2	.	.	.	<1%	0%	<1%
Chemistry-related Physics	**16**	**2.0**	0	7	**1%**	**0%**	**3%**
Acids, Bases, Salts; pH scale	1	.	.	.	<1%	0%	<1%
Chemical reactivity	1	.	.	.	<1%	0%	<1%
Dynamic equilibrium / Factors affecting solubility	1	.	.	.	<1%	0%	<1%
Electrochemistry	2	.	.	.	<1%	0%	<1%
Homogeneous and heterogeneous materials, Elements, Compounds, Mixtures	1	.	.	.	<1%	0%	<1%
Ionization energy, Electron affinity, Electronegativity	1	.	.	.	<1%	0%	<1%
MATTER	0	.	.	.	n/a	n/a	n/a
Periodicity, Metals and nonmetals	1	.	.	.	<1%	0%	<1%
Physical properties	4	.	.	.	<1%	0%	2%
Solutions, Suspensions, Colloids	1	.	.	.	<1%	0%	<1%
Weight, Mass, Volume, Density, Hardness, Malleability, Elasticity, Shape, Color	3	.	.	.	<1%	0%	<1%
Earth/Space Science-related Physics	**17**	**2.1**	0	5	**1%**	**0%**	**4%**
Beyond the solar system	2	.	.	.	<1%	0%	1%
Building & breaking	2	.	.	.	<1%	0%	<1%
Earth, sun, moon in the solar system	1	.	.	.	<1%	0%	<1%
Earth's history	1	.	.	.	<1%	0%	<1%
Evolution of the universe	2	.	.	.	<1%	0%	1%
Motion and location of celestial bodies	4	.	.	.	<1%	0%	<1%
Planets in the solar system	4	.	.	.	<1%	0%	<1%
Weather & climate	1	.	.	.	<1%	0%	<1%
Electrical Phenomena	**20**	**2.5**	0	3	**10%**	**0%**	**17%**
AC/DC circuits, Capacitors, Resistors, Electronics, Semi-conductors, Transformers, Motors, Ohm's Law	7	.	.	.	4%	0%	7%
Electric charge, Coulomb's law, Conductors, Insulators, Static electricity, Electrical fields, Alternating/direct current	7	.	.	.	4%	0%	6%
Electricity (Electrical Phenomena)	6	.	.	.	2%	0%	5%
Electromagnetism	**16**	**2.0**	0	3	**5%**	**0%**	**12%**
Induction, Charges in electric and magnetic fields, Electromagnetism	5	.	.	.	2%	0%	5%
Electricity (Electromagnetism)	6	.	.	.	2%	0%	5%

PHYSICS CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Magnetism (Electromagnetism)	5	.	.	.	1%	0%	5%
Energy and Physical/Chemical Change	**34**	**4.3**	0	7	**8%**	**0%**	**15%**
Calorimetry, Exothermic and endothermic reactions	1	.	.	.	<1%	0%	2%
CHEMICAL TRANSFORMATIONS	0	.	.	.	n/a	n/a	n/a
ENERGY & PHYSICAL PROCESSES	0	.	.	.	n/a	n/a	n/a
Energy and chemical change (activation energy)	3	.	.	.	<1%	0%	1%
First law of thermodynamics, Enthalpy	6	.	.	.	<1%	0%	3%
Heat and energy, changes of state; Thermal expansion; Kinetic-molecular theory, Heat capacity and latent heat	7	.	.	.	2%	0%	4%
Heat and temperature	6	.	.	.	2%	0%	4%
Second law of thermodynamics, Entropy	4	.	.	.	<1%	0%	2%
Thermodynamics / Thermal equilibrium [conduction, convection, radiation];	7	.	.	.	2%	0%	3%
Fluid Mechanics	**11**	**1.4**	0	2	**1%**	**0%**	**4%**
Air / fluid behavior	6	.	.	.	<1%	0%	2%
Types of forces (Fluid Mechanics)	0	.	.	.	n/a	n/a	n/a
Pressure (Fluid Mechanics)	5	.	.	.	<1%	0%	2%
Forces	**32**	**4.0**	2	5	**7%**	**2%**	**13%**
Balanced and unbalanced forces, Buoyancy, Action/reaction	8	.	.	.	1%	<1%	3%
Gravitational, Electromagnetic, Frictional, Centripetal, Nuclear	8	.	.	.	3%	2%	6%
Static equilibrium	5	.	.	.	<1%	0%	2%
Types of forces	6	.	.	.	1%	0%	6%
Types of forces (Forces)	0	.	.	.	n/a	n/a	n/a
Pressure (Forces)	5	.	.	.	<1%	0%	2%
Interactions of Science, Technology, Math and Society	**33**	**4.1**	1	7	**10%**	**<1%**	**23%**
HISTORY OF SCIENCE & TECHNOLOGY	5	.	.	.	<1%	0%	2%
Influence of science, technology on society	6	.	.	.	<1%	0%	3%
Influence of society on science, technology	3	.	.	.	<1%	0%	2%
Interactions of Science, Mathematics, & Technology	5	.	.	.	1%	0%	6%
Interactions of Science, Technology and Society	3	.	.	.	<1%	0%	2%
Mathematics, technology influence on science	3	.	.	.	1%	0%	10%
Science applications in mathematics, technology	8	.	.	.	5%	<1%	11%
Light and Optics	**25**	**3.1**	1	4	**5%**	**1%**	**11%**
Light	7	.	.	.	2%	0%	4%
Nature of light, Quantum theory of light, Intensity, Luminosity	6	.	.	.	<1%	0%	2%
Optics	6	.	.	.	<1%	0%	2%
Reflection, Refraction, Diffraction, Interference	6	.	.	.	1%	0%	4%
Magnetic Phenomena	**10**	**1.3**	0	2	**3%**	**0%**	**7%**

PHYSICS CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Magnetic materials, Fields, Forces, Properties	5	.	.	.	2%	0%	5%
Magnetism (Magnetic Phenomena)	5	.	.	.	1%	0%	5%
Motion and Newton's Laws	**34**	**4.3**	2	6	**16%**	**11%**	**32%**
Dynamics of motion	5	.	.	.	1%	0%	4%
Frames of reference for motion	2	.	.	.	<1%	0%	1%
Laws of motion, Momentum and collisions	8	.	.	.	5%	2%	10%
Measurement of time, space and mass	6	.	.	.	2%	0%	9%
Time, space and motion	5	.	.	.	2%	0%	9%
Types of motion / Describing motion	8	.	.	.	5%	3%	9%
Nature of Science	**9**	**1.1**	0	2	**4%**	**0%**	**18%**
NATURE OF SCIENCE	1	.	.	.	<1%	0%	<1%
Nature of Scientific Knowledge	6	.	.	.	3%	0%	11%
The Scientific Enterprise	2	.	.	.	1%	0%	8%
Nature of Technology/Engineering	**3**	**0.4**	0	1	**<1%**	**0%**	**<1%**
Nature or Conceptions of Technology (identifying needs and opportunities, generating a design, planning and making, evaluating)	3	.	.	.	<1%	0%	<1%
Quantum Theory	**28**	**3.5**	1	6	**5%**	**<1%**	**11%**
Atomic spectra	3	.	.	.	<1%	0%	<1%
Electromagnetic radiation and matter	7	.	.	.	2%	0%	6%
Line spectra, Matter waves, Uncertainty principle	5	.	.	.	<1%	0%	3%
Properties of quantum objects; Quantum numbers and orbital energies; Shapes of orbitals (VSEPR model)	4	.	.	.	<1%	0%	1%
Quantum nature of light, Photoelectric effect	4	.	.	.	<1%	0%	5%
Quantum theory & fundamental particles	5	.	.	.	<1%	0%	2%
Relativity	**7**	**0.9**	0	2	**<1%**	**0%**	**4%**
Mass/energy/velocity relationship	2	.	.	.	<1%	0%	<1%
Relativity theory	4	.	.	.	<1%	0%	2%
Speed of light; Relativistic effects at speeds near the speed of light	1	.	.	.	<1%	0%	2%
Solids, Liquids, Gases (Kinetic-Molecular Theory)	**20**	**2.5**	0	4	**3%**	**0%**	**13%**
Changes in states of matter [gases, liquids, solids], Gas laws, Phase changes and phase diagrams	6	.	.	.	<1%	0%	2%
Explanations of physical changes	2	.	.	.	<1%	0%	<1%
Inter-particle forces, Dispersion and flocculation of colloids	0	.	.	.	n/a	n/a	n/a
Kinetic-molecular theory	3	.	.	.	1%	0%	8%
Physical changes	3	.	.	.	<1%	0%	2%
PHYSICAL TRANSFORMATIONS	0	.	.	.	n/a	n/a	n/a
States of matter -- gases, liquids, solids	6	.	.	.	<1%	0%	2%
Sustainability	**15**	**1.9**	0	4	**1%**	**0%**	**2%**
Effects of Natural Disasters	1	.	.	.	<1%	0%	<1%
Food Production, Storage	0	.	.	.	n/a	n/a	n/a
General Sustainability standards	3	.	.	.	<1%	0%	<1%

PHYSICS CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Land, Water, Sea Resource Conservation	2	.	.	.	<1%	0%	<1%
Material & Energy Resource Conservation	5	.	.	.	<1%	0%	1%
Pollution - Causes and Treatment	4	.	.	.	<1%	0%	2%
World Population	0	.	.	.	n/a	n/a	n/a
Wave Phenomena	**15**	**1.9**	1	2	**7%**	**2%**	**18%**
Sound & vibration / including standing waves in strings and pipes, Doppler effect	8	.	.	.	3%	<1%	8%
Wave phenomena	7	.	.	.	4%	0%	10%
Work, Energy, Power	**14**	**1.8**	0	2	**5%**	**0%**	**11%**
Energy types / Conversions / Sources	7	.	.	.	3%	0%	6%
Work energy and power, efficiency; Simple machines	7	.	.	.	2%	0%	5%
No Code- Rolled Energy types, conversions, sources into 13312	0	.	.	.	n/a	n/a	n/a
Grand Total	**397**	**49.6**	28	70			

Appendix 3.4: Earth Sciences

EARTH SPACE SCIENCE Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Biogeochemical Cycles	**7**	**0.7**	0	2	**9%**	**0%**	**50%**
Water Cycle	5	.	.	.	9%	0%	50%
Chemical cycles (nitrogen, carbon, carbon dioxide, oxygen, etc.)	2	.	.	.	<1%	0%	4%
Physical cycles	0	.	.	.	n/a	n/a	n/a
Earth's Features and Materials	**18**	**1.8**	0	4	**17%**	**0%**	**48%**
Bodies of water	6	.	.	.	3%	0%	12%
Earth's composition	4	.	.	.	3%	0%	24%
Landforms	3	.	.	.	4%	0%	36%
Rocks, soil	5	.	.	.	7%	0%	25%
Ice forms	0	.	.	.	n/a	n/a	n/a
Geological Time	**6**	**0.4**	0	1	**1%**	**0%**	**5%**
Earth's history	6	.	.	.	1%	0%	5%
Solid Earth Processes	**6**	**0.6**	0	2	**6%**	**0%**	**25%**
Building & breaking	4	.	.	.	5%	0%	25%
Rock Cycle	2	.	.	.	<1%	0%	5%
The Solar System	**14**	**1.4**	1	2	**34%**	**12%**	**71%**
Earth, sun, moon in the solar system	10	.	.	.	32%	12%	71%
Planets in the solar system	4	.	.	.	2%	0%	8%
The Universe	**10**	**1.0**	0	2	**6%**	**0%**	**18%**
Beyond the solar system	5	.	.	.	2%	0%	6%
Evolution of the universe	0	.	.	.	n/a	n/a	n/a
Motion and location of celestial bodies	5	.	.	.	4%	0%	12%
Weather & Climate	**15**	**1.5**	0	2	**27%**	**0%**	**40%**
Atmosphere	7	.	.	.	8%	0%	25%
Weather & climate	8	.	.	.	19%	0%	36%
Grand Total	**76**	**7.4**	3	13			

EARTH SPACE SCIENCE Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Biogeochemical Cycles	**7**	**0.8**	**0**	**1**	**7%**	**0%**	**33%**
Water Cycle	2	.	.	.	1%	0%	7%
Chemical cycles (nitrogen, carbon, carbon dioxide, oxygen, etc.)	5	.	.	.	6%	0%	33%
Physical cycles	0	.	.	.	n/a	n/a	n/a
Earth's Features and Materials	**30**	**3.3**	**1**	**5**	**24%**	**11%**	**41%**
Bodies of water	8	.	.	.	10%	0%	33%
Earth's composition	6	.	.	.	5%	0%	11%
Ice forms	4	.	.	.	<1%	0%	2%
Landforms	6	.	.	.	4%	0%	13%
Rocks, soil	6	.	.	.	5%	0%	11%
Geological Time	**7**	**0.8**	**0**	**1**	**10%**	**0%**	**33%**
Earth's history	7	.	.	.	10%	0%	33%
Solid Earth Processes	**10**	**1.1**	**0**	**2**	**9%**	**0%**	**17%**
Building & breaking	7	.	.	.	8%	0%	15%
Rock Cycle	3	.	.	.	2%	0%	8%
The Solar System	**14**	**1.6**	**0**	**2**	**12%**	**0%**	**24%**
Earth, sun, moon in the solar system	8	.	.	.	8%	0%	15%
Planets in the solar system	6	.	.	.	4%	0%	9%
The Universe	**16**	**1.8**	**0**	**3**	**10%**	**0%**	**28%**
Beyond the solar system	7	.	.	.	4%	0%	15%
Evolution of the universe	4	.	.	.	2%	0%	5%
Motion and location of celestial bodies	5	.	.	.	4%	0%	11%
Weather & Climate	**17**	**1.9**	**1**	**2**	**27%**	**7%**	**44%**
Atmosphere	9	.	.	.	15%	4%	33%
Weather & climate	8	.	.	.	12%	0%	40%
Grand Total	**101**	**11.2**	**3**	**16**			

EARTH SPACE SCIENCE Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Biogeochemical Cycles	**4**	**1.3**	0	3	**1%**	**0%**	**2%**
Chemical cycles (nitrogen, carbon, carbon dioxide, oxygen, etc.)	1	.	.	.	<1%	0%	<1%
Physical cycles	1	.	.	.	<1%	0%	<1%
Water Cycle	2	.	.	.	<1%	0%	2%
Biology-related Earth/Space Science	**20**	**6.7**	3	9	**6%**	**4%**	**8%**
Biomes & ecosystems	2	.	.	.	1%	0%	2%
Competition among organisms, Mutual interactions: symbiosis, commensalism, parasitism	1	.	.	.	<1%	0%	<1%
Energy handling	1	.	.	.	<1%	0%	<1%
Energy handling, biochemistry of systems	1	.	.	.	<1%	0%	<1%
Evolution, speciation, diversity	1	.	.	.	<1%	0%	1%
Food webs/chains, Adaptations to various habitat conditions	2	.	.	.	<1%	0%	<1%
General Biodiversity standards	1	.	.	.	<1%	0%	<1%
Green plants, nonvascular and vascular	1	.	.	.	<1%	0%	<1%
Habitats & niches	1	.	.	.	<1%	0%	1%
Interdependence of life	1	.	.	.	<1%	0%	2%
Life cycles	1	.	.	.	<1%	0%	<1%
Mechanisms of evolution: Darwinism, Lamarckism; Implication of the theory of evolution Evidence for evolution, effects of evolution, processes of evolution	2	.	.	.	<1%	0%	1%
Needs of living things	3	.	.	.	1%	<1%	2%
Other organisms	1	.	.	.	<1%	0%	<1%
Variation as a natural phenomenon, Importance of diversity	1	.	.	.	<1%	0%	<1%
Chemistry-related Earth/Space Science	**15**	**5.0**	0	8	**3%**	**0%**	**5%**
Acids, Bases, Salts; pH scale	2	.	.	.	<1%	0%	1%
Chemical changes	1	.	.	.	<1%	0%	<1%
Chemical properties	1	.	.	.	<1%	0%	1%
Chemical reactivity	2	.	.	.	<1%	0%	<1%
Classification of matter	1	.	.	.	<1%	0%	<1%
Macromolecules, crystals, amorphous	1	.	.	.	<1%	0%	<1%
Mixing, Solutions, Colligative properties	1	.	.	.	<1%	0%	<1%
Organic & biochemical changes	1	.	.	.	<1%	0%	<1%
Periodic table	1	.	.	.	<1%	0%	<1%
Periodicity, Metals and nonmetals	1	.	.	.	<1%	0%	<1%
Physical properties	1	.	.	.	<1%	0%	1%
Weight, Mass, Volume, Density, Hardness, Malleability, Elasticity, Shape, Color	2	.	.	.	<1%	0%	1%
Earth's Features and Materials	**14**	**4.7**	4	5	**20%**	**19%**	**20%**
Bodies of water	3	.	.	.	5%	2%	7%
Earth's composition	3	.	.	.	5%	4%	6%
Ice forms	2	.	.	.	<1%	0%	2%
Landforms	3	.	.	.	5%	3%	6%
Rocks, soil	3	.	.	.	4%	3%	6%
Geological Time	**3**	**1.0**	1	1	**4%**	**4%**	**5%**

EARTH SPACE SCIENCE Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Earth's history	3	.	.	.	4%	4%	5%
Interactions of Science, Technology, Math and Society	**9**	**3.0**	1	5	**3%**	**1%**	**4%**
HISTORY OF SCIENCE & TECHNOLOGY	2	.	.	.	<1%	0%	1%
Influence of science, technology on society	2	.	.	.	<1%	0%	<1%
Influence of society on science, technology	1	.	.	.	<1%	0%	<1%
Interactions of Science, Mathematics, & Technology	0	.	.	.	n/a	n/a	n/a
Interactions of Science, Technology and Society	0	.	.	.	n/a	n/a	n/a
Mathematics, technology influence on science	1	.	.	.	<1%	0%	<1%
Science applications in mathematics, technology	3	.	.	.	1%	1%	1%
Nature of Science	**4**	**1.3**	1	2	**3%**	**<1%**	**6%**
NATURE OF SCIENCE	0	.	.	.	n/a	n/a	n/a
Nature of Scientific Knowledge	3	.	.	.	3%	<1%	6%
The Scientific Enterprise	1	.	.	.	<1%	0%	1%
Nature of Technology/Engineering	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Nature or Conceptions of Technology (identifying needs and opportunities, generating a design, planning and making, evaluating)	0	.	.	.	n/a	n/a	n/a
Physics-related Earth/Space Science	**36**	**12.0**	8	16	**19%**	**15%**	**25%**
Air / fluid behavior	2	.	.	.	<1%	0%	2%
Balanced and unbalanced forces, Buoyancy, Action/reaction	1	.	.	.	<1%	0%	1%
Electric charge, Coulomb's law, Conductors, Insulators, Static electricity, Electrical fields, Alternating/direct current	1	.	.	.	<1%	0%	<1%
Energy types / Conversions / Sources	3	.	.	.	3%	<1%	5%
Frames of reference for motion	1	.	.	.	<1%	0%	<1%
Gravitational, Electromagnetic, Frictional, Centripetal, Nuclear	3	.	.	.	1%	<1%	2%
Induction, Charges in electric and magnetic fields, Electromagnetism	1	.	.	.	<1%	0%	<1%
Laws of motion, Momentum and collisions	1	.	.	.	<1%	0%	2%
Light	1	.	.	.	<1%	0%	1%
Magnetic materials, Fields, Forces, Properties	2	.	.	.	1%	0%	2%
Measurement of time, space and mass	1	.	.	.	<1%	0%	3%
Nature of light, Quantum theory of light, Intensity, Luminosity	2	.	.	.	<1%	0%	1%
Optics	2	.	.	.	<1%	0%	1%
Reflection, Refraction, Diffraction, Interference	2	.	.	.	1%	0%	2%
Sound & vibration / including standing waves in strings and pipes, Doppler effect	1	.	.	.	1%	0%	3%
Time, space and motion	1	.	.	.	<1%	0%	1%
Types of forces	2	.	.	.	<1%	0%	2%

EARTH SPACE SCIENCE Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Types of motion / Describing motion	2	.	.	.	<1%	0%	2%
Wave phenomena	3	.	.	.	3%	2%	3%
Magnetism (Magnetic Phenomena)	1	.	.	.	<1%	0%	1%
Magnetism (Electromagnetism)	1	.	.	.	<1%	0%	1%
Types of forces (Fluid Mechanics)	0	.	.	.	n/a	n/a	n/a
Types of forces (Forces)	0	.	.	.	n/a	n/a	n/a
Pressure (Fluid Mechanics)	1	.	.	.	<1%	0%	2%
Pressure (Forces)	1	.	.	.	<1%	0%	2%
Solid Earth Processes	**5**	**1.7**	1	2	**8%**	**6%**	**11%**
Building & breaking	3	.	.	.	7%	5%	9%
Rock Cycle	2	.	.	.	1%	0%	2%
Sustainability	**13**	**4.3**	2	6	**5%**	**2%**	**9%**
Effects of Natural Disasters	3	.	.	.	2%	1%	2%
Food Production, Storage	1	.	.	.	<1%	0%	<1%
General Sustainability standards	0	.	.	.	n/a	n/a	n/a
Land, Water, Sea Resource Conservation	2	.	.	.	<1%	0%	2%
Material & Energy Resource Conservation	2	.	.	.	<1%	0%	1%
Pollution - Causes and Treatment	3	.	.	.	2%	1%	3%
World Population	2	.	.	.	<1%	0%	1%
The Solar System	**21**	**7.0**	7	7	**7%**	**6%**	**9%**
Earth, sun, moon in the solar system	3	.	.	.	5%	5%	5%
Planets in the solar system	3	.	.	.	3%	1%	5%
The Universe	**9**	**3.0**	3	3	**9%**	**6%**	**11%**
Beyond the solar system	3	.	.	.	3%	2%	5%
Evolution of the universe	3	.	.	.	2%	1%	2%
Motion and location of celestial bodies	3	.	.	.	4%	3%	5%
Weather & Climate	**6**	**2.0**	2	2	**12%**	**5%**	**16%**
Atmosphere	3	.	.	.	6%	3%	8%
Weather & climate	3	.	.	.	6%	2%	9%
Grand Total	**159**	**53.0**	35	67			

Appendix 3.5: Biology

BIOLOGY CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Biodiversity	**45**	**4.5**	3	6	**17%**	**8%**	**30%**
Animals (types)	10	.	.	.	5%	<1%	9%
Earth's history	4	.	.	.	<1%	0%	5%
Green plants, nonvascular and vascular	5	.	.	.	1%	0%	6%
Invertebrates	1	.	.	.	<1%	0%	4%
Other organisms	6	.	.	.	2%	0%	7%
Plants, fungi (types)	10	.	.	.	4%	1%	10%
Vertebrates	1	.	.	.	<1%	0%	2%
General Biodiversity standards	8	.	.	.	4%	0%	13%
Fungi	0	.	.	.	n/a	n/a	n/a
Cells: Structure & Function	**11**	**1.1**	0	3	**2%**	**0%**	**5%**
Biochemical processes in cells	4	.	.	.	<1%	0%	3%
Biological organisms are composed primarily of very few elements.	0	.	.	.	n/a	n/a	n/a
Cell structure and Basic function	2	.	.	.	<1%	0%	2%
Cells	1	.	.	.	<1%	0%	2%
Chemistry of cells (enzymes); Cell reproduction; Cell communication and regulation, Cell water relations	3	.	.	.	<1%	0%	2%
Types of cells / Diversity of cells	1	.	.	.	<1%	0%	2%
Evolution	**11**	**1.1**	0	3	**2%**	**0%**	**5%**
Adaptation	4	.	.	.	<1%	0%	2%
Evolution, speciation, diversity	1	.	.	.	<1%	0%	2%
Mechanisms of evolution: Darwinism, Lamarckism; Implication of the theory of evolution Evidence for evolution, effects of evolution, processes of evolution	1	.	.	.	<1%	0%	2%
Nature of species, Domestication	1	.	.	.	<1%	0%	3%
Variation as a natural phenomenon, Importance of diversity	4	.	.	.	<1%	0%	2%
Homeostasis	**38**	**3.8**	1	6	**13%**	**5%**	**21%**
Biofeedback in systems, Homeostasis, Sensory systems, Tropism, Responses to stimuli	2	.	.	.	<1%	0%	3%
Energy handling	8	.	.	.	2%	0%	4%
Energy handling, biochemistry of systems	4	.	.	.	<1%	0%	3%
Needs of living things	10	.	.	.	5%	<1%	12%
Sensing and responding	8	.	.	.	2%	0%	7%
General Homeostasis standards	6	.	.	.	2%	0%	6%
Human Biology: Health & Physiology	**36**	**3.6**	1	5	**21%**	**6%**	**33%**
Disease and health	7	.	.	.	3%	0%	11%
Nutrition	8	.	.	.	3%	0%	6%
Prevention of disease, Maintaining good health, Importance of exercise	7	.	.	.	4%	0%	9%
Types and causes of disease, Remedies	4	.	.	.	<1%	0%	4%
General Human Physiology and Nutrition standards	10	.	.	.	11%	6%	15%
Interaction and Interdependence in Living	**47**	**4.7**	3	7	**19%**	**11%**	**35%**

BIOLOGY CONTENT Primary (Grades 1-6)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Things							
Animal behavior	3	.	.	.	1%	0%	6%
Biomes & ecosystems	8	.	.	.	4%	0%	8%
Competition among organisms, Mutual interactions: symbiosis, commensalism, parasitism	5	.	.	.	<1%	0%	5%
Food webs/chains, Adaptations to various habitat conditions	7	.	.	.	3%	0%	12%
Habitats & niches	10	.	.	.	6%	3%	11%
Interdependence of life	6	.	.	.	2%	0%	6%
Migration of birds, fishes, butterflies, caribou	0	.	.	.	n/a	n/a	n/a
Rearing of young, Learned behavior	0	.	.	.	n/a	n/a	n/a
Territorialism; social groupings (beehive, herds), Mating behavior and selection	1	.	.	.	<1%	0%	1%
General Interaction and Independence standards	7	.	.	.	3%	0%	8%
Modern Genetics	**0**	**0.0**	0	0	**n/a**	**n/a**	**n/a**
Biochemistry of genetics (concept of the gene)	0	.	.	.	n/a	n/a	n/a
Population genetics, Biotechnology and Application of genetics	0	.	.	.	n/a	n/a	n/a
DNA, the hereditary substance; Structure of DNA; Replication mechanism DNA → DNA; Transformation of DNA replication mechanism DNA → RNA	0	.	.	.	n/a	n/a	n/a
Gene expression, Mutation, The Operon model in bacteria	0	.	.	.	n/a	n/a	n/a
Genetic engineering	0	.	.	.	n/a	n/a	n/a
Reproduction, Development & Heredity	**35**	**3.5**	2	5	**15%**	**6%**	**28%**
Cell division, Cell differentiation	1	.	.	.	<1%	0%	1%
Life cycles	9	.	.	.	2%	0%	5%
Meiosis, Mendelian/non-Mendelian genetics, Molecular genetics, Quantitative inheritance	1	.	.	.	<1%	0%	1%
Reproduction	6	.	.	.	3%	0%	10%
Reproduction, Dispersal, Succession / Life cycles of plants, insects, etc.	10	.	.	.	8%	3%	16%
Variation and inheritance	5	.	.	.	<1%	0%	2%
General Reproduction, Development & Heredity standards	3	.	.	.	<1%	0%	4%
Systems, Organs, and Tissues: Structure & Function	**40**	**4.0**	1	6	**12%**	**4%**	**25%**
Biochemistry of systems	5	.	.	.	2%	0%	6%
Systems	8	.	.	.	2%	0%	5%
Systems, organs, tissues	7	.	.	.	2%	0%	5%
The complementarity of structure and function	5	.	.	.	<1%	0%	3%
Organs	8	.	.	.	4%	0%	10%
Tissues	7	.	.	.	1%	0%	3%
LIFE SCIENCES	0	.	.	.	n/a	n/a	n/a
Grand Total	**263**	**26.3**	17	34			

BIOLOGY CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Biodiversity	**39**	**3.9**	1	8	**10%**	**2%**	**21%**
Animals (types)	5	.	.	.	1%	0%	4%
Earth's history	7	.	.	.	3%	0%	8%
Green plants, nonvascular and vascular	4	.	.	.	1%	0%	6%
Invertebrates	2	.	.	.	<1%	0%	<1%
Other organisms	6	.	.	.	<1%	0%	3%
Plants, fungi (types)	4	.	.	.	<1%	0%	4%
Vertebrates	3	.	.	.	<1%	0%	<1%
General Biodiversity standards	8	.	.	.	3%	0%	8%
Fungi	0	.	.	.	n/a	n/a	n/a
Cells: Structure & Function	**43**	**4.3**	2	6	**10%**	**3%**	**23%**
Biochemical processes in cells	7	.	.	.	2%	0%	6%
Biological organisms are composed primarily of very few elements.	1	.	.	.	<1%	0%	<1%
Cell structure and Basic function	9	.	.	.	2%	0%	5%
Cells	9	.	.	.	2%	0%	7%
Chemistry of cells (enzymes); Cell reproduction; Cell communication and regulation, Cell water relations	8	.	.	.	2%	0%	5%
Types of cells / Diversity of cells	9	.	.	.	2%	0%	7%
Evolution	**17**	**1.7**	0	4	**3%**	**0%**	**9%**
Adaptation	1	.	.	.	<1%	0%	<1%
Evolution, speciation, diversity	6	.	.	.	1%	0%	3%
Mechanisms of evolution: Darwinism, Lamarckism; Implication of the theory of evolution Evidence for evolution, effects of evolution, processes of evolution	5	.	.	.	<1%	0%	3%
Nature of species, Domestication	1	.	.	.	<1%	0%	<1%
Variation as a natural phenomenon, Importance of diversity	4	.	.	.	<1%	0%	4%
Homeostasis	**37**	**3.7**	1	5	**11%**	**2%**	**28%**
Biofeedback in systems, Homeostasis, Sensory systems, Tropism, Responses to stimuli	6	.	.	.	3%	0%	12%
Energy handling	9	.	.	.	5%	0%	13%
Energy handling, biochemistry of systems	5	.	.	.	<1%	0%	2%
Needs of living things	7	.	.	.	<1%	0%	3%
Sensing and responding	7	.	.	.	1%	0%	5%
General Homeostasis standards	3	.	.	.	<1%	0%	2%
Human Biology: Health & Physiology	**36**	**3.6**	2	5	**18%**	**7%**	**40%**
Disease and health	8	.	.	.	4%	0%	10%
Nutrition	6	.	.	.	2%	0%	8%
Prevention of disease, Maintaining good health, Importance of exercise	6	.	.	.	2%	0%	8%
Types and causes of disease, Remedies	6	.	.	.	3%	0%	16%
General Human Physiology and Nutrition standards	10	.	.	.	7%	4%	16%
Interaction and Interdependence in Living Things	**54**	**5.4**	4	7	**16%**	**4%**	**30%**
Animal behavior	3	.	.	.	<1%	0%	1%

BIOLOGY CONTENT Lower Secondary (Grades 7-10)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Biomes & ecosystems	8	.	.	.	4%	0%	16%
Competition among organisms, Mutual interactions: symbiosis, commensalism, parasitism	8	.	.	.	1%	0%	3%
Food webs/chains, Adaptations to various habitat conditions	10	.	.	.	3%	<1%	7%
Habitats & niches	10	.	.	.	4%	<1%	13%
Interdependence of life	9	.	.	.	2%	0%	3%
Migration of birds, fishes, butterflies, caribou	0	.	.	.	n/a	n/a	n/a
Rearing of young, Learned behavior	2	.	.	.	<1%	0%	3%
Territorialism; social groupings (beehive, herds), Mating behavior and selection	1	.	.	.	<1%	0%	<1%
General Interaction and Independence standards	3	.	.	.	2%	0%	11%
Modern Genetics	**19**	**1.9**	1	4	**3%**	**<1%**	**8%**
Biochemistry of genetics (concept of the gene)	6	.	.	.	<1%	0%	4%
DNA, the hereditary substance; Structure of DNA; Replication mechanism DNA → DNA; Transformation of DNA replication mechanism DNA → RNA	2	.	.	.	<1%	0%	2%
Gene expression, Mutation, The Operon model in bacteria	4	.	.	.	<1%	0%	3%
Genetic engineering	2	.	.	.	<1%	0%	2%
Population genetics, Biotechnology and Application of genetics	5	.	.	.	1%	0%	5%
Reproduction, Development & Heredity	**43**	**4.3**	2	7	**11%**	**4%**	**19%**
Cell division, Cell differentiation	7	.	.	.	1%	0%	7%
Life cycles	4	.	.	.	<1%	0%	2%
Meiosis, Mendelian/non-Mendelian genetics, Molecular genetics, Quantitative inheritance	6	.	.	.	1%	0%	3%
Reproduction	9	.	.	.	4%	0%	6%
Reproduction, Dispersal, Succession / Life cycles of plants, insects, etc.	8	.	.	.	3%	0%	5%
Variation and inheritance	7	.	.	.	1%	0%	5%
General Reproduction, Development & Heredity standards	2	.	.	.	<1%	0%	3%
Systems, Organs, and Tissues: Structure & Function	**42**	**4.2**	1	6	**18%**	**5%**	**33%**
Biochemistry of systems	9	.	.	.	4%	0%	10%
Systems	9	.	.	.	4%	0%	8%
Systems, organs, tissues	8	.	.	.	3%	0%	13%
The complementarity of structure and function	4	.	.	.	<1%	0%	5%
Organs	7	.	.	.	4%	0%	10%
Tissues	5	.	.	.	2%	0%	7%
LIFE SCIENCES	0	.	.	.	n/a	n/a	n/a
Grand Total	**330**	**33.0**	21	46			

BIOLOGY CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Biodiversity	**40**	**5.0**	3	9	**8%**	**2%**	**20%**
Animals (types)	6	.	.	.	<1%	0%	1%
Earth's history	3	.	.	.	<1%	0%	<1%
Fungi	3	.	.	.	<1%	0%	4%
General Biodiversity standards	3	.	.	.	<1%	0%	5%
Green plants, nonvascular and vascular	5	.	.	.	1%	0%	4%
Invertebrates	3	.	.	.	<1%	0%	4%
Other organisms	6	.	.	.	1%	0%	2%
Plants, fungi (types)	8	.	.	.	2%	<1%	7%
Vertebrates	3	.	.	.	<1%	0%	4%
Cells: Structure & Function	**34**	**4.3**	1	6	**16%**	**<1%**	**33%**
Biochemical processes in cells	7	.	.	.	6%	0%	18%
Biological organisms are composed primarily of very few elements.	2	.	.	.	<1%	0%	<1%
Cell structure and Basic function	7	.	.	.	3%	0%	7%
Cells	4	.	.	.	<1%	0%	2%
Chemistry of cells (enzymes); Cell reproduction; Cell communication and regulation, Cell water relations	8	.	.	.	5%	<1%	12%
Types of cells / Diversity of cells	6	.	.	.	1%	0%	3%
Chem/Physics-related Biology	**4**	**0.5**	0	2	**<1%**	**0%**	**<1%**
Energy types / Conversions / Sources	1	.	.	.	<1%	0%	<1%
First law of thermodynamics, Enthalpy	0	.	.	.	n/a	n/a	n/a
Heat and energy, changes of state; Thermal expansion; Kinetic-molecular theory, Heat capacity and latent heat	1	.	.	.	<1%	0%	<1%
Law of Conservation of Matter	0	.	.	.	n/a	n/a	n/a
Organic & biochemical changes	1	.	.	.	<1%	0%	<1%
Sound & vibration / including standing waves in strings and pipes, Doppler effect	1	.	.	.	<1%	0%	<1%
Earth/Space Science-related Biology	**8**	**1.0**	0	4	**<1%**	**0%**	**1%**
Atmosphere	0	.	.	.	n/a	n/a	n/a
Bodies of water	1	.	.	.	<1%	0%	<1%
Chemical cycles (nitrogen, carbon, carbon dioxide, oxygen, etc.)	3	.	.	.	<1%	0%	<1%
Earth, sun, moon in the solar system	2	.	.	.	<1%	0%	<1%
Water Cycle	0	.	.	.	n/a	n/a	n/a
Weather & climate	2	.	.	.	<1%	0%	<1%
Evolution	**25**	**3.1**	0	5	**4%**	**0%**	**10%**
Adaptation	5	.	.	.	<1%	0%	1%
Evolution, speciation, diversity	6	.	.	.	<1%	0%	2%
Mechanisms of evolution: Darwinism, Lamarckism; Implication of the theory of evolution Evidence for evolution, effects of evolution, processes of evolution	6	.	.	.	2%	0%	3%
Nature of species, Domestication	2	.	.	.	<1%	0%	<1%
Variation as a natural phenomenon, Importance of diversity	6	.	.	.	1%	0%	4%
Homeostasis	**26**	**3.3**	1	6	**10%**	**<1%**	**18%**

BIOLOGY CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	Topic Count	Avg	Min	Max	Avg	Min	Max
Biofeedback in systems, Homeostasis, Sensory systems, Tropism, Responses to stimuli	6	.	.	.	4%	0%	9%
Energy handling	6	.	.	.	3%	0%	8%
Energy handling, biochemistry of systems	2	.	.	.	<1%	0%	2%
General Homeostasis standards	2	.	.	.	<1%	0%	<1%
Needs of living things	6	.	.	.	1%	0%	4%
Sensing and responding	4	.	.	.	<1%	0%	3%
Human Biology: Health & Physiology	**28**	**3.5**	0	5	**7%**	**0%**	**17%**
Disease and health	6	.	.	.	1%	0%	4%
General Human Physiology and Nutrition standards	6	.	.	.	2%	0%	4%
Nutrition	4	.	.	.	<1%	0%	3%
Prevention of disease, Maintaining good health, Importance of exercise	6	.	.	.	1%	0%	2%
Types and causes of disease, Remedies	6	.	.	.	3%	0%	6%
Interaction and Interdependence in Living Things	**41**	**5.1**	1	10	**7%**	**1%**	**13%**
Animal behavior	2	.	.	.	<1%	0%	1%
Biomes & ecosystems	6	.	.	.	1%	0%	3%
Competition among organisms, Mutual interactions: symbiosis, commensalism, parasitism	6	.	.	.	1%	0%	2%
Food webs/chains, Adaptations to various habitat conditions	8	.	.	.	2%	<1%	4%
General Interaction and Independence standards	3	.	.	.	<1%	0%	<1%
Habitats & niches	5	.	.	.	<1%	0%	2%
Interdependence of life	7	.	.	.	1%	0%	3%
Territorialism; social groupings (beehive, herds), Mating behavior and selection	2	.	.	.	<1%	0%	<1%
Migration of birds, fishes, butterflies, caribou	1	.	.	.	<1%	0%	<1%
Rearing of young, Learned behavior	1	.	.	.	<1%	0%	<1%
Interactions of Science, Technology, Math and Society	**26**	**3.3**	0	5	**4%**	**0%**	**11%**
HISTORY OF SCIENCE & TECHNOLOGY	6	.	.	.	<1%	0%	2%
Influence of science, technology on society	6	.	.	.	1%	0%	2%
Influence of society on science, technology	4	.	.	.	<1%	0%	2%
Interactions of Science, Mathematics, & Technology	2	.	.	.	<1%	0%	<1%
Interactions of Science, Technology and Society	1	.	.	.	<1%	0%	<1%
Mathematics, technology influence on science	1	.	.	.	<1%	0%	<1%
Science applications in mathematics, technology	6	.	.	.	1%	0%	3%
Modern Genetics	**32**	**4.0**	1	5	**9%**	**3%**	**29%**
Biochemistry of genetics (concept of the gene)	5	.	.	.	1%	0%	4%
DNA, the hereditary substance; Structure of DNA; Replication mechanism DNA → DNA; Transformation of DNA replication mechanism DNA → RNA	8	.	.	.	2%	<1%	6%
Gene expression, Mutation, The Operon model in bacteria	7	.	.	.	2%	0%	4%
Genetic engineering	5	.	.	.	2%	0%	10%
Population genetics, Biotechnology and	7	.	.	.	2%	0%	6%

BIOLOGY CONTENT Upper Secondary (Courses)	INCLUSION (Topic "HITS" per Category)				EMPHASIS		
Categories and Topics	**Topic Count**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Application of genetics							
Nature of Science	**10**	**1.3**	0	2	**8%**	**0%**	**19%**
NATURE OF SCIENCE	0	.	.	.	n/a	n/a	n/a
Nature of Scientific Knowledge	6	.	.	.	6%	0%	15%
The Scientific Enterprise	4	.	.	.	2%	0%	8%
Nature of Technology/Engineering	**2**	**0.3**	0	1	**<1%**	**0%**	**1%**
Nature or Conceptions of Technology (identifying needs and opportunities, generating a design, planning and making, evaluating)	2	.	.	.	<1%	0%	1%
Reproduction, Development & Heredity	**41**	**5.1**	4	6	**13%**	**6%**	**26%**
Cell division, Cell differentiation	8	.	.	.	2%	<1%	4%
General Reproduction, Development & Heredity standards	2	.	.	.	<1%	0%	1%
Life cycles	1	.	.	.	<1%	0%	1%
Meiosis, Mendelian/non-Mendelian genetics, Molecular genetics, Quantitative inheritance	8	.	.	.	4%	<1%	10%
Reproduction	8	.	.	.	3%	1%	5%
Reproduction, Dispersal, Succession / Life cycles of plants, insects, etc.	8	.	.	.	3%	<1%	6%
Variation and inheritance	6	.	.	.	<1%	0%	2%
Sustainability	**27**	**3.4**	0	6	**4%**	**0%**	**9%**
Effects of Natural Disasters	1	.	.	.	<1%	0%	<1%
Food Production, Storage	5	.	.	.	<1%	0%	2%
General Sustainability standards	3	.	.	.	<1%	0%	2%
Land, Water, Sea Resource Conservation	5	.	.	.	<1%	0%	2%
Material & Energy Resource Conservation	4	.	.	.	<1%	0%	2%
Pollution - Causes and Treatment	5	.	.	.	<1%	0%	2%
World Population	4	.	.	.	<1%	0%	1%
Systems, Organs, and Tissues: Structure & Function	**31**	**3.9**	0	6	**11%**	**0%**	**28%**
Biochemistry of systems	6	.	.	.	2%	0%	5%
LIFE SCIENCES	1	.	.	.	<1%	0%	1%
Organs	6	.	.	.	3%	0%	8%
Systems	6	.	.	.	2%	0%	6%
Systems, organs, tissues	2	.	.	.	<1%	0%	2%
The complementarity of structure and function	4	.	.	.	<1%	0%	4%
Tissues	6	.	.	.	2%	0%	6%
Grand Total	**375**	**46.9**	26	72			

Appendix 4: Interdisciplinary Themes: Singapore - *Interaction*

Singapore presents standards for Primary through Lower Secondary based on themes meant to encompass a core body of life and physical science concepts. Four themes—Diversity, Systems, Energy, and Interaction are common to both the Primary and Lower Secondary levels. This appendix shows the approach taken by Singapore in implementing the Interaction theme across the Primary and Lower Secondary grade spans.

PRIMARY 3-4 & PRIMARY 5-6[10]

KNOWLEDGE, UNDERSTANDING AND APPLICATION

The approach in this revised syllabus towards the learning of science is based on themes that students can relate to in their everyday experiences, and to the commonly observed phenomena in nature. The aim is to enable students to appreciate the links between different themes/topics and thus allow the integration of scientific ideas. The five themes chosen are: ***Diversity, Cycles, Systems, Energy*** *and* ***Interactions***. These themes encompass a core body of concepts in both the life and physical sciences. This body of concepts has been chosen because it provides a broad based understanding of the environment, and it will help build a foundation upon which students can rely on for further study.

Although the content of the syllabus is organised into 5 themes, the topics under each theme are not to be viewed as compartmentalised blocks of knowledge. In general, there are no clear boundaries between these themes. There may be topics common to different themes. Hence, a conscious effort is needed to demonstrate the relationship between themes whenever possible. To help teachers and students appreciate and understand the themes, key inquiry questions[111] are included for each theme. These questions can guide teachers and engage students in uncovering the important ideas at the heart of each theme. They can also use these questions to raise more specific questions for the respective topics under each theme.

Another feature of the syllabus is the spiral approach. This is characterised by the revisiting of concepts and skills at different levels and with increasing depth. The spiral approach allows the learning of scientific concepts and skills to match students' cognitive development. It therefore helps students build upon their existing understanding of concepts and facilitates the gradual mastery of skills.

Interactions

Students should appreciate that a study of the interactions between and within systems helps Man to better understand the environment and his role in it. Interactions occur within an organism, between organisms as well as between organisms and the environment. There are also interactions between forces and objects. The interaction of Man with his environment drives the development of Science and Technology. At the same time, Science and Technology influences the way Man interacts with his environment. By understanding the interactions between Man and his environment, students can better appreciate the consequences of their actions and be responsible for their actions. In this theme, students learn about the *interaction of forces* and *interactions within the environment*. Key inquiry questions include:

• How does Man interact with his surroundings?

• What are the consequences of Man's interactions with his surroundings?

---

[10] Source: **Science Syllabus Primary 2008** © Copyright 2007 Curriculum Planning & Development Division. Ministry of Education, Singapore. Year of implementation: from 2008

[11] Reference: Wiggins, J. and McTighe, J. (1998). *Understanding by Design*. Alexandria, Va.: Association for Supervision and Curriculum Development.

Table 1: An Overview of the Primary Science Syllabus

Syllabus Requirement			White Space
Themes	*** Lower Block (Primary 3 and 4)**	****Upper Block (Primary 5 and 6)**	The freed up curriculum time is to enable teachers to use more engaging teaching and learning approaches, and/or to implement customised school-based programmes as long as the aims of the syllabus are met. This enables teachers to make learning more meaningful and enjoyable for their students.
Diversity	• Diversity of living and non-living things (General characteristics and classification) • Diversity of materials		
Cycles	• Cycles in plants and animals (Life cycles) • Cycles in matter and water (Matter)	• Cycles in plants and animals (Reproduction) • Cycles in matter and water (Water)	
Systems	• Plant system (Plant parts and functions) • Human system (Digestive system)	• Plant system (Respiratory and circulatory systems) • Human system (Respiratory and circulatory systems) • Cell system • Electrical system	
Interactions	• Interaction of forces (Magnets)	• Interaction of forces (Frictional force, gravitational force, force in springs) • Interaction within the environment	
Energy	• Energy forms and uses (Light and heat)	• Energy forms and uses (Photosynthesis) • Energy conversion	

Topics which are underlined are not required for students taking Foundation Science.

About Interactions:
Understanding the interactions between and within systems helps Man to better understand the environment and his role in it. Interactions occur within an organism, between organisms as well as between organisms and the environment. There are also interactions between forces and objects. The interaction of Man with his environment drives the development of Science and Technology. At the same time, Science and Technology influences the way Man interacts with his environment. By understanding the interactions between Man and his environment, students can better appreciate the consequences of their actions and be responsible for their actions. In this theme, we learn about the *interaction of forces* and *interactions in the environment.*

Note:
*** Lower Block**
**** Upper Block**

Suggested Key Inquiry Questions in Interactions include:

- *How does Man interact with his surroundings?*
- *What are the consequences of Man's interactions with his surroundings?*

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interactions of Forces		
• *Recognise that a magnet can exert a push or a pull. • *Identify the characteristics of magnets. - magnets can be made of iron or steel - magnets have two poles. A freely suspended bar magnet comes to rest pointing in a N-S direction - unlike poles attract and like poles repel - magnets attract magnetic materials • *List some uses of magnets in everyday objects.	• *Compare magnets and non-magnets. • *Make a magnet by the 'Stroke' method and the electrical method.	• *Show curiosity in exploring magnets and question what they find.

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interactions of Forces		
• **Identify a force as a push or a pull. • **Show an understanding of the effects of a force. - A force can move a stationary object - A force can speed up, slow down or change the direction of motion - A force can stop a moving object - A force may change the shape of an object • **Recognise and give examples of the different types of forces. - magnetic force - gravitational force - elastic spring force - frictional force • **Recognise that objects have weight because of the gravitational force between them and the Earth.	• **Investigate the effect of friction on the motion of objects and communicate findings. • **Investigate the effects of forces on springs and communicate findings.	• **Show objectivity by using data and information to validate observations and explanations about forces. • **Value individual effort and team work.

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interactions within the Environment		
- A population is defined as a group of plants and animals of the same kind, living and reproducing at a given place and time. - A community consists of many populations living together in a particular place. • **Show an understanding that different habitats support different communities. e.g. garden, field, pond, seashore, tree • **Recognise that adaptations serve to enhance survival and can be structural or behavioural. - cope with physical factors - obtain food - escape predators - reproduce by finding and attracting mates or dispersing seeds • **Give examples of man's impact (both positive and negative) on the environment. e.g. deforestation, global warming, pollution		

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interactions within the Environment		
• **Describe the characteristics of a local environment. e.g. temperature, amount of light • **Identify the factors that affect the survival of an organism. - physical characteristics of the environment - availability of food - types of other organisms present • **Discuss the effect on organisms when the environment becomes unfavourable. e.g. organisms adapt and survive; move to other places or die • **Trace the energy pathway from the Sun through living things and identify the roles of various organisms (producers, consumers, decomposers; predators, preys) in a food chain and a food web. • **Differentiate among the terms organism, population and community. - An organism is a living thing.	• **Observe, collect and record information regarding the interacting factors within an environment.	• **Show concern by being respectful and responsible towards the environment and the organisms living in it. • **Show concern for Man's impact on the environment. • **Value individual effort and team work.

About Interactions:
Understanding the interactions between and within systems helps Man to better understand the environment and his role in it. Interactions occur within an organism, between organisms as well as between organisms and the environment. There are also interactions between forces and objects. The interaction of Man with his environment drives the development of Science and Technology. At the same time, Science and Technology influences the way Man interacts with his environment. By understanding the interactions between Man and his environment, students can better appreciate the consequences of their actions and be responsible for their actions. In this theme, we learn about the *interaction of forces* and *interactions in the environment.*

Note:
**** Upper Block**

Suggested Key Inquiry Questions in Interactions include:

- *How does Man interact with his surroundings?*
- *What are the consequences of Man's interactions with his surroundings?*

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interaction of Forces		
• .**Identify a force as a push or a pull. • **State the effects of a force. - A force can move a stationary object - A force can speed up, slow down or change the direction of motion - A force can stop a moving object - A force may change the shape of an object • **Recognise and give examples of the different types of forces. - magnetic force - gravitational force - frictional force	• **Investigate the effect of friction on the motion of objects and communicate findings.	• **Show objectivity by using data and information to validate observations and explanations about forces. • **Value individual effort and team work.

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interaction of Forces		
• **Recognise that objects have weight because of the gravitational force between them and the Earth		

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interactions within the Environment		
• **Identify the following factors that affect the survival of an organism. - temperature and light - availability of food - types of other organisms present • **Trace the energy pathway from the Sun through living things and identify the roles of various organisms (producers, predators, preys) in a food chain. • **Recognise that different habitats support different organisms. e.g. garden, field, pond, seashore, tree • **Recognise that adaptations serve to enhance survival and can be structural or behavioural. - cope with physical factors - obtain food - escape predators - reproduce by finding and attracting mates or dispersing seeds • **Give examples of man's impact (both positive and negative) on the environment. e.g. deforestation, global warming, pollution	• **Observe, collect and record information regarding the interacting factors within an environment.	• **Show concern by being respectful and responsible towards the environment and the organisms living in it. • **Show concern for Man's impact on the environment. • **Value individual effort and team work.

Lower Secondary Express/Normal (Academic)[12]

Knowledge, Understanding and Application

The Lower Secondary Science Syllabus is structured in a similar way to the Primary Science Syllabus. The topics in the Physical and Life Sciences are organised into 6 main themes. They are: **Science & Technology; Measurement; Diversity; Models and Systems; Energy;** and **Interactions**. The latter four themes are similar to those found in Primary Science. The theme Models and Systems is an extension of a similar theme Systems in Primary Science. The concepts introduced in Primary Science under the similar themes are revisited and consolidated in Lower Secondary Science for further development in terms of knowledge, skills and processes. The Lower Secondary Science Syllabus uses the Scientific Inquiry approach to weave the knowledge, skills, and attitudes in science throughout the 6 themes. In addition, the applications and impact of science and technology are included wherever appropriate. To help teachers and students appreciate and understand the themes, some key inquiry

[12] Source: **Science Syllabus**
Lower Secondary
Express/Normal (Academic)

questions[113] are included for each theme. These questions can guide teachers and engage students in uncovering the important ideas at the heart of each theme. They can also use these questions to raise more specific questions for the respective topics under each theme.

Interactions

Students should appreciate that there are interactions between the living world and the environment at various levels: interactions which occur within an organism; between organisms; and between organisms and the environment. There are also interactions between forces and objects, and energy and matter. In this theme, we examine the interaction of forces and energy between and within living and non-living systems as well as with the environment. Examples of these interactions include transmission of heat, chemical changes, and energy flow through a food chain in an ecosystem. Key inquiry questions in Interactions include:

• How does knowledge of interactions between and within systems help Man better understand his environment?

• What are the interactions between physical phenomena and life processes?

Table 1: Overview of Lower Secondary Science Express/Normal (Academic) Syllabus

Designed for 85% of the curriculum time.[2]		White Space
Themes	**Topics**	The 15% freed up curriculum time is to enable teachers to use more engaging teaching and learning approaches, and/or to implement customised school-based programmes as long as the aims of the syllabus are met. This enables teachers to make learning more meaningful and enjoyable for their students.
Science & Technology	Science processes & applications • Scientific inquiry • Science and technology in society	
Measurement	Making measurements • Use of measuring instruments • Physical quantities & units	
Diversity	Diversity of matter • Classification of matter • Elements, compounds & mixtures • Solutions & suspensions Diversity of plant and animal life • Classification of plant and animal life	
Models & Systems	Models of cells & matter • Cells – structure, function & organisation • Particulate model of matter • Simple concepts of atoms & molecules Plant & human systems • Transport in living things • Digestion in animals • Sexual reproduction in human beings	

[13] Reference: Wiggins, J. and McTighe, J. (1998). *Understanding by Design*. Alexandria, Va.: Association for Supervision and Curriculum Development.

Designed for 85% of the curriculum time.[2]		White Space
Energy	Energy forms & uses - Energy forms & conversion - Light - Electricity - Photosynthesis & respiration	
Interaction	Interactions of forces & energy - Concept of force & pressure - Moment of a force - Work - Effects of heat - Transmission of heat - Chemical changes - Simple concepts of populations, community and ecosystem - Energy transfer process in the ecosystem - Nutrient cycles in the ecosystems	

Theme: Interactions Students should appreciate that there are interactions between the living world and the environment at various levels: interactions which occur within an organism; between organisms; and between organisms and the environment. There are also interactions between forces and objects, and energy and matter.	**Key Inquiry questions in Interactions include:** • How does knowledge of interactions between and within systems help Man better understand his environment? • What are the interactions between physical phenomena and life processes?

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**

Interaction of forces & energy -
Concept of force & pressure
• describe the effects of forces:
  • on the state of rest or motion of a body
  • on the size and shape of a body
• use the Newton as the S.I. unit of force
• identify some examples of forces, including gravitational force, frictional force and magnetic force, and predict their effects on an object
• relate pressure to force and area, using appropriate every day examples
	• use a spring balance as one of the ways to measure force
	• communicate their understanding of forces and justify their answers to questions on forces with reasons
		• show an appreciation of scientific attitudes such as curiosity, objectivity and perseverance in making careful observation and experimentation on force and its related concepts

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
Interaction of forces & energy – Moment of a force • state what is meant by moment of a force • calculate the moment of a force using the equation: moment of a force about a point = force x perpendicular distance from the pivot to the line of action of the force [Principle of moments NOT required] • describe the application of forces in levers • identify the application of moment of a force in everyday life	• solve problems related to moment of a force	• show an appreciation of scientific attitudes such as curiosity, objectivity and perseverance in making careful observation and experimentation on force and its related concepts
Interaction of forces & energy – Work • state what is meant by work done • calculate work done by a force using: work done = force x distance moved in the direction of the force [Restrict calculations to cases where the direction of the force is parallel to the direction of the distance moved.] • state the unit of work as the joule	• compare between situations involving forces where work is done and where work is not done	• show an appreciation of scientific attitudes such as curiosity, objectivity and perseverance in making careful observation and experimentation on force and its related concepts

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**

Interaction of forces & energy – Effects of heat
• describe some effects and applications of expansion and contraction in everyday life such as:
  • riveting
  • gaps in bridges, pavement and MRT lines
  • thermostats
	• infer that generally, solids, liquids and gases expand when heat is absorbed and contract when heat is given out
	• communicate their understanding of the effects of heat with every day examples
		• show an appreciation of scientific attitudes such as curiosity, objectivity and perseverance in making careful observation and experimentation on heat and its related concepts

Interaction of forces & energy – Transmission of heat • explain what is meant by conduction, convection and radiation • identify and explain applications of heat conduction and convection (e.g. in cooling, heating and insulation) • show an understanding that the rate of heat loss or gain through radiation is affected by the temperature and the nature of the surface • identify and explain applications of heat radiation (e.g. radiant heaters, solar radiation)	• infer that thermal expansion results in a change in volume of the substance and therefore the density of the substance • deduce from experiments that different materials have different rates of heat flow	• show an appreciation of scientific attitudes such as curiosity, objectivity and perseverance in making careful observation and experimentation on heat and its related concepts

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**

Interaction of forces & energy – Chemical changes
• describe a chemical reaction as a process leading to the formation of new products
• show an awareness that there are different types of reactions such as combustion, thermal decomposition, oxidation
• identify a change which leads to formation of new product(s) as a chemical change.
• use word equations to represent chemical reactions
	• Investigate the changes that matter (i.e. element, compound or mixture) undergoes through
	  • mixing
	  • heating
	  • exposure to light
	  • passing of an electric current
		• show an appreciation of the social issues of pollutants in the environment
		• show an appreciation of man's responsibility to have care and concern for the environment

Interaction of forces & energy - Simple concepts of populations, community and ecosystem • explain the terms 'population' and 'community' in a named ecosystem • identify a habitat and some of the organisms associated with the habitat • explain the importance of various physical factors like air, water, temperature, light, minerals and acidity/alkalinity, to the life of the organisms • show an understanding of the interrelationship among the various organisms in a community (Examples of interrelationships are predator-prey relationship, mutualism and parasitism)	• investigate an environment using measurement instruments such as datalogger probes to collect data on physical quantities such as pH, temperature and light intensity	• show an appreciation of the importance for man to understand and maintain the connections among living things • show an appreciation of man's responsibility to have care and concern for living things and the environment

Learning Outcomes		
Knowledge, Understanding and Application	**Skills and Processes**	**Ethics and Attitudes**
• show an understanding that habitat together with the organisms living in it forms an ecosystem • explain the importance of conserving the environment		
Interaction of forces & energy - Energy transfer process in the ecosystem • describe the process of energy flow through the food chain in a named ecosystem starting with the green plant as a primary food producer	• infer how food consumed by animals and the energy produced during respiration is temporarily stored for use in life processes	• show an appreciation of the importance for man to understand and maintain the connections among living things • show an appreciation of man's responsibility to have care and concern for living things and the environment
Interaction of forces & energy - Nutrient cycles in the ecosystem • show an understanding of the concept of recycling of nutrients trapped in living organisms and explain the role of decomposers in these processes	• infer the role of decomposers in recycling of nutrients in the environment	• show an appreciation of the importance for man to understand and maintain the connections among living things • show an appreciation of man's responsibility to have care and concern for living things and the environment

Appendix 5: Comparison of the Treatment of *ENERGY [Heat and Electricity]* in Primary, Lower Secondary and Upper Secondary

It is critical to link content and skills in standards documents. Countries differ in their approaches to these links depending on whether they use an interdisciplinary approach or a discipline-based approach. Thus, it is instructive to compare the development of a similar concept (heat and electrical energy) in each approach. If we trace the pathways that Singapore, Canada, and Finland follow in developing the concept of energy, we find Singapore and Canada situate energy in a web of interrelated ideas, whereas Finland presents energy more as an isolated topic, linked primarily to electricity.

SINGAPORE	ONTARIO, CANADA	FINLAND
STANDARDS DOCUMENTS: Primary: ▪ Science Syllabus Primary P3, P4, P5, & P6 (Standard) 2008 Lower Secondary: ▪ Lower Secondary Express/Normal (Academic) (2008) Upper Secondary: ▪ Biology Higher 1 (2010) ▪ Chemistry Higher 1 (2010) ▪ Physics Higher 1 (2010)	STANDARDS DOCUMENTS: Primary: ▪ The Ontario Curriculum - Grades 1-8 Science and Technology - 2007 Lower Secondary: ▪ The Ontario Curriculum - Science Grades 9 & 10 – 2008 Upper Secondary: The Ontario Curriculum - Grades 11 and 12 Science - 2008 ▪ Biology ▪ Chemistry ▪ Physics ▪ Earth and Space Science	STANDARDS DOCUMENTS: National Core Curriculum for Basic Education 2004 Primary: ▪ Environment and Natural Studies: 1-4 ▪ Biology and Geography: 5-6 ▪ Physics and Chemistry: 5-6 Lower Secondary: ▪ Biology ▪ Chemistry: 7-9 ▪ Geography: 7-9 Upper Secondary: ▪ Biology ▪ Chemistry ▪ Physics
Central to Singapore's curriculum framework is the inculcation of the spirit of scientific inquiry. The conduct of inquiry is founded on three integral domains, which frame the practice of science. (p.1.) Three domains: ***(a) Knowledge, Understanding and Application*** ***(b) Skills and Processes*** ***(c) Ethics and Attitudes*** *White Space* - The 15% freed up curriculum time is to enable teachers to use more engaging teaching and learning approaches, and/or to implement	Ontario Canada's Standards are based on six fundamental cross-cutting concepts: ▪ ***Matter*** ▪ ***Energy*** ▪ ***Systems and Interactions*** ▪ ***Structure and Function*** ▪ ***Sustainability and Stewardship*** ▪ ***Change and Continuity*** These are related to big ideas that describe aspects of the fundamental concepts that are addressed at each grade level.	Finland's standards are based on three broad areas in grades 1-6: ▪ ***Environment and Natural Studies: 1-4*** ▪ ***Biology and Geography: 5-6*** ▪ ***Physics and Chemistry: 5-6*** In grades 1-4, the content areas of Environmental and Natural Studies are: ▪ ***Matter and energy**** ▪ ***Organism and their environments*** ▪ ***The globe and its areas*** ▪ ***Man and the environment***

SINGAPORE	ONTARIO, CANADA	FINLAND
customized school-based programmes as long as the aims of the syllabus are met. This enables teachers to make learning more meaningful and enjoyable for their students The syllabi are based on five themes at the Primary grades and 6 themes in the Lower Secondary grades that students can relate to in their everyday experiences, and to the commonly observed phenomena in nature. The aim is to enable students to appreciate the links between different themes/topics and thus allow the integration of scientific ideas. The five Primary themes are: ▪ ***Diversity,*** ▪ ***Cycles,*** ▪ ***Systems,*** ▪ ***Energy and*** ▪ ***Interaction***. The six Lower Secondary themes are: ▪ ***Diversity,*** ▪ ***Energy,*** ▪ ***Interaction,*** ▪ ***Science & Technology,*** ▪ ***Measurement and*** ▪ ***Models & Systems.*** To help teachers and students appreciate and understand the themes, key inquiry questions are included for each theme. For example, in Energy students learn about various energy forms, uses and conversion. Key inquiry questions include: *How does energy affect Man and his surroundings? Why is it important to conserve energy?* Another feature of the syllabus is the spiral approach. This is characterized by the revisiting of concepts and skills at different levels and with increasing depth.	Ontario has three goals for its Science and technology program: 1) to relate science and technology to society and the environment; 2) to develop the skills, strategies and habits of mind required for scientific inquiry and technological problem solving; 3) to understand the basic concepts of science and technology. The goals lead to a set of overall expectations and related specific expectations for each grade 1-8. ***Energy****: Energy comes in many forms, and can change forms. It is required to make things happen (to do work). Work is done when a force causes movement.*	*Only the first area includes Physics, i.e., electricity, heat, light and sound. The content of standards in grades 5-6 are generally focused on traditional concepts in the disciplines. All the standards are organized around *Objectives*, *Core Contents*, and *Descriptions of Good Performances.*

SINGAPORE	ONTARIO, CANADA	FINLAND
PRIMARY	**PRIMARY**	**PRIMARY**
Lower Block (Primary 3 and 4) **Upper Block (Primary 5 and 6)**	**Grade 5: Understanding Earth and Space Systems: Conservation of Energy and Resources**	**Grades 1-4 Environment and Natural Studies** **Grades 5-6 Physics and Chemistry**
Energy- Forms and Uses (Light and heat) **Lower Block (Primary 3 and 4)** Knowledge, Understanding and Application ▪ Recognize that an object can be seen when it reflects light or when it is a source of light. ▪ Recognize that a shadow is formed when light is completely or partially blocked by an object ▪ List some common sources of heat. ▪ State that the temperature of an object is a measurement of its degree of hotness. ▪ Differentiate between heat and temperature. ▪ Show an understanding that heat flows from a hotter to a colder object until both reach the same temperature. ▪ Relate the change in temperature of an object to the gain or loss of heat by the object. ▪ List some effects of heat gain/loss in our everyday life -contraction/expansion of objects -change in state of matter ▪ Identify good and bad conductors of heat. -good conductors: metals -bad conductors: wood, plastic, air Skills and Processes ▪ Investigate the transparency of materials to light and communicate findings, e.g., using data logger ▪ Measure temperature using a thermometer or a data logger Ethics and Attitudes ▪ Show concern for the need to conserve energy. ▪ Show objectivity by seeking data and information to validate observations and explanations about heat **Upper Block (Primary 5-6)**	**Overall Expectations-by the end of Grade 5** 1. analyze the immediate and long-term effects of energy and resource use on society and the environment and evaluate options for conserving energy and resources; 2. investigate energy transformation and conservation; 3. demonstrate an understanding of the various forms and sources of energy and the ways in which energy can be transformed and conserved Understanding basic concepts ▪ 3.1 Identify a variety of forms of energy (*e.g., electrical, chemical, mechanical, heat, light, kinetic) and give examples from everyday life of how that energy is used)* ▪ 3.2 Identify renewable and non-renewable sources of energy (*e.g., renewable: sun, wind, ocean waves and tides, wood; non-renewable: fossil fuels such as coal and natural gas)* ▪ 3.3 describe how energy is stored and transformed in a given device or system (*e.g., in a portable electric device, chemical energy stored in a battery is transformed into electrical energy and then into other forms of energy, such as mechanical, sound, and/or light energy)* ▪ 3.4 recognize that energy cannot be created or destroyed but can only be changed from one form to *another (e.g., chemical energy in a battery becomes electrical energy)* ▪ 3.5 explain that energy that is apparently "lost" from a system has been transformed into other energy forms (usually heat or sound) that are not useful to the system *(e.g., sound from a car's engine does not help the car move)* **Grade 6: Understanding Matter and Energy:**	**Grades 1-4 Environment and Natural Studies** **Natural phenomena** (related to heat and electricity) ▪ phenomena related to heat; heat sources ▪ functioning principles of simple devices; investigating the strength of various structures magnetic and electrical phenomena Performances The pupils will: ▪ know how to connect up a simple electrical circuit using a battery, lamp, and wires; ▪ know the electrical devices used in a home; ▪ understand that using electricity is associated with dangers; and ▪ know how to use electrical devices safely ▪ know about various sources of light, sound, and heat; ▪ recognize and know how to investigate light-, sound- and heat-related phenomena such as the propagation of sound, the propagation and reflection of light, the flow of heat, and heating ▪ know how to sort wastes, avoid littering, and know how to spare water, electricity, and heat. **Grades 5-6 Physics and Chemistry** **Energy and electricity** ▪ Producing heat, light, and motion with the aid of electricity; safety with electricity ▪ Various ways of producing electricity and heat; energy sources **Electricity** Core Contents ▪ electric and magnetic forces between objects ▪ direct-current circuits; ▪ basic phenomena of electric circuits; ▪ safe application of those phenomena in everyday

SINGAPORE	ONTARIO, CANADA	FINLAND
Knowledge, Understanding and Application ▪ Recognize that energy is required to make things work or move. ▪ State that living things need energy to carry out life processes. ▪ Recognize that the Sun is our primary source of light and heat energy ▪ Show an understanding that food produced by plants becomes the source of energy for animals ▪ Differentiate the ways in which plants and animals obtain their food ▪ *Recognize that energy from most of our energy resources is derived in some ways from the Sun. ▪ Recognize and give examples of the various forms of energy. -kinetic energy -potential energy -light energy -electrical energy -sound energy -heat energy Skills and Processes ▪ Investigate the requirements (water, light energy and carbon dioxide) for photosynthesis (production of sugar and oxygen) and communicate findings ▪ Investigate energy conversion from one form to another and communicate findings. Ethics and Attitudes ▪ Show objectivity by using data and information to validate observations and explanations about photosynthesis ▪ Show concern for the need to conserve energy usage in our everyday life. ***Interactions*** Interactions includes the following related Knowledge, Understanding and Application:	**Electricity and Electrical Devices** Overall Expectations-by the end of grade 6 1. evaluate the impact of the use of electricity on both the way we live and the environment; 2. investigate the characteristics of static and current electricity, and construct simple circuits; 3. demonstrate an understanding of the principles of electrical energy and its transformation into and from other forms of energy Understanding basic concepts ▪ 3.1 distinguish between current and static electricity ▪ 3.2 use the principles of static electricity to explain common electrostatic phenomena *(e.g., the attraction of hairs to a comb that has been rubbed on a piece of wool; the attraction of small pieces of paper to a plastic ruler that has been rubbed with a rag; the attraction of pieces of clothing to each other when they come out of the clothes dryer)* ▪ 3.3 identify materials that are good conductors of electricity (e.g., copper, gold, silver, aluminum, water [when it has a high mineral content) and good insulators *(e.g., glass, plastic rubber ceramics)* ▪ 3.4 describe how various forms of energy can be transformed into electrical energy *(e.g., batteries use chemical energy; hydroelectric plants use water power; nuclear generating stations use nuclear energy; wind turbines use wind power; solar panels use energy from the sun; wave power stations use energy from ocean waves)* ▪ 3.5 identify ways in which electrical energy is transformed into other forms of energy (*e.g., electrical energy is transformed into heat energy in a toaster, light and sound energy in a television, mechanical energy in a blender)* ▪ 3.6 explain the functions of the components of a simple electrical circuit *(e.g., a battery is the*	life and technology ▪ electromagnetic induction and its use in energy transmission; ▪ use of electricity at home Description Of Good Performance At The End Of The Sixth Grade The pupils will ▪ know about different voltage supplies, such as a battery and an accumulator, and know how to do experiments in which electricity is used to produce light, heat, and motion know that electricity and heat can be generated from various natural resources, and ▪ know how to classify natural resources as renewable or non-renewable. ▪ know the principles of using electrical and heat-producing devices safely and economically, and know how to estimate and calculate the costs of utilizing electrical devices of various power levels ▪ understand the relationship between potential difference and the electrical current in a closed circuit, as well as the effect of resistance on the magnitude of electric current; and know how to make predictions about the functioning of a circuit and how to use a circuit diagram as a model of the circuit ▪ know about applications such as electrical devices and electronic communication ▪ know about the processes associated with production and transmission of electricity, such as the functioning of a transformer, and know how to explain the conversion of energy at a power plant and evaluate the advantages and disadvantages of different types of power plants. Core Contents **Heat**

SINGAPORE	ONTARIO, CANADA	FINLAND
▪ Trace the energy pathway from the Sun through living things and identify the roles of various organisms (producers, consumers, decomposers, predators, prey) in a food chain and food web. ***Systems*** (Electrical system) Systems includes the following related <u>Knowledge, Understanding and Application</u>: ▪ Recognize that an electric circuit consisting of an energy source (battery) and other circuit components (wire, bulb, switch) forms an electrical system. ▪ State that a current can only flow through a closed circuit ▪ Identify electrical conductors and insulators <u>Skills and processes</u> ▪ Construct simple circuits from circuit diagrams' ▪ Investigate the effect of some variables on the current in a circuit and communicate findings. -number of batteries (arranged in series) -number of bulbs (arranged in series) <u>Ethics and Attitudes</u> ▪ Show <u>concern</u> for the need to conserve and to have proper use and handling of electricity ▪ Value individual effort and team work	*power source; a length of wire is the conductor that carries the electrical current to the load; a light bulb or motor is the load*) ▪ 3.7 describe series circuits (components connected in a daisy chain) and parallel circuits (components connected side-by side like the rungs of a ladder), and identify where each is used. *(e.g., some strings of patio lights are in series circuits – when one light burns out, the whole string goes out; parallel circuits are used for wiring lighting and electrical outlets in your house-when one light burns out, the others keep burning)* ▪ 3.8 describe ways in which the use of electricity by society, including the amount of electrical energy used, has changed over time *(e.g., drying clothes in a dryer instead of using a clothesline; playing video games instead of playing board games; using electric lights instead of candles)*	▪ phenomena associated with the heating and cooling of objects and substances; description of those phenomena with appropriate concepts and laws; importance and applications of thermal phenomena ▪ conservation and degradation of energy; heat as a form of energy <u>Description Of Good Performance At The End Of The Sixth Grade</u> The pupils will: ▪ recognize phenomena related to the flow and storage of heat in nature and know how to interpret those phenomena ▪ know how to characterize basic phenomena of thermodynamics, such as thermal expansion and the heating of an object, with the aid of quantities and experimental laws that describe those phenomena ▪ know how to use the laws of heating, changes of state, and thermal expansion when examining and explaining thermal phenomena in nature.
LOWER SECONDARY	**LOWER SECONDARY**	**LOWER SECONDARY**
This Lower Secondary Science Syllabus is essentially a continuation and further development of the Primary Science Syllabus. It is also a bridge to, and a foundation for, the pursuit of scientific studies at upper secondary levels. The three domains remain the same (see above) and are contextually linked to the roles played by science to establish its relevance and relationship to modern-day living: Science in daily life (personal perspective focusing on the individual); Science in society (social perspective focusing on human	Lower Secondary (Grades 9 and 10) addresses one cross-cutting area and four disciplines: ▪ **Scientific Investigation Skills and Career Exploration,** ▪ **Biology,** ▪ **Chemistry,** ▪ **Earth and Space Science and** ▪ **Physics.** Ontario specifies three overall expectations for each area, dedicating one of the three overarching expectations to related societal issues	**Grade 7-9 Physics** The core task of physics instruction in the seventh through ninth grades is to broaden the pupils' knowledge of physics, and their conception of physics and to strengthen skills in the acquisition of information **Electricity** <u>Core Content</u> ▪ Electric and magnetic forces between objects ▪ Direct-current circuits; basic phenomena of electric circuits; safe application of those phenomena in everyday life and technology

SINGAPORE	ONTARIO, CANADA	FINLAND
interactions; Science and the environment (naturalistic perspective focusing on man-nature relationship) The themes expand to *include* ▪ ***Science and Technology* and *Measurement;*** ▪ ***Systems** expands to **Models and Systems*** ***Energy*** Key inquiry questions in Energy include: *-How can we harness energy to improve our quality of life?* *-Why must energy be conserved?* **Energy Forms & Uses - Energy Forms & Conversion** Knowledge, Understanding and Application ▪ state what is meant by energy ▪ describe different forms of energy (e.g., kinetic, potential, light and sound) and how energy changes from one form to another Skills and Processes ▪ infer that energy is conserved and can be transformed from one form to another Ethics and Attitudes ▪ show an appreciation of the need for Singapore, which has no natural resources of her own, to conserve energy **Energy Forms & Uses – Light** Knowledge, Understanding and Application ▪ explain how reflection is affected by a smooth and rough surface ▪ state the characteristics of the image formed by a plane mirror ▪ describe the effects and uses of reflecting surfaces (e.g. plane and curved) ▪ describe some effects and consequences of refraction ▪ describe the dispersion of white light by a	**Earth and Space Science: The Study of the Universe** Describe the sun's composition and energy source, and explain how its energy warms Earth and supports life on the planet (e.g., with reference to the types of radiation the sun emits and the interaction of the sun's energy with Earth's atmosphere) **Physics: The Characteristics of Electricity** **Relating Science to Technology, Science, and the Environment** ▪ Analyze the design of a technological device that improves its electrical efficiency or protects other devices by using or controlling static electricity (e.g., paint sprayers, photocopiers, lightning rods, grounding wires) ▪ Assess some of the social, economic, and environmental implications of the production of electrical energy in Canada from renewable and non-renewable sources (e.g., wind, solar, hydro, coal, oil, natural gas, nuclear) ▪ Produce a plan of action to reduce electrical energy consumption at home (e.g., using EnerGuide information when purchasing appliances), and outline the roles and responsibilities of various groups (e.g., government, business, family members) in this endeavour **Developing Skills of Investigation and Communication** ▪ Use appropriate terminology related to electricity, including, but not limited to: *ammeter, amperes, battery, current, fuse, kilowatt hours, load, ohms, potential difference, resistance, switch, volt- meter,* and *volts* ▪ Conduct investigations into the transfer of static electric charges by friction, contact, and	▪ Electromagnetic induction and its use in energy transmission; use of electricity at home Performances ▪ Know the principles of using electrical and heat-producing devises safely and economically, and know how to estimate and calculate the costs of utilizing electrical devices of various power levels ▪ Understand the relationship between potential difference and the electric current in a closed circuit, as well as the effect of resistance on the magnitude of electric current; and know how to make predictions about the functioning of a circuit and how to use a circuit diagram as a model of a circuit ▪ Know about applications of such as electrical devices and electronic communication ▪ Know about the processes associated with production and transmission of electricity, such as the functioning of a transformer, and know how to explain the conversion of energy at a power plant and evaluate the advantages and disadvantages of different types of power plants Core Content **Heat** ▪ Phenomena associated with the heating and cooling of objects and substances; description of those phenomena with appropriate concepts and laws; importance and applications of thermal phenomena ▪ Conservation and degradation of energy; heat as a form of energy Performances ▪ Recognize phenomena related to the flow and storage of heat in nature and know how to interpret those phenomena ▪ Know how to characterize basic phenomena of thermodynamics, such as thermal expansion and the heating of an object, with the aid of

SINGAPORE	ONTARIO, CANADA	FINLAND
prism ▪ explain how we see the colour of objects in white light and coloured light such as red, blue and green. Skills and Processes ▪ compare the speed of light, sound and common moving objects ▪ investigate the effects of reflection and refraction in practical activities and make inferences through observations in everyday life Ethics and Attitudes ▪ show an appreciation of scientific attitudes such as creativity and perseverance in measuring the speed of light to a high degree of accuracy **Energy Forms & Uses - Electricity** Knowledge, Understanding, and Application ▪ explain what is meant by current, potential difference and resistance, stating their units ▪ draw and interpret circuit diagrams and set up circuits containing electrical sources, switches, lamps, resistors (fixed and variable), ammeters and voltmeters ▪ recognize that the resistance of a circuit can be varied by arranging resistors in series or in parallel [Calculations are NOT required] ▪ explain qualitatively the chemical, heating and magnetic effects of an electric current and list some applications ▪ explain what is meant by power and state its units ▪ discuss the importance of reducing electrical energy wastage ▪ state some electrical hazards and precautionary measures to ensure the safe use of electricity in the home Skills and Processes	induction, and produce labeled diagrams to explain the results ▪ Predict the ability of different materials to hold or transfer electric charges (i.e., to act as insulators or conductors), and test their predictions through inquiry ▪ Plan and carry out inquiries to determine and compare the conductivity of various materials (e.g., metals, plastics, glass, water) ▪ Design, draw circuit diagrams of, and construct series and parallel circuits (e.g., a circuit where all light bulbs go out when one light bulb is removed; a circuit that allows one of several light bulbs to be switched on and off in- dependently of the others), and measure electric current *I*, potential difference *V*, and resistance *R* at various points in the circuits, using appropriate instruments and SI units ▪ Analyse and interpret the effects of adding an identical load in series and in parallel in a simple circuit ▪ Investigate the quantitative relationships between current, potential difference, and resistance in a simple series circuit ▪ Solve simple problems involving potential difference *V*, electric current *I*, and resistance *R*, using the quantitative relationship $V = IR$ ▪ Determine the energy consumption of various appliances, and calculate their operating costs (e.g., using the kilowatt hour rate from a utility bill) ▪ Calculate the efficiency of an energy converter, using the following equation: percent efficiency = (*Eout /Ein*) × 100% ▪ Understanding Basic Concepts ▪ Identify electrical quantities (i.e., current, potential difference, resistance, and electrical energy), and list their symbols and their corresponding SI units (e.g., electric current: *I*,	quantities and experimental laws that describe those phenomena ▪ Know how to use the laws of heating, changes of state, and thermal expansion when examining and explaining thermal phenomena in nature

SINGAPORE	ONTARIO, CANADA	FINLAND
▪ investigate the effect of varying resistance on the current in the circuit using fixed or variable resistors ▪ solve simple problems on the cost of using electrical appliances, using kilowatt- hour as a unit of electrical energy consumption ▪ communicate their understanding of electricity and justify their answers to questions on electricity with reasons Ethics and Attitudes ▪ show an appreciation of the need for Singapore, which has no natural resources of her own, to conserve energy **Energy Forms & Uses - Photosynthesis and Respiration** Knowledge, Understanding, and Application ▪ outline the process of photosynthesis by which plants manufacture carbohydrates using raw materials ▪ trace the primary food source in a food chain to the green plant ▪ show an understanding of the conditions necessary for photosynthesis ▪ show an understanding of how plants take in oxygen and remove carbon dioxide ▪ describe aerobic respiration and state its importance and construct a word equation for aerobic respiration Skills and Processes ▪ compare the conditions for healthy growth of ornamental plants and large scale crop production ▪ compare respiration and breathing ▪ compare photosynthesis and respiration Ethics and Attitudes ▪ show an appreciation of the importance for man to understand and maintain the connections among living things	ampere) ▪ Explain the characteristics of conductors and insulators and how materials allow static charge to build up or be discharged ▪ Compare and contrast static electricity with alternating current (AC) and direct current (DC) (e.g., the charge on a charged electroscope, the charge in a functioning circuit) ▪ Identify the components of a simple DC circuit (e.g., electrical source, load, connecting wires, switch, fuse), and explain their functions ▪ Explain the characteristics of electric current, potential difference, and resistance in simple series and parallel circuits, noting how the quantities differ in the two circuits ▪ Describe, qualitatively, the interrelationships between resistance, potential difference, and electric current (e.g., the effect on current when potential difference is changed and resistance is constant) ▪ Explain what different meters (e.g., ammeters, voltmeters, multimeters) measure and how they are connected within an electrical circuit to measure electrical quantities ▪ Explain how various factors (e.g., wire length, wire material, cross-sectional area of wire) influence the resistance of an electrical circuit	

SINGAPORE	ONTARIO, CANADA	FINLAND
▪ show an appreciation of man's responsibility to have care and concern for living things and the environment **Interaction of Forces & Energy – Effects of heat** Knowledge, Understanding, and Application ▪ describe some effects and applications of expansion and contraction in everyday life such as: -riveting -gaps in bridges, pavement and MRT lines -thermostats Skills and Processes ▪ infer that generally, solids, liquids and gases expand when heat is absorbed and contract when heat is given out ▪ communicate their understanding of the effects of heat with every day examples Ethics and Attitudes ▪ show an appreciation of scientific attitudes such as curiosity, objectivity and perseverance in making careful observation and experimentation on heat and its related concepts **Interaction of Forces & Energy – Transmission of Heat** Knowledge, Understanding, and Application ▪ explain what is meant by conduction, convection and radiation ▪ identify and explain applications of heat conduction and convection (e.g. in cooling, heating and insulation) ▪ show an understanding that the rate of heat loss or gain through radiation is affected by the temperature and the nature of the surface ▪ identify and explain applications of heat radiation (e.g. radiant heaters, solar radiation)		

SINGAPORE	ONTARIO, CANADA	FINLAND
Skills and Processes ▪ infer that thermal expansion results in a change in volume of the substance and therefore the density of the substance ▪ deduce from experiments that different materials have different rates of heat flow Ethics and Attitudes ▪ show an appreciation of scientific attitudes such as curiosity, objectivity and perseverance in making careful observation and experimentation on heat and its related concepts		

Appendix 6: Acquiring Skills of Inquiry: Hong Kong - *Investigative Study*

Hong Kong highlights inquiry as one of three major areas of its curriculum and urges teachers to devise experiments in which students need to design the procedure—not just follow instructions. Moreover, the curriculum and assessment guides that accompany the country's Upper Secondary courses allocate time for independent investigations. At Upper Secondary, most laboratory activities are low-level and confirmatory. However, Chemistry lists a 20-hour investigative study that is well designed and worthy of emulation. Hong Kong's Investigative Study in Chemistry is reproduced below.

2.3.3 Investigative Study
Topic XVI Investigative Study in Chemistry (20 hours)

Overview
This topic aims to provide students with opportunities to design and conduct an investigation with a view to solving an authentic problem. A portion of curriculum time is set aside for this purpose. Students are expected to make use of their knowledge and understanding of chemistry, together with generic skills − including, but not limited to, creativity, critical thinking, communication and problem-solving − to engage in a group-based experimental investigative study. Through the learning process in this study, students can enhance their practical skills and develop an awareness of the need to work safely in the laboratory.

Learning Outcomes
Students should be able to

- justify the appropriateness of an investigation plan;
- carry out a risk assessment for a scientific investigation;
- put forward suggestions for ways of improving the validity and reliability of a scientific investigation;
- use accurate terminology and appropriate reporting styles to communicate the findings and conclusions of a scientific investigation;
- evaluate the validity of conclusions with reference to the process of investigation and the data and information gathered;
- demonstrate mastery of manipulative skills and observation skills as well as good general bench performance;
- show appropriate awareness of the importance of working safely in the laboratory and elsewhere.

Implementation
In general, the investigative study involves the following processes: identifying relevant information; defining questions for study; planning an investigation; choosing equipment and resources; performing an investigation; organising and analysing information; and drawing conclusions based on available evidence.

The following is a rough estimate of the time required for the different parts of the study.

- Searching for and defining questions for investigation – 3 hours
- Developing an investigation plan – 4 hours
- Conducting the investigation – 6 hours
- Organising and analysing data for a justified conclusion – 4 hours
- Presenting findings in written reports, posters and by other means – 3 hours

Students should have some experience and be provided with guidelines on the following aspects before conducting an investigative study:

- How to work together in a group to develop an investigation plan and solve a problem
- How to select an appropriate question for the study, e.g. brainstorming techniques

- How to search for relevant information from various sources
- How to write an investigation plan
- How to write a laboratory report or make a poster for presentation

The investigative study aims to provide students with learning experiences which promote a sense of ownership of their learning and problem-solving in a group. Students should not be overloaded with an excessive number of tasks. The investigation can be conducted in groups of three to five students.
The investigation can be undertaken on completion of a relevant topic of the curriculum.
For instance, an investigative study on the topic "Chemical cell" can be carried out towards the end of S5 and completed at the beginning of S6. In other words, students can develop their investigation plan from March to May of S5, the investigation can be conducted at the end of S5, and the presentation can be done at the beginning of S6. Alternatively, it is possible to conduct an investigation in conjunction with the learning of a topic. It is therefore possible to conduct and complete the investigation mentioned above in S5. The study should focus on authentic problems, events or issues which involve key elements such as "finding out" and "gathering first-hand information". Also, to maximise the benefit of learning from the investigation within the time allocated, teachers and students should work together closely to discuss and decide on an appropriate and feasible topic. The scope and depth of the study should be given adequate consideration.

Listed below are some possible topics for investigation.

- Variation in the amount of active ingredient in a bleach solution upon storage.
- Analysis of the vitamin C content in citrus fruits or vegetables.
- Extraction of naturally occurring chemicals and testing their uses, e.g. natural pest repellent from citrus fruit peelings.
- Synthesis of a photodegradable soapy detergent and investigating its characteristics.
- Construction and testing of a chemical cell.
- Construction and testing of a home-made alcohol breathalyser.

Assessment
To facilitate learning, teachers and students can discuss and agree on the following assessment criteria with due consideration given to factors that may facilitate or hinder the implementation of the study in a particular school environment.

- Feasibility of the investigation plan (i.e. is the topic being studied researchable?)
- Understanding of relevant chemistry concepts and concerns about safety
- Manipulative skills and general bench performance
- Proper data collection procedures and ways of handling possible sources of error
- Ability to analyse and interpret data obtained from first-hand investigation
- Ability to evaluate the validity and reliability of the investigation process and the findings
- Ability to communicate and defend the findings in front of the teacher and peers
- Appropriateness of references to back up the methods and findings
- Attitudes towards the investigation

A number of assessment methods, such as observation, questioning, oral presentations, poster presentation sessions and the scrutiny of written products (investigation plans, reports, posters, etc.) can be used where appropriate.

Source: **Science Education Key Learning Area. Chemistry.** Curriculum and Assessment Guide, (Secondary 4 - 6) (Final Version) Jointly prepared by the Curriculum Development Council and the Hong Kong Examinations and Assessment Authority. Recommended for use in schools by the Education and Manpower Bureau. HKSARG. ©2007. P. 82 – 84.

Appendix 7: The Incorporation of Mathematics: Singapore - *Upper Secondary Higher 1 Physics*

Singapore's Upper Secondary Higher 1 Physics course is an example of a set of science standards that require connections with mathematics. "Candidates" are expected to understand related concepts in algebra, geometry, and trigonometry necessary for learning the Higher 1 Physics standards.

SINGAPORE - UPPER SECONDARY PHYSICS HIGHER 1[14]

MATHEMATICAL REQUIREMENTS

Arithmetic

Candidates should be able to:

(a) recognise and use expressions in decimal and standard form (scientific) notation.

(b) use appropriate calculating aids (electronic calculator or tables) for addition, subtraction, multiplication and division. Find arithmetic means, powers (including reciprocals and square roots), sines, cosines, tangents (and the inverse functions), exponentials and logarithms (lg and ln).

(c) take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified.

(d) make approximate evaluations of numerical expressions (e.g. $\pi 2 = 10$) and use such approximations to check the magnitude of machine calculations.

Algebra

Candidates should be able to:

(a) change the subject of an equation. Most relevant equations involve only the simpler operations but may include positive and negative indices and square roots.

(b) solve simple algebraic equations. Most relevant equations are linear but some may involve inverse and inverse square relationships. Linear simultaneous equations and the use of the formula to obtain the solutions of quadratic equations are included.

(c) substitute physical quantities into physical equations using consistent units and check the dimensional consistency of such equations.

(d) formulate simple algebraic equations as mathematical models of physical situations, and identify inadequacies of such models.

(e) recognise and use the logarithmic forms of expressions like ab, a/b, xn, ekx; understand the use of logarithms in relation to quantities with values that range over several orders of magnitude.

(f) manipulate and solve equations involving logarithmic and exponential functions.

(g) express small changes or errors as percentages and vice versa.

(h) comprehend and use the symbols <, >, Y, [, «, », ≈, /, ∝, <x> (= *x*), Σ, Δx, δx, √.

Geometry and trigonometry

Candidates should be able to:

[14] Source: PHYSICS HIGHER 1 (Syllabus 8866). Ministry of Education. Singapore

(a) calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of rectangular blocks, cylinders and spheres.

(b) use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle.

(c) use sines, cosines and tangents (especially for 0°, 30°, 45°, 60°, 90°). Use the trigonometric relationships for triangles:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}; \qquad a^2 = b^2 + c^2 - 2bc\cos A$$

(d) use $\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small θ; $\sin 2\theta + \cos 2\theta = 1$.

(e) understand the relationship between degrees and radians (defined as arc/radius), translate from one to the other and use the appropriate system in context.

Vectors

Candidates should be able to:

(a) find the resultant of two coplanar vectors, recognising situations where vector addition is appropriate.

(b) obtain expressions for components of a vector in perpendicular directions, recognising situations where vector resolution is appropriate.

Graphs

Candidates should be able to:

(a) translate information between graphical, numerical, algebraic and verbal forms.

(b) select appropriate variables and scales for graph plotting.

(c) for linear graphs, determine the slope, intercept and intersection.

(d) choose, by inspection, a straight line which will serve as the line of best fit through a set of data points presented graphically.

(e) recall standard linear form $y = mx + c$ and rearrange relationships into linear form where appropriate.

(f) sketch and recognise the forms of plots of common simple expressions like $1/x$, x^2, $1/x^2$, $\sin x$, $\cos x$, e^{-x}.

(g) use logarithmic plots to test exponential and power law variations.

(h) understand, draw and use the slope of a tangent to a curve as a means to obtain the gradient, and use notation in the form dy/dx for a rate of change.

(i) understand and use the area below a curve where the area has physical significance.

The ELECTRICITY AND MAGNETISM section of Singapore's Physics Higher 1 course illustrates the connection between the content and performance expectations of the course, with the Mathematical Requirements.

PHYSICS HIGHER 1[15]

SECTION IV ELECTRICITY AND MAGNETISM

8. Current of Electricity

Content

• Electric current

• Potential difference

• Resistance and resistivity

• Sources of electromotive force

Learning Outcomes

Candidates should be able to:

(a) show an understanding that electric current is the rate of flow of charged particles.

(b) define charge and the coulomb.

(c) recall and solve problems using the equation $Q = It$.

(d) define potential difference and the volt.

(e) recall and solve problems using $V = W/Q$.

(f) recall and solve problems using $P = VI$, $P = I^2R$.

(g) define resistance and the ohm.

(h) recall and solve problems using $V = IR$.

(i) sketch and explain the I-V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp.

(j) sketch the temperature characteristic of a thermistor.

(k) recall and solve problems using $R = \rho l/A$.

(l) define e.m.f. in terms of the energy transferred by a source in driving unit charge round a complete circuit.

(m) distinguish between e.m.f. and p.d. in terms of energy considerations.

(n) show an understanding of the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power.

9. D.C. Circuits

Content

• Practical circuits

• Series and parallel arrangements

[15] Ibid

Learning Outcomes

Candidates should be able to:

(a) recall and use appropriate circuit symbols as set out in SI Units, Signs, Symbols and Abbreviations (ASE, 1981) and Signs, Symbols and Systematics (ASE, 2000).

(b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus.

(c) solve problems using the formula for the combined resistance of two or more resistors in series.

(d) solve problems using the formula for the combined resistance of two or more resistors in parallel.

(e) solve problems involving series and parallel circuits for one source of e.m.f.

10. Electromagnetism

Content

• Force on a current-carrying conductor

• Force on a moving charge

• Magnetic fields due to currents

• Force between current-carrying conductors

Learning Outcomes

Candidates should be able to:

(a) show an appreciation that a force might act on a current-carrying conductor placed in a magnetic field.

(b) recall and solve problems using the equation $F = BIl\sin\theta$, with directions as interpreted by Fleming's left-hand rule.

(c) define magnetic flux density and the tesla.

(d) show an understanding of how the force on a current-carrying conductor can be used to measure the flux density of a magnetic field using a current balance.

(e) predict the direction of the force on a charge moving in a magnetic field.

(f) sketch flux patterns due to a long straight wire, a flat circular coil and a long solenoid.

(g) show an understanding that the field due to a solenoid may be influenced by the presence of ferrous core.

(h) explain the forces between current-carrying conductors and predict the direction of the forces.

Appendix 8: Alignment of Curriculum, Instruction and Assessment

Hong Kong's Curriculum and Assessment Guides *are designed to provide the rationale and aims of the subject curriculum, followed by chapters on the curriculum framework, curriculum planning, pedagogy, assessment and use of learning and teaching resources*. One key concept underlying the senior secondary curriculum is that curriculum, pedagogy and assessment should be well aligned.

The following is an excerpt from Hong Kong's Chemistry Curriculum and Assessment Guide (Secondary 4 - 6) showing the organization and instructional support materials incorporated in their science standards documents. Section 2.3.1 Compulsory Part Topic II Microscopic World I has been included as an example of the organization of a mandatory part of the Chemistry standards.

Hong Kong Curriculum and Assessment guides are unique in that they show the time allocations for each topic in the given curriculum. In the case of Chemistry (S4-6), the time allocated to the Compulsory Part is 198 hours. *The Microscopic World* is a compulsory topic which is allocated 24 of the 198 hours of instruction. In addition, Hong Kong specifies the time allocation for the Elective Part (Total 52 hours), and for the Investigative Study (20 hours).

HONG KONG – CHEMISTRY (S4-6) *MICROSCOPIC WORLD*
Chemistry Curriculum and Assessment Guide (Secondary 4 - 6)[16]

Contents

[16] **Chemistry** Curriculum and Assessment Guide (Secondary 4 - 6)
Jointly prepared by the Curriculum Development Council and the Hong Kong Examinations and Assessment Authority. Recommended for use in schools by the Education and Manpower Bureau. HKSARG. ©2007

6.5.1 Acquisition of Resources
6.5.2 Sharing Resources
6.5.3 Storing Resources

Appendices
1. Timetable arrangement and deployment of teachers to cater for the diverse needs of students
2. Experimental techniques for the Chemistry Curriculum

Glossary

2.3.1 Compulsory Part
Topic II Microscopic World I (24 hours)

Overview

The study of chemistry involves the linkage between phenomena in the macroscopic world and the interaction of atoms, molecules and ions in the microscopic world. Through studying the structures of atoms, molecules and ions, and the bonding in elements and compounds, students will acquire knowledge of some basic chemical principles. These can serve to further illustrate the macroscopic level of chemistry, such as patterns of change, observations in various chemical reactions, the rates of reactions and chemical equilibria. In addition, students should be able to perform calculations related to chemical formulae, which are the basis of mole calculations to be studied in later topics. Students should also be able to appreciate the interrelation between bonding, structures and properties of substances by learning the properties of metals, giant ionic substances, simple molecular substances and giant covalent substances. With the knowledge of various structures, students should be able to differentiate the properties of substances with different structures, and to appreciate that knowing the structure of a substance can help us decide its applications. While materials chemistry is becoming more important in applied chemistry, this topic provides the basic knowledge for further study of the development of new materials in modern society.

Through activities such as gathering and analysing information about atomic structure and the Periodic Table, students should appreciate the impact of the discoveries of atomic structure and the development of the Periodic Table on modern chemistry. Students should also be able to appreciate that symbols and chemical formulae constitute part of the common language used by scientists to communicate chemical concepts.

Students should learn	**Students should be able to**
a. Atomic structure	• elements, atoms and symbols • classification of elements into metals, non-metals and metalloids • electrons, neutrons and protons as subatomic particles • simple model of atom • atomic number (Z) and mass number (A) • isotopes • isotopic masses and relative atomic masses based on 12C=12.00 • electronic arrangement of atoms (up to Z=20) • stability of noble gases related to their electronic arrangements • state the relationship between element and atom

	• use symbols to represent elements • classify elements as metals or non-metals on the basis of their properties • be aware that some elements possess characteristics of both metals and non-metals • state and compare the relative charges and the relative masses of a proton, a neutron and an electron • describe the structure of an atom in terms of protons, neutrons and electrons • interpret and use symbols such as ^{23}Na • deduce the numbers of protons, neutrons and electrons in atoms and ions with given atomic numbers and mass numbers • identify isotopes among elements with relevant information • perform calculations related to isotopic masses and relative atomic masses • understand and deduce the electronic arrangements of atoms • represent the electronic arrangements of atoms using electron diagrams • relate the stability of noble gases to the octet rule
b. The Periodic Table	• the position of the elements in the Periodic Table related to their electronic arrangements • similarities in chemical properties among elements in Groups I, II, VII and 0 • understand that elements in the Periodic Table are arranged in order of ascending atomic number • appreciate the Periodic Table as a systematic way to arrange elements • define the group number and period number of an element in the Periodic Table • relate the position of an element in the Periodic Table to its electronic structure and vice versa • relate the electronic arrangements to the chemical properties of the Group I, II, VII and 0 elements • describe differences in reactivity of Group I, II and VII elements • predict chemical properties of unfamiliar elements in a group of the Periodic Table
c. Metallic bonding	• describe the simple model of metallic bond
d. Structures and properties of metals	• describe the general properties of metals • relate the properties of metals to their giant metallic structures
e. Ionic and covalent bond	• transfer of electrons in the formation of ionic bond • cations and anions • electron diagrams of simple ionic compounds • names and formulae of ionic compounds • ionic structure as illustrated by sodium chloride • sharing of electrons in the formation of covalent bond • single, double and triple bonds • electron diagrams of simple covalent molecules

	• names and formulae of covalent compounds • formula masses and relative molecular masses • describe, using electron diagrams, the formation of ions and ionic bonds • draw the electron diagrams of cations and anions • predict the ions formed by atoms of metals and non-metals by using information in the Periodic Table • identify polyatomic ions • name some common cations and anions according to the chemical formulae of ions • name ionic compounds based on the component ions • describe the colours of some common ions in aqueous solutions • interpret chemical formulae of ionic compounds in terms of the ions present and their ratios • construct formulae of ionic compounds based on their names or component ions • describe the structure of an ionic crystal • describe the formation of a covalent bond • describe, using electron diagrams, the formation of single, double and triple bonds • describe the formation of the dative covalent bond by means of electron diagram using H3O+ and NH4 • + as examples • interpret chemical formulae of covalent compounds in terms of the elements present and the ratios of their atoms • write the names and formulae of covalent compounds based on their component atoms • communicate scientific ideas with appropriate use of chemical symbols and formulae • define and distinguish the terms: formula mass and relative molecular mass • perform calculations related to formula masses and relative molecular masses of compounds
f. Structures and properties of giant ionic substances	• describe giant ionic structures of substances such as sodium chloride and caesium chloride • state and explain the properties of ionic compounds in terms of their structures and bonding
g. Structures and properties of simple molecular substances	• describe simple molecular structures of substances such as carbon dioxide and iodine • recognise that van der Waals' forces exist between molecules • state and explain the properties of simple molecular substances in terms of their structures and bonding
h. Structures and properties of giant covalent substances	• describe giant covalent structures of substances such as diamond, graphite and quartz • state and explain the properties of giant covalent substances in terms of their structures and bonding
i. Comparison of structures and properties of important types of substances	• compare the structures and properties of substances with giant ionic, giant covalent, simple molecular and giant metallic structures

- deduce the properties of substances from their structures and bonding, and vice versa
- explain applications of substances according to their structures

Suggested Learning and Teaching Activities
Students are expected to develop the learning outcomes using a variety of learning experiences. Some related examples are:

- searching for and presenting information on the discoveries related to the structure of an atom.
- searching for and presenting information on elements and the development of the Periodic Table.
- performing calculations related to relative atomic masses, formula masses and relative molecular masses.
- drawing electron diagrams to represent atoms, ions and molecules.
- investigating chemical similarities of elements in the same group of the Periodic Table (e.g. reactions of group I elements with water, group II elements with dilute hydrochloric acid, and group VII elements with sodium sulphite solution).
- predicting chemical properties of unfamiliar elements in a group of the Periodic Table.
- writing chemical formulae for ionic and covalent compounds.
- naming ionic and covalent compounds.
- exploring relationship of colour and composition of some gem stones.
- predicting colours of ions from a group of aqueous solutions (e.g. predicting colour of $K^+(aq)$, $Cr_2O_7^{2-}(aq)$ and $Cl^-(aq)$ from aqueous solutions of potassium chloride and potassium dichromate).
- investigating the migration of ions of aqueous solutions, e.g. copper(II) dichromate and potassium permanganate, towards oppositely charged electrodes.
- building models of three-dimensional ionic crystals and covalent molecules.
- using computer programs to study three-dimensional images of ionic crystals, simple molecular substances and giant covalent substances.
- building models of diamond, graphite, quartz and iodine.
- predicting the structures of substances from their properties, and vice versa.
- justifying some particular applications of substances in terms of their structures.
- reading articles or writing essays on the applications of materials such as graphite and aluminium in relation to their structures.

Values and Attitudes
Students are expected to develop, in particular, the following *values and attitudes*:

- to appreciate that scientific evidence is the foundation for generalisations and explanations about matter.
- to appreciate the usefulness of models and theories in helping to explain the structures and behaviours of matter.
- to appreciate the perseverance of scientists in developing the Periodic Table and hence to envisage that scientific knowledge changes and accumulates over time.
- to appreciate the restrictive nature of evidence when interpreting observed phenomena.
- to appreciate the usefulness of the concepts of bonding and structures in understanding phenomena in the macroscopic world, such as the physical properties of substances.

STSE Connections
Students are encouraged to appreciate and comprehend issues which reflect the interconnections of science, technology, society and the environment. Related examples are:

- Using the universal conventions of chemical symbols and formulae facilitates communication among people in different parts of the world.

- Common names of substances can be related to their systematic names (e.g. table salt and sodium chloride; baking soda and sodium hydrogencarbonate).
- Some specialised new materials have been created on the basis of the findings of research on the structure, chemical bonding, and other properties of matter (e.g. bullet-proof fabric, superconductors and superglue).

Appendix 9: Connecting Standards with Assessment

There are many ways in which debate on standards policy in the US have attempted to ameliorate our long history of standards characterized by shallow coverage, disconnected lists of topics, an too little attention to how understandings can be supported and scaffolded from grade to grade. One way in which it has been suggested that these weaknesses can be overcome, is in writing standards that clearly lay out which specific aspects of scientific knowledge and practices should be assessed in large-scale as well as classroom assessment and in which grades. In fact, the influential report *Taking Science to School* from the National Research Council (citation) suggests that such linkage to assessment can include a discussion of examples of possible test items and tasks (pg. 247).

From this perspective, it is instructive to observe the specific ways in which some of the countries in this report address these linkages.

For example, in the *England Science: Level descriptions from level 1 to exceptional performance*, 2010) a set of attainment targets are specified, which will enter effect in English secondary schools in summer 2011. These attainment targets are a revision of others that have been statutory since 1999 - which corresponds to the document coded in this benchmarking study and examined by Achieve's qualitative reviewers. These targets describe, for students of different abilities and levels of maturity, the specific ways in which pupils can be said to demonstrate the acquisition of knowledge, skills and understandings that correspond to each key stage. Teachers are instructed that: *In deciding on a pupil's level of attainment at the end of a key stage, teachers should judge which description best fits the pupil's performance. When doing so, each description should be considered alongside descriptions for adjacent level.* (Pg. 7)

The attainment targets are therefore intended to be specific criteria against which students' progress is to be assessed. An example of these can be seen in the following excerpt from the attainment targets, one pertaining to materials and their properties and the earth:

Attainment target 3: materials and their properties

Level 1
Pupils know about a range of properties [for example, texture, appearance] and communicate observations of materials in terms of these properties.

Level 2
Pupils identify a range of common materials and know about some of their properties. They describe similarities and differences between materials. They sort materials into groups and describe the basis for their groupings in everyday terms [for example, shininess, hardness, smoothness]. They describe ways in which some materials are changed by heating or cooling or by processes such as bending or stretching.

Level 3
Pupils use their knowledge and understanding of materials when they describe a variety of ways of sorting them into groups according to their properties. They explain simply why some materials are particularly suitable for specific purposes [for example, glass for windows, copper for electrical cables]. They recognise that some changes [for example, the freezing of water] can be reversed and some [for example, the baking of clay] cannot, and they classify changes in this way.

Level 4
Pupils demonstrate knowledge and understanding of materials and their properties drawn from the key stage 2 or key stage 3 programme of study. They describe differences between the properties of different materials and explain how these differences are used to classify substances [for example, as solids, liquids, gases at key stage 2, as acids, alkalis at key stage 3]. They describe some methods [for example, filtration, distillation] that are used to separate simple mixtures. They use scientific terms [for example, evaporation, condensation] to describe changes. They use knowledge about some reversible and irreversible changes to make simple predictions about whether other changes are reversible or not.

Level 5
Pupils demonstrate an increasing knowledge and understanding of materials and their properties drawn from the key

stage 2 or key stage 3 programme of study. They describe some metallic properties [for example, good electrical conductivity] and use these properties to distinguish metals from other solids. They identify a range of contexts in which changes [for example, evaporation, condensation] take place. They use knowledge about how a specific mixture [for example, salt and water, sand and water] can be separated to suggest ways in which other similar mixtures might be separated.

Level 6

Pupils use knowledge and understanding of the nature and behaviour of materials drawn from the key stage 3 programme of study to describe chemical and physical changes, and how new materials can be made. They recognise that matter is made up of particles, and describe differences between the arrangement and movement of particles in solids, liquids and gases. They identify and describe similarities between some chemical reactions [for example, the reactions of acids with metals, the reactions of a variety of substances with oxygen]. They use word equations to summarise simple reactions. They relate changes of state to energy transfers in a range of contexts [for example, the formation of igneous rocks].

Level 7

Pupils use knowledge and understanding drawn from the key stage 3 programme of study to make links between the nature and behaviour of materials and the particles of which they are composed. They use the particle model of matter in explanations of phenomena [for example, changes of state]. They explain differences between elements, compounds and mixtures in terms of their constituent particles. They recognise that elements and compounds can be represented by symbols and formulae. They apply their knowledge of physical and chemical processes to explain the behaviour of materials in a variety of contexts [for example, the way in which natural limestone is changed through the action of rainwater, ways in which rocks are weathered]. They use patterns of reactivity [for example, those associated with a reactivity series of metals] to make predictions about other chemical reactions.

Level 8

Pupils demonstrate an extensive knowledge and understanding drawn from the key stage 3 programme of study, which they use to describe and explain the behaviour of, and changes to, materials. They use the particle model in a wide range of contexts. They describe what happens in a range of chemical reactions and classify some [for example, oxidation, neutralisation]. They represent common compounds by chemical formulae and use these formulae to form balanced symbol equations for reactions [for example, those of acids with metals, carbonates or oxides]. They apply their knowledge of patterns in chemical reactions to suggest how substances [for example, salts] could be made.

Exceptional performance

Pupils demonstrate both breadth and depth of knowledge and understanding drawn from the key stage 3 programme of study when they describe and explain the nature and behaviour of materials. They use particle theory in a wider range of contexts, recognising that differences in the properties of materials relate to the nature of the particles within them. They recognise, and give explanations for, examples of chemical behaviour that do not fit expected patterns. They routinely use balanced symbol equations for reactions. They interpret quantitative data about chemical reactions, suggesting explanations for patterns identified.

From: Science Full Programme of Study & Targets all stages pg. 79. NC online version The National Curriculum for England www.nc.uk.net. © Crown copyright 1999

As can be observed in the example, the attainment targets are formulated in terms of the types of evidence that can be referenced in determining the level that each pupil has attained. Therefore, assessment is in effect, an intrinsic part of the standard.

Hong Kong offers a contrasting perspective. The standards in secondary schools are themselves called *Curriculum and Assessment Guides* – and the discussion of assessments permeates the entire document. These documents discuss a wide range of types of evidence that should be collected to verify student's attainment of specific learning targets. An example might be considered for the case of Biology standards in secondary school:

Students should learn	Students should be able to
a. Microbiology	
Viruses	
• Multiplication of viruses	• Describe how a virus reproduces by infecting a living cell.
Diversity of microorganisms	• Distinguish different groups of microorganisms based on group features.
• Representative organisms of Bacteria, Protista and Fungi	• Discuss the effects of environmental factors on the growth of microorganisms.
Growth of microorganisms (e.g. yeast)	
• Growth requirement	• Measure and identify the different stages of growth of microorganisms in culture.
– Temperature, pH, carbon and nitrogen sources, oxygen and water availability	• Outline the principle of aseptic techniques.
• Stages of growth	• Use aseptic techniques and follow safety procedures in handling, culturing and disposing of microorganisms.
• Measurement of growth	
– Cell counts, biomass and optical methods	

Source: "Biology Curriculum and Assessment Guide (Secondary 4-6)," pg. 54.

This example is typical of the entire standards document – all learning targets are presented along with a specification of the types of things students should be able to do that *demonstrate* their attainment of these goals.

In Ontario, similar to the preceding illustrations, an important priority in their standards is "to promote greater consistency in the assessment of student work across the province" (The Ontario Curriculum – Exemplars Grades 3 and 4: Science and Technology pg. 4). But the approach is different – rather than a only detailing specifications of the measurement standards or criteria for determining the level of attainment of pupils, Ontario has designed a set of assessment tasks and scoring rubrics, and collected and published samples of genuine student work that are regarded as illustrations of the types of skills and knowledge that students should give evidence of as verification of their attainment of various levels of proficiencies associated with Ontario's curriculum goals.

The tasks are described in detail, including the types of measures that they are intended to provide, and then the rubrics are also detailed. Proficiency levels are tied to each one of these rubrics, and finally, two examples of genuine student work, associated with each one of the proficiency levels, are provided as illustrations. Each example is discussed and linked to both the rubric and the original description of the proficiency levels.

Page 58. The Ontario Curriculum – Exemplars, Grades 1 and 2: Science and Technology

MAKING A TOY

The Task

Students were asked to build a toy for a young child incorporating mechanisms and simple machines. Specifically they were to:

- clarify the problem;
- brainstorm some possible solutions;
- draw design sketches for three of the solutions;
- choose one sketch as their plan;
- design and build a model;
- test the model and make any necessary changes;
- reflect on their learning.

Expectations

This task gave students the opportunity to demonstrate their achievement of all or part of each of the following selected overall and specific expectations from the strand Structures and mechanisms; Grade 2 – Movement

Students will:

1. Describe the position and movement of objects, and demonstrate an understanding of how simple mechanisms enable an object to move;
2. Design and make simple mechanisms, and investigate their characteristics;
3. Recognize that different mechanisms an systems move in different ways, and that the different types of movement determine the design and method of production of these mechanisms and systems;
4. Ask questions about and identify needs or problems related to structures an mechanisms, and explore possible answers and solutions;
5. Plan investigations to answer some of these questions or solve some of these problems, and describe the steps involved;
6. Communicate the procedures and results of investigations and explorations for specific purposes, using drawings, demonstrations, and oral and written description.

Prior Knowledge and Skills

To complete this task, students were expected to have some knowledge or skills related to the following:

- attaching axles and wheels
- making hinges and other simple linkages
- recognizing different simple machines
- using a design-process model
- connecting parts to create movement in different ways and directions

Task Rubric – Grade 2: Making a Toy

Expectations	Level 1	Level 2	Level 3	Level 4
Understanding of Basic Concepts	**The student:**			
	Demonstrates limited understanding of how mechanisms enable movement and changes in direction	Demonstrates some understanding of how mechanisms enable movement and changes in direction	Demonstrates general understanding of how mechanisms enable movement and changes in direction	Demonstrates thorough understanding of how mechanisms enable movement and changes in direction
Design Skills	**The student:**			
Identifying the problem/need	Describes with limited clarity the challenge of designing an building a model of a toy incorporating simple machines	Describes with some clarity the challenge of designing an building a model of a toy incorporating simple machines	Clearly describes the challenge of designing an building a model of a toy incorporating simple machines	Precisely describes the challenge of designing an building a model of a toy incorporating simple machines
	Lists a few of the steps needed to execute the plan	Lists some of the steps needed to execute the plan	Lists most of the steps needed to execute the plan	Lists in a detailed manner all or almost all of the steps needed to execute the plan
Making the plan	Creates a minimally labeled plan	Creates a partially labeled plan	Creates a fully labeled plan	Creates a detailed, fully labeled plan
Executing and evaluating the plan	Makes a few modifications to the plan as needed	Makes some modifications to the plan as needed	Makes appropriate modifications to the plan as needed, giving reasons for the modifications	Makes appropriate, detailed modifications to the plan as needed, giving reasons for the modifications
	Creates a model that resembles the plan to a limited extent	Creates a model that resembles the plan to some extent	Creates a model that resembles the plan including most recorded modifications	Creates a model that resembles the plan to a limited extent including most or almost all recorded modifications
	Makes limited improvements to the model	Makes some improvements to the model	Makes considerable improvements to the model	Makes insightful improvements to the model
Communication of Required Knowledge	**The student:**			
	Makes limited use of appropriate science and technology vocabulary to describe simple machines and their mechanisms	Makes some use of appropriate science and technology vocabulary to describe simple machines and their mechanisms	Makes general use of appropriate science and technology vocabulary to describe simple machines and their mechanisms	Makes extensive use of appropriate science and technology vocabulary to describe simple machines and their mechanisms
	Explains with limited clarity how the mechanism or simple machine is used to	Explains with some clarity how the mechanism or simple machine is used to	Explains clearly how the mechanism or simple machine is	Explains precisely how the mechanism or simple machine is used to create movement,

Expectations	Level 1	Level 2	Level 3	Level 4
	create movement, including changes in speed and direction	create movement, including changes in speed and direction	used to create movement, including changes in speed and direction	including changes in speed and direction
	Provides a simple explanation of how the toy could be used to improve fine-motor skills	Provides a somewhat clear explanation of how the toy could be used to improve fine-motor skills	Provides a clear explanation of how the toy could be used to improve fine-motor skills	Provides a complex and detailed explanation of how the toy could be used to improve fine-motor skills
Relating of Science and Technology to each other and to the world outside the school	**The student:**			
	Describes in limited detail similarities between the model and mechanisms and simple machines in real-life objects	Describes in some detail similarities between the model and mechanisms and simple machines in real-life objects	Describes in detail similarities between the model and mechanisms and simple machines in real-life objects	Describes in rich detail similarities between the model and mechanisms and simple machines in real-life objects

All of these examples show how countries conceive of standards as being inextricably linked to a discussion of the body of evidence that must be assessed in order verify how well standards have been attained or note. This linkage with an evidentiary base is one feature of a strong standards document.

Appendix 10: Scientific Inquiry/Research Skills, and Technological Problem-Solving Skills Continua in Ontario, Canada

Canada's standards for grades 1-8 include a separate, but parallel matrix for Scientific Inquiry/Research Skills and for Technological Problem-Solving Skills that describes a full continuum of stages of proficiency[17]. These matrices chart the extent of student learning from beginning to exploring to emerging to competent to proficient in four key areas: 1) Initiating and Planning; 2) Performing and Recording; 3) Analysing and Interpreting and 4) Communication. This appendix contains a side-by-side excerpt that highlights commonalities in the inquiry and design process for two stages (Exploring and Proficiency) along the continuum.

Continuum For Scientific Inquiry/Research Skills		**Continuum for Technological Problem-Solving Skills**	
Exploring	**Proficient**	**Exploring**	**Proficient**
Initiating and Planning		**Initiating and Planning**	
The Student:		The Student:	
asks questions that could lead to investigations, and chooses one that will be the basis for an investigation	asks questions that arise from practical problems and issues, and formulates a specific question that will be the basis for an investigation	identifies practical problems to solve in the immediate environment	identifies practical problems to solve
uses a teacher-prepared organizational system for gathering and organizing information	plans an organizational system for gathering and organizing information, using a variety of strategies (e.g., sketch board outlines of a series of events) and organizational patterns (e.g., order of importance)	with support (e.g., as a class or in small groups), generates a list of possible solutions to a practical problem and determines which are realistic in the classroom and/or the real world	identifies possible solutions to a practical problem and prioritizes them with regard to their potential for solving the problem
with support, selects print and multimedia resources from those provided by the teacher	independently selects print, multimedia, and electronic resources	selects a possible solution to implement	selects a possible solution, and provides reasons for the choice that take into account considerations such as function, aesthetics, environmental impact
		makes a simple plan (individually or in small groups), including simple drawings and/or diagrams, to carry out the solution	outlines in detail, including technical drawings and/or diagrams, each step of a plan to solve the problem
		with support (e.g., as a class or in small groups), establishes a limited number of criteria for evaluating proposed solutions to the problem	contributes to establishing general criteria for evaluating objects or devices designed to solve the problem
Performing and Recording			
The Student:			
with support, selects information from print and multimedia	selects information from print, multimedia, and electronic resources that he		

[17] The Ontario Curriculum – Grades 9 & 10 Science – 2008 p. 15-18

Continuum For Scientific Inquiry/Research Skills		Continuum for Technological Problem-Solving Skills	
Exploring	**Proficient**	**Exploring**	**Proficient**
resources provided by the teacher	or she has found independently		
records information gathered, using a teacher-prepared organizational system	records information gathered, using a variety of strategies (e.g., sketch board out- lines of a series of events) and organizational patterns (e.g., order of importance		
matches information to research needs (e.g., differentiates between factual information and information based on opinion)	selects sources of information, showing awareness of currency and bias		
references sources by title, author, date	uses appropriate academic referencing, including publisher, volume, date of document, location and date of interview		
Analysing and Interpreting		**Analysing and Interpreting**	
The Student:		The Student:	
states a simple conclusion in answer to the question being investigated, on the basis of information gathered	states a conclusion in answer to the question being investigated, on the basis of information gathered	identifies how well the chosen solution solved the practical problem, using the pre-determined criteria	explains how well the chosen solution solved the practical problem, using qualitative and/or quantitative data, and suggests possible changes to the criteria and the solution
makes a simple evaluation of research procedures used	makes an evaluation of the research procedure used, suggests changes that could be made to it, and gives reasons for the suggested changes	identifies some things that could be done differently to improve the solution to the problem	identifies and explains what changes could be made to the plan and the testing process, and how to improve the solution to the problem, and gives reasons for the changes
demonstrates understanding that the accuracy and value of information will vary from source to source	verifies the validity of and compares information gathered from research	identifies some possible beneficial and non-beneficial impacts of the chosen solution for himself/herself or others	identifies the effects of the chosen solution on himself/herself, others, and/or the environment, considering things such as cost, materials, time, and/or space, and sag-gests ways in which undesirable effects could be lessened or eliminated
summarizes the information, using pictures and words	summarizes relevant information, using jot notes, outlines		
Communicating		**Communicating**	
The Student:		The Student:	
presents research orally; in charts, graphs, or labeled drawings; and/or in	presents research in numeric, symbolic, graphical, and/or linguistic forms of communication to	describes orally, and/or using drawings, pictures, and/or simple sentences, the problem and how he	describes orally, and using labelled drawings and diagrams, charts, graphs, and/or written descriptions, the

Continuum For Scientific Inquiry/Research Skills		Continuum for Technological Problem-Solving Skills	
Exploring	**Proficient**	**Exploring**	**Proficient**
written words to answer the question investigated	answer the question investigated	or she solved it	problem and how he or she solved it
		uses grade-appropriate science and technology vocabulary correctly	uses grade-appropriate science and technology vocabulary correctly