

DP Country Alignment Studies: Alignment of DP Chemistry with the Chemistry Subjects in Eleven Comparison Programmes/Standards

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Acronyms

21CC	21 st century competencies
AHL	additional higher level
BGE	Basic General Education
BHSC	Brazilian High School Curriculum
BNCC	(Brazilian) National Common Curricular Base
CAS	creativity, activity, service
CCSS	Common Core State Standards
CP	Career-related Programme
DP	Diploma Programme
EDUFI	Finnish National Agency for Education
FB	French Baccalaureate (<i>Baccalauréat</i>)
FI	Formative Itinerary
FNCC	Finnish National Core Curriculum
GCE	General Certificate of Education
GUSE	General upper secondary education
HL	higher level
HS	High school
IB	International Baccalaureate
IBO	International Baccalaureate Organisation
JHSC	Japanese High School Curriculum
KHSCG	South Korean High School Certificate of Graduation
LS	Life Sciences
NST	Natural Sciences and Technology
MBG	Mexican Bachillerato General
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MOE	Ministry of Education

MT	Mathematical Thinking
MYP	Middle Years Programme
NGSS	Next Generation Science Standards
OSSD	Ontario Secondary School Diploma
OSSLT	Ontario Secondary School Literacy Test
PoS	Practices of Science
PS	Physical Sciences
PYP	Primary Years Programme
RfP	Request for Proposal
RQ	Research Question
SB	Spanish Baccalaureate (<i>Bachillerato</i>)
SGA	Singaporean GCE A Level
SL	standard level
SMC	Science and Mathematics Course
TOK	theory of knowledge
UP	University Preparation
USA	United States of America
VCAA	Victorian Curriculum and Assessment Authority
VCE	Victorian Certificate of Education

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1. Executive Summary

1.1 Project Aims and Context

The International Baccalaureate (IB) Organization is a not-for-profit educational foundation offering four programmes across the world. One of them – the Diploma Programme (DP) – is a two-year upper secondary programme, primarily intended to prepare students for university matriculation and higher education.

Ecctis was commissioned by the IB to conduct a series of in-depth studies that assessed the level of alignment between the DP and comparison points within the upper secondary education systems of Australia (Victoria), Canada (Ontario), the United States, Singapore, South Korea, Finland, France, Spain, Brazil, Mexico, and Japan.¹ The studies identified areas of similarity and difference between the DP and these educational systems, providing valuable insights to inform the IB's development of tools and resources for IB teachers, supporting their navigation between the DP and local curriculum of each country. The studies also contributed to supporting fair recognition of the DP by institutions, employers, and other key stakeholders – ultimately supporting the progression and mobility of DP graduates. For all countries, the studies assessed alignment at both the programme and subject levels, with a particular focus on mathematics and science. For some countries, additional subjects were included in the analysis, as outlined in the table below:

Table 1: Additional subjects included in the country studies.

Country	Additional DP Subject(s)	Country	Additional DP Subject(s)
Australia	History	Brazil	Language A: language and literature History Philosophy Brazilian social studies
United States	English		
France	Philosophy Theory of knowledge (TOK)		
Spain	Economics Business management	Mexico	Language A: language and literature
		Japan	Language A: literature Language B History

This report constitutes one of the project's deliverables and aims to specifically answer the research questions pertaining to how the DP chemistry curriculum aligns with the chemistry curriculum in each of the comparison programmes/standards in these studies, namely:

- Australia: Victorian Certificate of Education (VCE)
- Canada: Ontario Secondary School Diploma (OSSD)
- Finland: Finnish National Core Curriculum (FNCC) / General Upper Secondary Education (GUSE)
- Singapore: Singaporean GCE A Level (SGA)
- South Korea: Korean High School Certificate of Graduation (KHSCG)
- US: Next Generation Science Standards (NGSS)
- France: French Baccalauréat (FB)

¹ The DP Country Alignment reports can be accessed at: www.ibo.org/research/curriculum-research/dp-studies/dp-country-alignment-studies-2023/

- Spain: Spanish Bachillerato (SB)
- Brazil: Brazilian High School Curriculum (BHSC)
- Mexico: Mexican Bachillerato General (MBG)
- Japan: Japanese High School Curriculum (JHSC).

1.2 Research Questions and Methods

All comparative studies in this series have been framed by responses to Research Questions (RQs), both at programme and subject levels. For this study, the RQs were the following:

RQ1: To what degree do the DP chemistry curricula align with the upper secondary chemistry curricula of the eleven comparison programmes? In what way are the curricula similar and in what way are they different? To what degree do the subjects align with regard to:

1.1: Content

- Topics (i.e. scope of content area, breadth, depth)
- Learning activities (i.e. difficulty, demand).

1.2: Expected learning outcomes

- Knowledge
- Competencies (i.e. subject-specific, 21st century competencies).

To answer the above RQs, Ecctis developed and applied a bespoke methodology which involved the comparative analysis of key components of the DP and the comparison subjects, including: learning outcomes, content, and demand.

Where appropriate, Ecctis complemented its standard comparative methodology with a comprehensive mapping method, extracting themes from the DP to evaluate their presence in the comparison point(s). Additionally, to assess demand at subject level, Ecctis designed and deployed an expert panel approach, scoring each individual subject against a common set of demand criteria.²

² Each individual subject was scored for: cognitive skills evidenced in the learning outcomes (based on the Revised Bloom's Taxonomy), depth of knowledge (adapted from Webb's Depth of Knowledge levels), volume of work (a tri-factor score considering breadth, depth and allocated timeframe), and outstanding areas of subject demand (stretch areas).

1.3 Key Findings

With regard to subjects compared in the subject-level comparative analysis, the following table presents the agreed scope:

Table II: DP chemistry and comparison subjects

		Comparison subjects per country and comparison programme					
Country	International	Australia	Canada	Finland	Singapore	South Korea	US
Programme/ Standards	DP	Victoria (VCE)	Ontario (OSSD)	Finland (FNCC)	Singapore (SGA)	South Korea (KHSCG)	Next Generation Science Standards (NGSS)
Subjects	Chemistry SL and HL	Chemistry Units 1, 2, 3 & 4	Grade 9 & 10 Science: Academic Grade 11 & 12 Chemistry	Chemistry (compulsory and optional modules)	Higher 1 (H1) Chemistry Higher 2 (H2) Chemistry Higher 3 (H3) Chemistry	Chemistry I Chemistry II Integrated Science Scientific Investigation	Physical Sciences Standards (high school)
		Comparison subjects per country and comparison programme (continued)					
		France	Spain	Brazil	Mexico	Japan	
		France (FB)	Spain (SB)	Brazil (BHSC)	Mexico (MBG)	Japan (JHSC)	
		Physics-chemistry	Physics and Chemistry Chemistry	Natural Sciences and Technology (Basic General Education and Formative Itinerary)	Natural Sciences, Experimental Sciences and Technology units	Advanced Chemistry Chemistry for the Science and Mathematics Course	

Detailed findings from the subject-level analysis are summarised in the [5. Key Findings](#) section and fully detailed in the respective country sections in the main body of this report:

- [Australia: Victorian Certificate of Education \(VCE\)](#)
- [Canada: Ontario Secondary School Diploma \(OSSD\)](#)
- [Finland: Finnish National Core Curriculum \(FNCC\) / General Upper Secondary Education \(GUSE\)](#)
- [Singapore: Singaporean GCE A Level \(SGA\)](#)
- [South Korea: Korean High School Certificate of Graduation \(KHSCG\)](#)
- [USA: Next Generation Science Standards \(NGSS\).](#)
- [France: French Baccalauréat](#)
- [Spain: Spanish Bachillerato.](#)
- [Brazil: Brazilian High School Curriculum \(BHSC\)](#)
- [Mexico: Mexican Bachillerato General \(MBG\)](#)
- [Japan: Japanese High School Curriculum \(JHSC\)](#)

1.4 Cross-cutting Findings

In addition to the insights gained from the analysis of each comparison subject against DP chemistry, the study also adopted a cross-cutting perspective of the chemistry curricula across all countries included in the studies. This horizontal analysis identified key similarities, differences, and trends relating to learning outcomes, content and demand. The findings are summarised in the visuals and bullet points that follow.

1.4.1 Learning Outcomes

Table III: Presence of the DP's science learning outcomes in the comparison chemistry curricula.

Themes extracted from learning outcomes of the DP sciences subject group	Presence in the comparison curricula										
	VCE (Victoria)	OSSD (Ontario)	FNCC/ GUSE (Finland)	SGA (Singapore)	KHSCG (South Korea)	NGSS (US)	FB (France)	SB (Spain)	BHSC (Brazil)	MBG (Mexico)	JHSC (Japan)
1. Conceptual understanding and making connections											
2. Use and application of knowledge, methods, tools, and techniques that characterize science											
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)											
4. Skills for scientific inquiry											
5. Development of technological skills											
6. Effective collaboration and communication											
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science											

Key:

	This theme is well-evidenced in the learning outcomes of the comparison curriculum.		This theme is partially evidenced in the learning outcomes of the comparison curriculum.		This theme is not evidenced in the learning outcomes of the comparison curriculum.
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The table above displays the learning outcome themes extracted from the DP sciences subject group (which apply to chemistry) and summarises their presence in the chemistry curricula of the eleven comparison programmes/standards.

- Overall, most comparison chemistry curricula have a high degree of alignment with the DP's learning outcome themes for science. Rarely are any of the DP science learning outcome themes absent from the comparison curricula and, from the other perspective, very few themes emerge from the comparison curricula that are significantly different to the DP's.
- In contrast to the DP, FB and NGSS, the other curricula have course-specific outcomes, with some featuring both overarching outcomes for the sciences subject area and course-specific outcomes. That said, the course-specific outcomes for OSSD, VCE, FNCC, KHSCG, and JHSC differ primarily because they are contextualised for the content of each course; whereas the SGA, SB, BHSC, and MBG contain outcomes which describe somewhat different skills for each course, as well as content.
- Some DP themes are consistently well-evidenced in the learning outcomes of the comparison curricula, particularly *Use and application of knowledge, methods, tools, and techniques that characterize science*, *Creativity and critical thinking*, and *Skills for scientific inquiry*.
- The themes of *Developing conceptual understanding and making connections* and *Developing technological skills* are the least evident in the learning outcomes of the comparison curricula, though are still present in the majority.
- The few themes featured in the comparison curricula that are different from the DP's include the OSSD's greater national focus and emphasis on careers; the NGSS's and FB's stronger emphasis on using models; the FNCC's particular emphasis on understanding how collaboration with outside agencies is important in gaining skills and knowledge in chemistry; the SB's focus on making links specifically between physics and chemistry; and the BHSC's focus on historic contextualisation of scientific information.

1.4.2 Content

Table IV: Presence of DP chemistry SL content in the chemistry curricula of the comparison programmes/standards.³

DP chemistry – SL content		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
Structure 1. Models of the particulate nature of matter	1.1 Introduction to the particulate nature of matter											
	1.2 The nuclear atom											
	1.3 Electron configurations											
	1.4 Counting particles by mass: The mole											
	1.5 Ideal gases											
Structure 2. Models of bonding and structure	2.1 The ionic model											
	2.2 The covalent model											
	2.3 The metallic model											
	2.4 From models to materials											
Structure 3. Classification of matter	3.1 The periodic table: Classification of elements											
	3.2 Functional groups: Classification of organic compounds											
Reactivity 1. What drives chemical reactions?	1.1 Measuring enthalpy changes											
	1.2 Energy cycles in reactions											
	1.3 Energy from fuels											
Reactivity 2. How much, how far and how fast?	2.1 How much? The amount of chemical change											
	2.2 How fast? The rate of chemical change											
	2.3 How far? The extent of chemical change											
Reactivity 3. What are the mechanisms of chemical change?	3.1 Proton transfer reactions											
	3.2 Electron transfer reactions											
	3.3 Electron sharing reactions											
	3.4 Electron-pair sharing reactions											
Experimental programme												

³ NB: only topics covered featured at the respective level (i.e. SL) have been included in the table.

Table V: Presence of DP chemistry AHL content in the chemistry curricula of the comparison programmes/standards.⁴

DP chemistry – AHL content		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
Structure 1. Models of the particulate nature of matter	1.2 The nuclear atom											
	1.3 Electron configurations											
Structure 2. Models of bonding and structure	2.2 The covalent model											
	2.3 The metallic model											
	2.4 From models to materials											
Structure 3. Classification of matter	3.1 The periodic table: Classification of elements											
	3.2 Functional groups: Classification of organic compounds											
Reactivity 1. What drives chemical reactions?	1.2 Energy cycles in reactions											
	1.4 Entropy and spontaneity											
Reactivity 2. How much, how far and how fast?	2.2 How fast? The rate of chemical change											
	2.3 How far? The extent of chemical change											
Reactivity 3. What are the mechanisms of chemical change?	3.1 Proton transfer reactions											
	3.2 Electron transfer reactions											
	3.4 Electron-pair sharing reactions											
Experimental programme												

Key:

	Strong presence of this topic in the comparison curriculum.		Partial presence of this topic in the comparison curriculum.		Little or no presence of this topic in the comparison curriculum.
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All the chemistry content within each comparison curriculum is considered here. To view the chemistry content within specific subjects, and how it aligns with DP chemistry, refer to the relevant country in Section 4. Subject-Level Alignment of the report.

⁴ NB: only topics covered featured at the respective level (i.e. AHL) have been included in the table.

1.4.2.1 Structure

- Some curricula differ to the DP by combining chemistry with one or more sciences in some or all their subjects. The combining of sciences is a particularly significant feature of the FB, SB, BHSC, and MBG. Indeed, the FB offers only Physics-chemistry, and the SB offers physics and chemistry in the first year and a stand-alone chemistry course in the second. The MBG core units integrate the sciences, while optional stand-alone chemistry units are offered in the final year. Lastly, in the BHSC, the formative itinerary component combines all sciences.
- Most curricula offer different levels of chemistry study in a similar way to the DP offering SL and HL. This is done by either offering subjects at different levels (as in the SGA) or by allowing students to choose how many chemistry or combined science courses they study (as in other curricula, excluding the NGSS).
- DP chemistry is unique in its organisation of content into *Structure* and *Reactivity*. Also, its overarching structure remains the same for both SL and HL, whereas the structure of content tends to differ between chemistry courses in the comparison curricula. Only the KHSCG and the SGA keep the same content structure for their different chemistry courses.
- In the DP and most comparison curricula, all content within a specific chemistry course is compulsory. The few exceptions to these are in the FNCC and VCE, which feature optional topics and areas for chemistry.

1.4.2.2 Content Alignment

- Nearly all curricula contain at least some similar content to that of the DP's main *Structure* and *Reactivity* topics. Only the BHSC had very little to no content from one of these main topics, namely *Reactivity 3. What are the mechanisms of chemical change?*.
- Coverage of the DP chemistry SL content is generally strong across all curricula, with especially the VCE, OSSD, SGA, FB, and SB showing strong alignment with most topics. Generally, a considerable amount of SL content from most of the main *Structure* and *Reactivity* topics is present across the curricula. However, it can be noted that content from *Reactivity 3. What are the mechanisms of chemical change?* is the least present across the curricula overall.
- Coverage of DP chemistry AHL content varies more across the comparison curricula. The OSSD, KHSCG, SGA, FB, and SB cover some AHL content from each of the main *Structure* and *Reactivity* topics. In particular, the SGA covers most of the AHL content in all sub-topics. The OSSD, KHSCG, FB, and SB also cover AHL content from most sub-topics, though with a higher number of sub-topics being only partially covered. In contrast, the NGSS, BHSC, MBG, and JHSC have very little presence of AHL content.

- The AHL content of certain sub-topics is more commonly covered across the comparison curricula. The most covered AHL content is from *Structure 2.4 From models to materials*, *Structure 1.2 The nuclear atom and structure*, *Structure 3.1 The periodic table: Classification of elements*, *Reactivity 1.2 Energy cycles in reactions*, and *Reactivity 2.3 How far? The extent of chemical change*. In contrast, the AHL content from some sub-topics is absent from the majority of the curricula; most notably, *Structure 2.2 The covalent model*, *Structure 3.2 Functional groups: Classification of organic compounds*, and *2.2 How fast? The rate of chemical change*.
- When considering topics or areas present in the comparison curricula but not in the DP, one notable difference is the coverage of the properties of water and the human metabolism topic areas. While the DP covers these in its biology curriculum, some comparison programmes (e.g. the VCE and KHSCG) cover them in their chemistry curricula instead. Another difference relates to the theme of making connections to 'real life'. While the DP does promote this in its nature of science section, this is less prevalent in the chemistry-specific content; while the FNCC, KHSCG, MBG, and JHSC place significant emphasis on this in their chemistry curricula. The SGA's coverage of oxides and chlorides is also more significant than that of the DP's, with SGA chemistry devoting a significant proportion of its curriculum to studying examples of these chemical compounds and trends/patterns running through these. Likewise, the BHSC features topics such as water and sewage treatment, as well as the risks associated with exposure to and improper disposal of materials. Finally, the MBG includes the chemistry of the air and nanotechnology, which do not feature in DP chemistry.
- Overall, the comparison curricula tend to feature a considerable amount of SL content. The SGA, OSSD, KHSCG, FB, and SB have the strongest content alignment with DP chemistry, as they also cover a significant proportion of AHL content.

1.4.3 Demand

The table provides a visual representation of the demand scores that the expert panel awarded to the DP chemistry subjects and respective subjects in each of the eleven comparison programmes/standards.

Table VI: The demand scores of chemistry subjects from the DP and eleven comparison programmes/standards.

Demand category	Scores																			
	DP (IB)		VCE	OSSD		FNCC		SGA			KHSCG	NGSS	FB	SB	BHSC		MBG		JHSC	
	SL	HL	Chem.	G 11	G 12	C	All	H1	H2	H3	Chem.	PS	PC	Chem.	BG	FI	C	All	AC	S
Revised Bloom's Cognitive Skills	3	3	2.5	2	2.5	2	2.5	2	2.5	3	2	2	2	2	2.5	3	2	2	2	2
Depth of Knowledge	2	3	2	1.5	2	1	2.5	1	2	3	2	1	2	2.5	1	2	1	2	1.5	2
Volume of Work	2	3	1	2	2	0.5	1.5	1	2	3	2	0	2	3	0.5	1.5	1	1	1.5	1.5
Outstanding Demand Areas	2	3	1	0	1	1	1	1	1	1	1	0	1	1	1	2	1	1	1	1

Key:

VCE (Australia): Chem: Chemistry	OSSD (Canada): G11: Grade 11 Chemistry G12: Grade 12 Chemistry	FNCC/GUSE (Finland): C: Compulsory Chemistry modules All: Compulsory and optional Chemistry modules	SGA (Singapore): H1: Higher 1 Chemistry H2: Higher 2 Chemistry H3: Higher 3 Chemistry	KHSCG (South Korea): Chem: Pathway including Chemistry I, Chemistry II, Integrated Science, and Scientific Investigation	NGSS (US): PS: Standards for Physical Sciences
FB (France): PC: Physics-chemistry	SB (Spain): Chem: Chemistry	BHSC (Brazil): BG: Basic general education FI: Formative itinerary	MBG (Mexico): C: Compulsory science units (chemistry) All: Compulsory and optional science units (chemistry)	JHSC (Japan): AC: Advanced Chemistry S: Chemistry for the Science and Mathematics Course	

- With the exception of one subject in the SGA and BHSC, all subjects in the comparison curricula score less than DP chemistry for Bloom's cognitive skills. Scores tend to be 2 or 2.5, demonstrating that, across the curricula, learning outcomes tend to have slightly less evidence of evaluation and creative thinking than the DP, though do demonstrate evidence of analysis. The only subjects scoring the same as DP chemistry (score of 3) are SGA H3 and BHSC FI.
- Except for the NGSS, all comparison curricula have at least one subject/pathway which scores the same as, or very similarly, to DP chemistry at SL for depth of knowledge. In contrast, only the SGA offers a course which scores the same as DP chemistry at HL for depth of knowledge (i.e. the maximum score for this category), though it's worth noting that the FNCC and SB offer courses which score very similarly. The OSSD, SGA, FNCC, BHSC, MBG, and JHSC include at least one subject or course which scores less than DP chemistry at SL in this category. This would also be true for KHSCG and VCE, depending on the electives/units chosen.
- In terms of volume of work, a number of comparison curricula have courses that score the same as DP chemistry SL for this category, namely the OSSD, KHSCG, SGA, and FB. In contrast, only the SGA and SB have course which has a heavy workload, same as DP chemistry HL. Notably, a number of comparison programmes/standards only feature subjects with a lower volume of work than both SL and HL, namely the VCE, FNCC, NGSS, BHSC, MBG, and JHSC.
- Except for one subject in the BHSC, all comparison subjects score less than DP chemistry at both SL and HL for outstanding demand areas. BHSC FI scores the same as DP chemistry at SL for this category.
- In summary, whilst most comparison programmes/standards offer a chemistry subject or pathway that has similar demand to that of DP chemistry SL, only the SGA offers a subject that has reasonable alignment with DP chemistry HL. Furthermore, outstanding areas of demand is the primary category in which comparison subjects score lower than DP chemistry.

2. Introduction

2.1 Context and Scope

The International Baccalaureate (IB) Organization is a not-for-profit educational foundation offering four programmes across the world, including the Primary Years Programme (PYP), Middle Years Programme (MYP), Diploma Programme (DP) and the Career-related Programme (CP). The DP – the IB’s two-year upper secondary Diploma Programme – is conceived as a preparatory programme for university matriculation and higher education, aimed at developing students with ‘excellent breadth and depth of knowledge’ who ‘flourish physically, intellectually, emotionally and ethically’.⁵

Ecctis was commissioned by the IB to conduct a series of in-depth studies to assess the level of alignment between the DP and comparison points within the upper secondary education systems of Australia (Victoria), Canada (Ontario), the United States, Singapore, South Korea, Finland, France, Spain, Brazil, Mexico, and Japan.⁶ More specifically, the studies identified areas of similarity and difference between the DP and these educational systems at the programme level by comparing philosophical underpinnings, structures, entry requirements, assessment methods, and learning pathways. The studies also examined how the DP compared with selected benchmarks in terms of intended student learning outcomes at the subject level. For all countries, the studies focused on mathematics and sciences, with some also including additional subjects, as outlined in the table below:

Table 1: Additional subjects included in the country studies

Country	Additional DP Subject(s)	Country	Additional DP Subject(s)
Australia	History	Brazil	Language A: language and literature History Philosophy Brazilian social studies (BSS)
United States	English	Mexico	Language A: language and literature
France	Philosophy Theory of knowledge (TOK)	Japan	Language A: literature Language B History
Spain	Economics Business management		

Ultimately, this series of comparative studies informed the IB’s development of tools and resources for IB teachers, helping them navigate between the DP and the local curriculum. In doing so, the studies also contributed to further supporting fair recognition of the DP by institutions, employers, and other key stakeholders, supporting progression and mobility for DP graduates.

This report forms one of the key deliverables of the project and is designed to address the research questions related to the extent of alignment between DP chemistry and the chemistry subjects within each of the eleven comparison programmes/standards examined in these studies, namely:

⁵ International Baccalaureate. (2022). *Diploma Programme*. <https://www.ibo.org/programmes/diploma-programme/>

⁶ The full reports can be accessed at: www.ibo.org/research/curriculum-research/dp-studies/dp-country-alignment-studies-2023/

- Australia: Victorian Certificate of Education (VCE)
- Canada: Ontario Secondary School Diploma (OSSD)
- Finland: Finnish National Core Curriculum (FNCC)/General Upper Secondary Education (GUSE)
- Singapore: Singaporean GCE A Level (SGA)
- South Korea: Korean High School Certificate of Graduation (KHSCG)
- US: Common Core State Standards (CCSS)
- France: French Baccalauréat (FB)
- Spain: Spanish Bachillerato (SB)
- Brazil: Brazilian High School Curriculum (BHSC)
- Mexico: Mexican Bachillerato General (MBG)
- Japan: Japanese High School Curriculum (JHSC).

2.2 Research Questions

All comparative studies in this series have been framed by responses to Research Questions (RQs), both at programme level and subject level. For this study specifically, the RQ is as follows:

Table 2: Research questions

RQ1: To what degree do the DP chemistry curricula align with the upper secondary chemistry curricula of the eleven comparison programmes? In what way are the curricula similar and in what way are they different? To what degree do the subjects align with regard to: 1.1: Content • Topics (i.e. scope of content area, breadth, depth) • Learning activities (i.e. difficulty, demand). 1.2: Expected learning outcomes • Knowledge • Competencies (i.e. subject-specific, 21st century competencies).
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With regard to subjects to be compared in the subject-level comparative analysis, the following table indicates the agreed scope:

Table 3: DP chemistry subjects and comparison subjects

		Comparison subjects per country and comparison programme					
Country	International	Australia	Canada	Finland	Singapore	South Korea	US
Programme/ Standards	DP	Victoria (VCE)	Ontario (OSSD)	Finland (FNCC)	Singapore (SGA)	South Korea (KHSCG)	Next Generation Science Standards (NGSS)
Subjects	chemistry SL and HL	Chemistry Units 1, 2, 3 & 4	Grade 9 & 10 Science: Academic Grade 11 & 12 Chemistry	Chemistry	Higher 1 (H1) Chemistry Higher 2 (H2) Chemistry Higher 3 (H3) Chemistry	Chemistry I Chemistry II Integrated Science and Scientific Investigation (common courses)	Physical Sciences standards (high school)
		Comparison subjects per country and comparison programme (continued)					
		France	Spain	Brazil	Mexico	Japan	
		France (FB)	Spain (SB)	Brazil (BHSC)	Mexico (MBG)	Japan (JHSC)	
		Physics-chemistry	Physics and Chemistry Chemistry	Natural Sciences and Technology: Basic General Education Formative Itinerary	Natural Sciences, Experimental Sciences and Technology units	Basic Chemistry Advanced Chemistry Chemistry for the Science and Mathematics Course	

DP chemistry been considered at both standard level (SL) and higher level (HL).

2.3 Report Structure

In responding to the above RQ, this report includes the following sections:

- [3. Methodology](#): this section provides a brief overview of the methodology applied in this study. This includes details of how the document selection and identification of comparison points for the study took place; a definition of 'alignment'; an outline of the methodology used for comparisons at subject level; and an outline of the methodology used to assess demand.
- [4. Subject-Level Alignment](#): this section presents the synthesised analysis from the subject-level comparisons between the DP chemistry subjects and the chemistry subjects in the eleven comparison programmes. For each comparison subject, this includes the comparative analysis on their learning outcomes, content, and demand.
- [5. Key Findings](#): this section outlines the key findings from the subject-level comparisons undertaken between the DP chemistry subjects and those of each of the eleven comparison programmes. In doing so, it provides a top-level conclusion on subject-level alignment for each programme, and a succinct summary of key similarities and key differences.
- [6. Cross-cutting findings](#): this section outlines the key cross-cutting findings from the various subject-level comparisons carried out between the DP chemistry subjects and those of each of the eleven comparison programmes. In doing so, it unpicks the main trends identified at the learning outcomes, content and demand levels, highlighting noticeable similarities and differences.
- [7. Bibliography](#): this section references all sources cited in the study, including the documents used for both programme- and subject-level curriculum analyses.

3. Methodology

3.1 Document Selection and Identification of Comparison Points

To undertake the comparative analyses at subject level, the following core documentation was reviewed (supplemented by additional documentation – detailed in the Bibliography – where relevant and available):

IB Documentation

- DP: From principles into practice
- Programme standards and practices
- DP chemistry subject guide

VCE Documentation

- Documentation by the Victorian Curriculum and Assessment authority (VCAA)
- VCE Chemistry Study Design.

OSSD Documentation

- Ontario Curriculum and Resources (website)
- The Ontario Curriculum – secondary subjects guides:
 - science (grades 9 and 10)
 - chemistry (grades 11 and 12).

Finland Documentation

- Finnish National Agency for Education – National Core Curriculum for General Upper Secondary Education
- The Finnish Curriculum – General Upper Secondary Subject Syllabus:
 - chemistry.

Singapore Documentation

- Ministry of Education (MOE) – Singapore (website)
- MOE – Singapore's Post-Secondary Education booklet
- The Singapore Curriculum – Pre-University Subject Syllabi:
 - H1 chemistry
 - H2 chemistry
 - H3 chemistry.

South Korea Documentation

- MOE – The National Curriculum for Primary and Secondary Schools
- MOE – Education in Korea (website)
- MOE – Science Curriculum, including chemistry electives.

NGSS Documentation

- 'Principles of the Framework' section in the NGSS website
- The NGSS for Physical Sciences (high school).

France Documentation

- French Baccalaureate curriculum (website), including information about underpinning philosophy and pedagogy
- The French Baccalaureate – subject programmes:
 - Physics and Chemistry *Général Première*
 - Physics and Chemistry *Général Terminale*

Spain Documentation

- Government of Spain, Ministry of Education and Vocational Training (website), including information about Key Competences of the SB,⁷ as well as the specific competences (SCs), evaluation criteria and content covered in each of the following subjects:
 - physics and chemistry
 - chemistry
- Where possible, due to the less detailed nature of the SB curriculum, this was complemented by a review of publicly available official textbooks. References to these can be found in the Bibliography section of this report.

Brazil Documentation

- Ministry of Education updates to the National Curriculum Guidelines for High School Education
- National Common Curricular Base (BNCC) for high school Natural Sciences and Technology
- Curricular References for the Preparation of Formative Itineraries
- Rio de Janeiro Referential Curriculum (RJRC)
- Rio de Janeiro specialisation pathways for formative itineraries in Natural Sciences and Technology

Mexico Documentation

- Learning Progressions for Natural Sciences, Experimental Sciences and Technology
- Programmes of Study (Science):
 - Chemical Reactions – Conservation of Matter in the Formation of New Substances
 - Conservation of Energy and its Interaction with Matter
 - Ecosystems – Interactions, Energy and Dynamics
 - Energy in the Processes of Daily Life
 - Matter and its Interactions
 - Organisms, Structures and Processes. Heredity and Biological Evolution
 - Selected Topics in Chemistry I & II

Japan Documentation

- High School Course of Study (Announced in 2018)
- Commentary on the High School Curriculum Guidelines for Science

⁷ Government of Spain, Ministry of Education and Vocational Training. (2022) Royal Decree 243/2022. <https://www.boe.es/buscar/act.php?id=BOE-A-2015-37>; https://educagob-educacionyfp-gob-es.translate.goog/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/competencias-clave.html?_x_tr_sl=es&_x_tr_tl=en&_x_tr_hl=en-US&_x_tr_pto=wapp

3.1.1 Learning Outcomes Comparison

For the Learning Outcomes comparisons, as not all subjects in each of the qualifications reviewed explicitly name learning outcomes in their syllabi, Ecctis used the following categories of the curriculum documentation for comparison:

Table 4: Learning outcomes for comparison of the DP chemistry and respective comparison subjects

Chemistry		
Programme/ Standards	Subject	Categories utilised as learning outcomes
DP	Chemistry	DP chemistry – aims and assessment objectives
Australia, Victoria (VCE)	Chemistry	Outcomes
Canada, Ontario (OSSD)	Chemistry	Overall Expectations
Finland (FNCC)	Chemistry	task of the subject transversal competences general objectives
Singapore (SGA)	Chemistry H1, H2, H3	Practices of Science, Syllabus Aims
South Korea (KHSCG)	Chemistry I, Chemistry II, integrated science, scientific investigation	subject introductions (titled 'Character') objectives
USA (NGSS)	Physical Sciences standards (high school) (NGSS physical sciences)	High school Physical Sciences standards • HS-PS1 Matter and its Interactions • HS-PS2 Motion and Stability: Forces and Interactions • HS-PS3 Energy • HS-PS4 Waves and their Applications in Technologies for Information Transfer⁸
France (FB)	Physics-chemistry	Skills developed as part of scientific research
Spain (SB)	Physics and Chemistry Chemistry	Specific Competencies
Brazil (BHSC)	Natural Sciences and Technology (Basic General Education and Formative Itinerary)	Specific Competencies and skills in the BNCC Skills in the curricular references for formative itineraries.
Mexico (MBG)	Natural Sciences, Experimental Sciences and Technology units	Learning Progressions Extended Disciplinary Competencies Generic Competencies
Japan (JHSC)	Basic Chemistry Advanced Chemistry	General Subjects - Science - subject area objectives and individual subject objectives
	Chemistry for the Science and Mathematics Course (SMC)	Specialised Subjects - Science and Mathematics – subject area objectives and individual subject objectives

Although not all labelled as learning outcomes per se, the above categories were chosen as they were deemed to provide the most complete picture of the skills and knowledge that students should obtain upon completion of each subject. For more information on the mapping process, see the Measuring Alignment section.

⁸ NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Topic arrangements of the NGSS*. Available from: <https://www.nextgenscience.org/overview-topics>

3.1.2 Content Comparison

For the BHSC Natural Sciences and Technology (NST) subjects, it can be noted that the analysis drew upon a range of sources to establish a more detailed picture of the chemistry content used in high school education. The primary document used for basic general education (BGE) subjects is the BNCC (National Common Curricular Base). The BNCC merges skills and content into 'specific skills' for Natural Sciences and Technology. The specific skills emphasise skills rather than describing content through topics and subtopics and are generic to all sciences. As such, to provide a more concrete picture of the chemistry content covered, the Rio de Janeiro Referential Curriculum (RJRC) for high school was used to complement the BNCC for the content analysis of chemistry in BGE.

The RJRC was also used to analyse the content of a formative itinerary (FI) specialising in Natural Sciences and Technology. While the formative itineraries offered can vary from state to state, the RJRC provided insight into the type of chemistry content that these can cover. The analysis reviewed the specialisation pathways offered in Rio de Janeiro for a formative itinerary in Natural Sciences and Technology.⁹

The following table shows the documentation and sections that were used to inform the content analysis of each BHSC Natural Sciences and Technology (NST) subject.

Table 5: Documentation and sections used for the content analysis of BHSC subjects.

	Document: BNCC	Document: Curricular references for FI	Document: RJRC
BHSC subjects	Section	Section	Section
BHSC NST (BGE)	Specific competencies and skills for NST	N/A	Chemistry (for BGE)
BHSC NST (FI)	N/A	Specific skills associated with structuring axis	NST Specialisation Pathways (for the FI)

3.2 Measuring Alignment (Similarities and Differences)

Alignment is a key concept for this series of studies, which aims to unpick the level of alignment between the DP and each of the eleven comparison programmes. Although Ecctis has sought to represent the alignment findings as straightforwardly as possible in this report, alignment is not a simple concept, so it is important to establish Ecctis' approach in this regard.

Alignment, as a term, is often used in education circles to refer to *internal* coherence between learning outcomes, assessment methods, teaching practices and other features of teaching and learning. This report does not consider *internal* alignment, but what might appropriately be labelled *external* alignment. Alignment of this type looks at the extent to which a programme (in this case, the DP) aligns with other educational programmes (in this case, the eleven comparison programmes). This form of external alignment is particularly key to understand for an organisation like the IB which operates in so many international contexts, often alongside national curricula, where teachers and students may seek to move back and forth between IB and national streams of education.

⁹ Formative itineraries which integrated several areas of knowledge were not reviewed.

Within this narrower definition of *external* alignment, the idea is still broad and could be seen from any number of perspectives. In this series of studies, the IB has specifically asked Ecctis to consider alignment from the specific perspectives outlined by the RQs. The RQs thereby define the limits of the type of alignment that have been considered within the subject reports. Namely:

- At the subject level (in selected subjects):
 - Alignment of learning outcomes
 - Alignment of content
 - Alignment of demand.

To form a comprehensive picture of alignment, Ecctis' approach has used multiple repeating steps within each report:

- Analysing to what extent each comparison programme has similarities with the DP.
- Analysing to what extent each comparison programme lacks features contained within the DP.
- Analysing to what extent the DP lacks features contained within each comparison programme.

In this respect, **alignment is a measure of the extent to which there are similarities and differences between key selected criteria of two educational programmes.** High alignment indicates significant similarities, with few differences in key areas, whereas low alignment results from many differences in important aspects, with perhaps only few or non-impactful similarities. Alignment judgements in this study took a holistic view of similarities and differences and the likely impact these will have on what skills and knowledge students possess upon completion of a subject and programme of study. As such, the study did not use fixed quantitative criteria to differentiate high from low alignment, but rather produced informed, holistic judgements drawing on an outcomes-focused perspective.

3.2.1 Mapping

To accurately measure the alignment of the DP subjects to each comparison programme's subjects, it was necessary to map the similarities and differences across the selected alignment criteria. This necessitates identification of the same structural features in the DP and in the comparison programmes so that a mapping process can be undertaken.

Mapping, in this case, refers to detailed analysis of a feature of an education programme (generally as represented within that programme's documentation). Specifically, mapping applies the same analytical method to two separate sets of data (for example, the learning outcomes of two different curricula), enabling similarities and differences between those two data sets to be understood through the different results of applying the same mapping method to both. Another important feature of mapping is that there is a paper trail of the analysis, as the approach is methodical, testable, and repeatable.

Section 3.3 below provides further detail on how mapping has been applied in this study at subject level. For more information on how mapping has been applied in this series of studies at programme level, refer to sections 3.2.1 of the country alignment reports.

3.3 Method: Subject-Level Comparison

Different methods were used to analyse the alignment at subject level regarding learning outcomes, subject content, and demand. Each approach is outlined below.

3.3.1 Learning Outcomes

To analyse the alignment of learning outcomes at the subject level, the process began by extracting six to eight themes from the DP's subject-level learning outcomes for each subject being analysed, encompassing both skills and knowledge areas. This thematic code was then mapped onto the learning outcomes of the DP subject and the comparison subjects from the eleven comparison programmes.

The top-level results of the mapping process are represented with a table per subject. Following the tables, a written commentary is provided regarding the presence of DP knowledge areas and skills (represented by themes) in each comparison subject and any significant knowledge areas and skills found in the respective comparison subject but not in the DP.

3.3.2 Content

To compare the content of the DP subjects and the comparison subjects, these are presented in the document in a simple tabular format. Additionally, content mapping took place through a simple process of establishing whether each content sub-topic covered by the DP subject in question has 'clear alignment' with any content in the comparison subjects. The mapping spreadsheets demonstrate the full logic of all judgements.

A commentary is provided on DP subject content not found to have alignment points in the comparison subjects and on comparison subject content topics not found to have alignment points in the DP subjects.

3.3.3 Demand

Comparing the demand of subject curricula is perhaps the most complex mapping and alignment analysis within this report. Ecctis' approach views demand from multiple perspectives to capture its relationship to skills as well as to the detail and scope of content.

To allow for a comprehensive assessment of the level of demand of the DP selected subjects against the respective comparison points, Ecctis has created a Demand Profile for each subject in the study. Each Demand Profile comprises four criteria designed to judge complexity, depth, breadth, workload levels and potential for intellectual stretch. These criteria have been applied uniformly across all subjects in the study, using an expert panel-approach (as outlined below).

Demand Profile – Subject-level Judgement

The Demand Profile is comprised of four scores (each between zero and three) based on specific criteria. Each score within each category has a specific definition which is listed in [Appendix A](#). A panel of subject, teaching, and curriculum design experts analysed each subject curriculum and arrived at a consensus on which score descriptor in each category best

matched with the curriculum in question. The categories which comprise the Demand Profile are as follows:

- **Revised Bloom's Cognitive Skills** score (0-3): this is an overall score of course demand, based entirely on a review of learning outcomes. Levels have been defined based on increasing emphasis of higher order cognitive skills taken from Bloom's Revised Taxonomy.¹⁰
- **Depth of Knowledge** (adapted from Webb's) score (0-3): this is an overall score evaluating the depth of knowledge or complexity of knowledge and skills required by curriculum standards and expectations. The score is focused on subject content and learning outcomes, complemented by assessment where relevant/possible. Levels have been defined based on the level of detail studied per topic, as well as the levels of thinking described in Webb's Depth of Knowledge framework.¹¹
- **Volume of Work** score (0-3): this is a trifactor score, considering:
 - a. breadth of content – i.e. how many topics and sub-topics are covered
 - b. depth of content – i.e. the extent to which the topics and sub-topics are focused upon, amplified and explored.¹²
 - c. specified timeframe – i.e. the time allocated for studying the subject.

The three factors – breadth, depth, and time – were all considered in defining the levels.
- **Outstanding Areas of Subject Demand** score (0-3): this score reflects the number of content areas viewed as more challenging and/or conducive to intellectual stretching of students. Levels have been defined on a scale of increasing number of 'stretch areas'.

Demand Panel: Expert Judgement Procedure

Demand analysis and judgements against the above criteria rested with a panel of experts comprised of both curriculum and teaching experts – i.e. international education researchers experienced in comparative secondary curriculum evaluation – and subject experts – i.e. researchers and consultants with a subject specialism in the relevant subject areas. For both expert types, teaching experience, understanding of appropriate national/international teaching contexts, and experience of curriculum and learning outcomes comparisons were prioritised.¹³

Five expert panels were hosted to judge the demand levels of the science subjects in this series of studies, details of each panel are shown below:

¹⁰ Krathwohl, D. (2002). A Revision of *Bloom's taxonomy: An Overview*. Theory Into Practice, Vol 41(4). Available from: www.tandfonline.com/doi/abs/10.1207/s15430421tip4104_2?journalCode=htip20

¹¹ Webb, N. L. (2002). *Depth-of-knowledge levels for four content areas*. Language Arts. Available from: [Microsoft Word - Webb DOK all content.doc \(pbworks.com\)](http://www.pbworks.com/Word-Webb-DOK-all-content.doc)

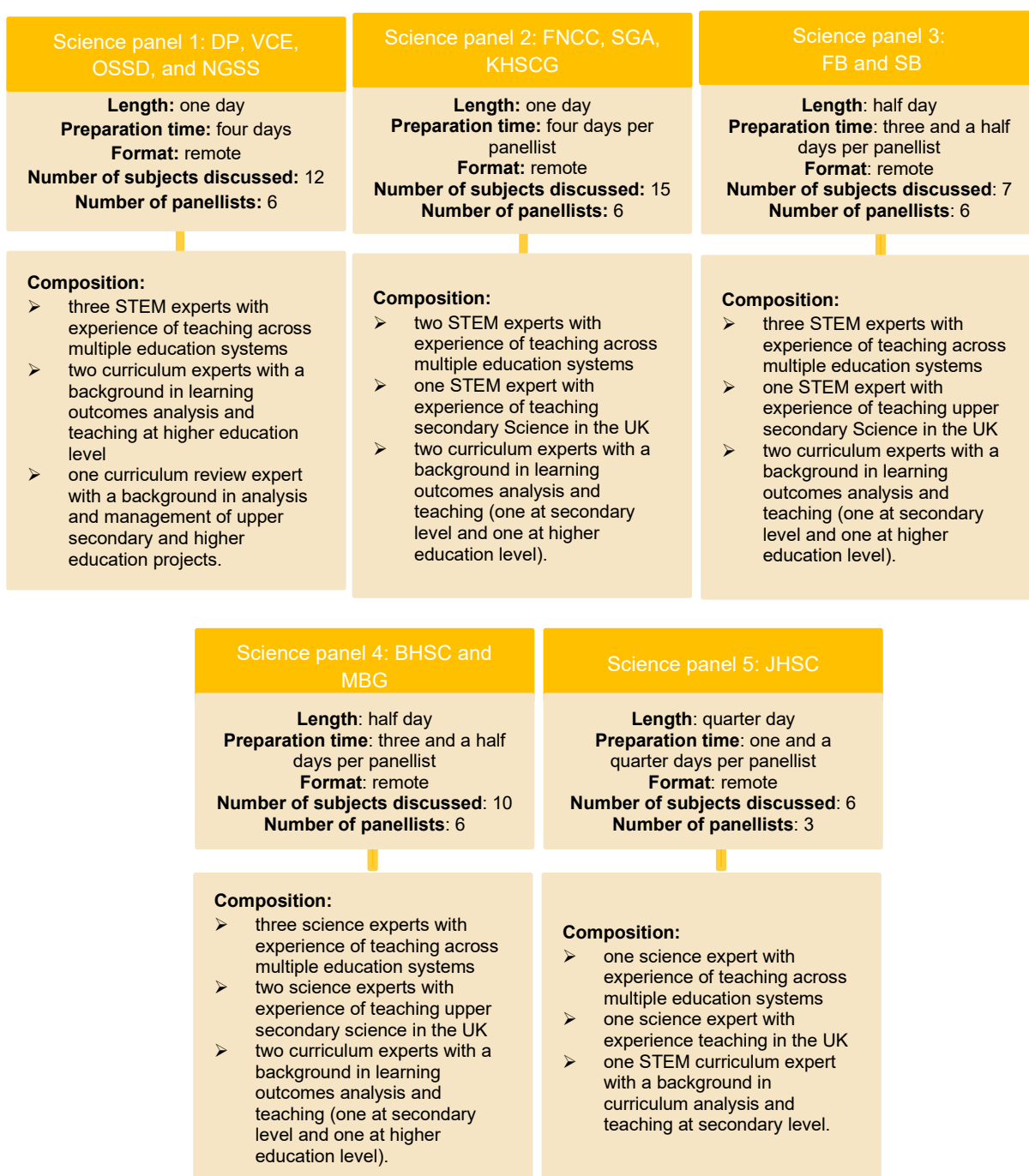
¹² Note: 'depth of content' primarily describes what is on the curriculum (i.e. the level of detail comprised in each topic), whereas 'depth of knowledge' describes what the students need to be able to do (i.e. how complex and extensive the thinking processes involved are).

¹³ To minimise potential biases and subjectivity, Ecctis' recruitment procedure excluded candidates with experience of teaching any of the comparison qualifications in this study.

1. Panel discussed the DP subjects and the subjects from the Victorian (Australia), Canadian (Ontario) and NGSS (US) curricula
2. Panel discussed the subjects from the Finnish (FNCC), Singaporean (SGA) and South Korean (KHSCG) curricula
3. Panel discussed the subjects from the French (FB) and Spanish (SB) curricula
4. Panel discussed the subjects from the Brazilian (BHSC) and Mexican (MBG) curricula
5. Panel discussed the subjects from the Japanese (JHSC) curriculum.

For each of these panels, the composition was as follows:

Figure 1: Demand panels details



All panellists were provided with the relevant extracts from the appropriate qualifications' specifications, including (where available):

- Learning outcomes and aims of the qualification
- Assessment structure
- Information about guided learning hours or curriculum time
- Assessment objectives
- Content.

The experts were also provided with a document containing:

- An introduction to the comparative analysis task
- Descriptions of the demand taxonomies
- The demands instrument (used to record findings).

Panellists conducted between one and four days of panel preparation, reviewing the appropriate curriculum documentation in detail and scoring each subject against the demand criteria provided (the template utilised for this has been included in [Appendix C](#)). Following this preparation, participants then took part in their respective panels, which were all hosted remotely on Microsoft Teams. The science demand panels lasted between a quarter day and one full working day.

All judgements resulted in scores from 0-3 for each demand criterion mentioned above, with each score for each criterion being pulled into each course's demand profile. The panel approach was used to debate the findings and scores reached by each member of the panel and arrive at an evidence-based consensus on every demand score for every subject.¹⁴

Visually, each demand profile is represented by radar diagrams to facilitate demand comparison between subjects.

NB: all demand scores produced should be interpreted as approximate judgements given the varying degrees of documentation and detail available for each curriculum, as well as likely variation on how the curricula are implemented in practice.

¹⁴ Note: each score was debated by the panel until a unanimous agreement was reached.

4. Subject-Level Alignment

This section focuses on answering RQ1 and the sub-questions associated to it, namely:

Table 6: Research questions

RQ1: To what degree do the DP chemistry curricula align with the upper secondary chemistry curricula of the eleven comparison programmes? In what way are the curricula similar and in what way are they different? To what degree do the subjects align with regard to: 1.1: Content • Topics (i.e. scope of content area, breadth, depth) • Learning activities (i.e. difficulty, demand). 1.2: Expected learning outcomes • Knowledge • Competencies (i.e. subject-specific, 21st century competencies).
--

Each sub-section below includes a brief overview of the respective comparison programme/standards and the comparison subjects. This is followed by an overview of the findings from the comparative analysis between the DP subjects and the comparison points regarding learning outcomes, content, and demand.

4.1 DP Chemistry Overview

The Diploma Programme (DP) was established in 1968 as a two-year pre-university programme for 16–19-year-old students.¹⁵

Students who aim to achieve the Diploma award must generally select one subject from each of the six subject groups:

- Studies in language and literature
- Language acquisition
- Individuals and societies
- Sciences
- Mathematics
- The arts.¹⁶

Students who do not wish to take a subject from the arts subject group may opt to study an additional sciences, individuals and societies, or languages course instead.

All subjects are studied concurrently over the two-year duration of the programme and most subjects can be taken at either SL or HL. In terms of teaching hours, the DP's documentation recommends 150 teaching hours for individual subjects at SL and 240 teaching hours at HL.¹⁷

¹⁵ International Baccalaureate. (2015). *Diploma Programme. From principles into practice*. p. 5.

¹⁶ International Baccalaureate. (2025). *DP curriculum*. Available from: [DP curriculum - International Baccalaureate®](#)

¹⁷ Ibid.

In addition to the six subjects taken from these groups, DP students will also need to complete three further curriculum components. Together, these three components comprise the DP 'core'. Theory of knowledge (TOK) allows students to reflect on the nature of knowledge by considering their subjects from a broader perspective.¹⁸ The extended essay is a self-directed piece of research which results in a 4000-word essay.¹⁹ Creativity, activity, service (CAS) is not formally assessed but requires that students undertake a creative endeavour, take part in something physically active, and participate in a voluntary or unpaid activity.²⁰

To achieve the IB Diploma a student must take at least three HL subjects.²¹ The maximum number of subjects that can be taken at higher level is four. HL subjects are intended to prepare learners for the discipline specialisation of higher education, whilst the SL subjects balance this by broadening the range of subjects studied.²²

As an optional subject, DP students may choose whether or not to study the DP chemistry course.

DP chemistry²³

Chemistry is a subject option offered within the DP sciences subject group, at both SL and HL. This subject has content that is common to both SL and HL, as well as AHL content that is featured only in the HL. Thus, the HL has greater breadth and depth than SL. This subject is designed to prepare students for university courses such as medicine, biological science and environmental science. HL is suitable for those intending to pursue further study in an area requiring a strong background in chemistry.

¹⁸ International Baccalaureate. (2025). *DP core*. Available from: [DP core - International Baccalaureate®](#)

¹⁹ Ibid.

²⁰ Ibid.

²¹ International Baccalaureate. (2025). *DP curriculum*.

²² International Baccalaureate. (2015). *Diploma Programme. From principles into practice*. p.6.

²³ International Baccalaureate. (2023). *Chemistry guide*.

The visual below shows the structure of the DP chemistry subject. Students taking the HL subject will study both the standard level (SL) and additional higher level (AHL) content. Students studying the SL subject will only study SL content.

Figure 2: DP chemistry content visualiser²⁴

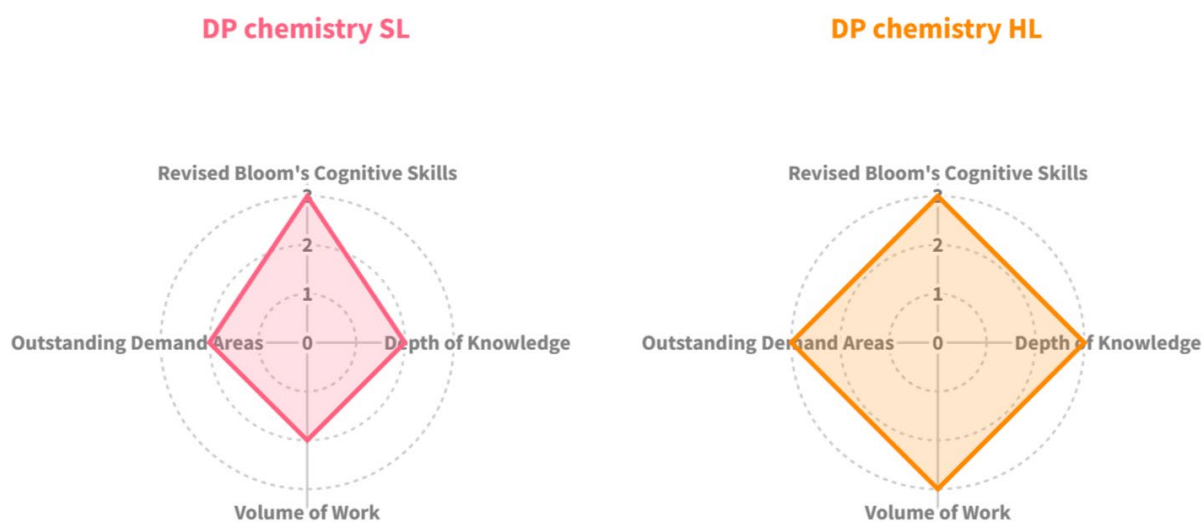
Structure	Structure 1. Models of the particulate nature of matter	Structure 1.1 – Introduction to the particulate nature of matter	Structure 1.2 – The nuclear atom (SL + AHL)	Structure 1.3 – Electron configurations (SL + AHL)	Structure 1.4 – Counting particles by mass: The mole	Structure 1.5 – Ideal gases
	Structure 2. Models of bonding and structure	Structure 2.1 – The ionic model	Structure 2.2 – The covalent model (SL + AHL)	Structure 2.3 – The metallic model (SL + AHL)	Structure 2.4 – From models to materials (SL + AHL)	
	Structure 3. Classification of matter	Structure 3.1 – The periodic table: Classification of elements (SL + AHL)	Structure 3.2 – Functional groups: Classification of organic compounds (SL + AHL)			
Reactivity	Reactivity 1. What drives chemical reactions?	Reactivity 1.1 – Measuring enthalpy changes	Reactivity 1.2 – Energy cycles in reactions (SL + AHL)	Reactivity 1.3 – Energy from fuels	Reactivity 1.4 – Entropy and spontaneity (HL only)	
	Reactivity 2. How much, how fast and how far?	Reactivity 2.1 – How much? The amount of chemical change	Reactivity 2.2 – How fast? The rate of chemical change (SL + AHL)	Reactivity 2.3 – How far? The extent of chemical change (SL + AHL)		
	Reactivity 3. What are the mechanisms of chemical change?	Reactivity 3.1 – Proton transfer reactions (includes AHL)	Reactivity 3.2 – Electron transfer reactions (SL + AHL)	Reactivity 3.3 – Electron sharing reactions	Reactivity 3.4 – Electron-pair sharing reactions (SL + AHL)	
Experimental programme	Practical work	Collaborative sciences project	Scientific investigation			

²⁴ '(HL only)' and '(SL + AHL)' are used to flag, respectively, topics only taught at HL and topics taught at both SL and HL, but which also feature additional higher level content.

The analysis in this study compared the chemistry subjects of each comparison programme with the DP chemistry.

In order to assess demand alignment between the DP chemistry and the comparison subjects, demand profiles were created for the DP chemistry SL and DP chemistry HL. Each of these were scored (0-3) in four demand categories. Below, the profiles are presented as radar diagrams. These demand profiles will be used for comparison in the demand section of each country.

Figure 3: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - DP chemistry has the same learning outcomes for both SL and HL, meaning that these scores are the same. These were judged to merit a score of 3 due to the high levels of critical thinking, critical awareness and elements of synthesis and creation present in the majority of aims and assessment objective 3.
- Regarding the scores for **Depth of Knowledge**:
 - DP chemistry SL was deemed to merit a score of 2 for Depth of Knowledge due to the mathematical pre-requisite skills and competences required to access the course, as well as the moderate to high level of cognitive complexity of the knowledge that students are expected to acquire. As to the HL course, the greater depth and additional opportunities provided for extended thinking in the additional higher level option topics pushed the score to a 3.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL was judged to comprise a moderate-heavy workload (a score of 2) as students are exposed to various chemistry topics, with each topic being allocated a standard to short time amount of time. The volume demands of the HL

course, on the other hand, were found to be sufficient to meet a score of 3 – even though the number of topics per hour is smaller, these topics are covered in great depth and with a focus on application.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - For the DP chemistry SL course (awarded a score of 2), the individual investigation research project that students need to undertake, the linking questions outlined in the syllabus and the collaborative sciences project were deemed to constitute areas of stretch. In addition to the latter, the HL course features additional higher levels topics which were deemed to include additional areas of stretch, meriting a score of 3.

4.2 Australia (Victoria)

The Victorian Certificate of Education (VCE) is awarded to students who successfully complete the last two years (11 and 12) of secondary education in the state of Victoria, Australia. This is typically achieved by successfully completing 16-24 units of study across a number of subjects. Each subject contains four units that last for one semester each and have a minimum scheduled classroom instruction time of 50 hours.²⁵ For most students, the VCE is completed over a two-year period. Students typically study Units 1 and 2 of each subject in their first year, and Units 3 and 4 in their second year.²⁶

The VCE is flexible, meaning that students can take longer than two years to complete studies if needed. Alternatively, the VCE course can also be completed in a shorter or earlier timeframe – some students may opt to start studying the VCE in year 10, while some may study Units 3 and 4 in year 11.²⁷ Additionally, those who are identified as outstanding students may opt to extend their studies by undertaking a university subject within the VCE.²⁸

Students have the option to study Unit 1 or Unit 2 of a subject as stand-alone units. However, students must enrol in Units 3 and 4 of the same subjects as a sequence. This sequence needs to be completed in the same year for the study score to be calculated.²⁹

To be awarded the VCE, candidates must successfully complete 16 units, including:

- three units from the English group, two of which must be a Unit 3 and 4 sequence.
- at least three additional Unit 3 and 4 sequences.

As illustrated by the above, students are not required to study any chemistry as part of the VCE, but they have the option to do so if they wish.

VCE chemistry³⁰

VCE chemistry is typically taken in the final two years of secondary education, Years 11 and 12 and includes four units of study. The units cover four themes within chemistry – Unit 1 is focused on the diversity of materials whilst Unit 2 covers the unique characteristics of water. Unit 3 focuses on chemical processes and their optimisation whereas Unit 4 is centred around organic compounds and chemistry. Students are not required to take all units and Units 1-3 do not have prerequisites; however, students taking Unit 4 are required to have completed Unit 3.

4.2.1 Learning Outcomes

The learning outcome themes for chemistry were taken from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for physics, chemistry, and biology. Similarly, the VCE curriculum sets out subject aims for the sciences,

²⁵ Victorian Curriculum and Assessment Authority. (n.d.). *How VCE Works – The Facts*. Available from: <https://www.vcaa.vic.edu.au/studentguides/myvce/Pages/HowVCEWorks.aspx>

²⁶ Ibid.

²⁷ Ibid.

²⁸ Ibid. No definition of what constitutes an 'outstanding student' is provided.

²⁹ Ibid.

³⁰ Victorian Curriculum and Assessment Authority. (2015). *Victorian Certificate of Education. Chemistry Study Design*. Available from: [VCE Chemistry Study Design \(vcaa.vic.edu.au\)](https://www.vcaa.vic.edu.au/VCE/Chemistry/StudyDesign)

which detail a range of intended skills and competencies on a subject level. The VCE curriculum also sets out key science skills which specify the generic scientific competencies that students are expected to develop and demonstrate throughout all four chemistry units. These are included in the cross-study specifications section of the curriculum as they apply to science subjects in general. However, in contrast to the DP, the aims and key science skills in the VCE are contextualised for each individual science – though the main concepts remain the same.

As well as the aims and key science skills, the VCE curriculum includes chemistry-specific outcomes. Indeed, each ‘area of study’ in a chemistry unit contains three ‘outcomes’ – listing topic-specific statements that address key knowledge and key skills. This differs to the DP, which does not set out specific chemistry outcomes. However, since the VCE’s sciences aims and key skills are detailed, the analysis mostly focuses on these, rather than the topic-specific outcomes in the areas of study of individual sciences.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the VCE chemistry curricula.

Table 7: Presence of the DP sciences subject group learning outcome themes in the VCE chemistry curriculum

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in VCE	
1. Conceptual understanding and making connections		Somewhat present. Developing conceptual understanding is not a focus of the aims and key science skills
2. Acquisition and application of knowledge, methods, tools, and techniques that characterise science		Present. Found in both aims and key science skills
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present. Found in both aims and key science skills
4. Skills for scientific inquiry		Present. Found in both aims and key science skills
5. Development of technological skills		Present. Found in the key science skills
6. Effective collaboration and communication		Present. Found in both aims and key science skills
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present. Found in both aims and key science skills

Key:

 This theme is well-evidenced in the learning outcomes of the VCE.	 This theme is partially evidenced in the learning outcomes of the VCE.	 This theme is not evident in the learning outcomes of the VCE.
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Presence of the DP’s Learning Outcome Themes

The DP’s learning outcome themes are found to be present in the aims and key science skills specified for all sciences – contextualised for chemistry. Application of scientific knowledge, methods, tools, and techniques are well evidenced in the VCE curricula. Examples of relevant

key science skills from the VCE curriculum relating to application include 'solving a scientific or technological problem' and 'select and use equipment, materials and procedures appropriate to [the] investigation'. Explicit reference to scientific application is also evident in the VCE aims, which include 'apply relevant occupational health and safety guidelines while undertaking practical investigations, including following recommended protocols from safety data sheets...'. Application, particularly in the context of problem solving, is also evident at unit level in outcomes which require the student to 'solve' and 'apply'.

Equally, the aims and key science skills strongly evidence the DP's theme of using creative and critical thinking, as references to analysing, evaluating, and problem-solving are frequently used throughout. Some specific examples relating to this theme are 'critically evaluate various types of information related to chemistry from journal articles, mass media and opinions presented in the public domain', 'apply ethical principles when undertaking and reporting investigations' and 'understand and apply the research, ethical and safety principles that govern the study and practice of the discipline in the collection, analysis, critical evaluation and reporting of data'. Another strong theme in the VCE is that of developing science inquiry skills. The key science skills especially related to this theme include 'Develop aims and questions, formulate hypotheses and make predictions', 'Comply with safety and ethical guidelines', and 'Construct evidence-based arguments and draw conclusions'.

Communication and collaboration skills, as well as communication of scientific ideas, are referenced throughout the units of the VCE and are explicitly included in the aims and key science skills. For example, the VCE key science skills describe that a student should be able to 'acknowledge sources of information and use standard scientific referencing conventions' and develop 'a range of individual and collaborative science investigation skills'. Moreover, the aims state that students should be enabled to 'communicate clearly and accurately an understanding of the discipline using appropriate terminology, conventions and formats'.

Regarding the DP's theme of awareness of global and local issues and the ethical, environmental, societal, and cultural impact of science, the VCE curricula demonstrate this theme mostly in their aims. Indeed, the aims similarly state that students should 'develop an informed perspective on contemporary science-based issues of local and global significance'; 'understand the cooperative, cumulative, evolutionary and interdisciplinary nature of science as a human endeavour, including its possibilities, limitations and political and sociocultural influences'; and 'analyse and evaluate bioethical issues using relevant approaches to bioethics and ethical concepts, including the influence of social, economic, legal and political factors relevant to the selected issue'.

Nevertheless, it can be noted that developing conceptual understanding is not a focus of the VCE chemistry learning outcomes, though it is implied in the key science skills statement 'discuss relevant chemical information, ideas, concepts, theories and models and the connections between them'.

Other Themes in the VCE

Although mainly skills-focused, the VCE aims also provide additional detail on the attitudes and values intended to be developed in students throughout the study. For example, VCE students are supposed to 'develop attitudes that include curiosity, open-mindedness, creativity, flexibility, integrity, attention to detail and respect for evidence-based conclusions'.

These attitudes fall outside of the scope of the DP learning outcome themes but may relate more to the attributes expressed in the IB learner profile, for example 'Risk Taker', 'Open-Minded' and 'Principled'.

Summary

The chemistry learning outcomes of the DP and VCE are well aligned. The VCE learning outcomes have similar themes to the DP – including application, creativity and critical thinking, scientific inquiry skills, technological skills, effective communication and collaboration, and wider awareness of issues and impacts. Nevertheless, although there are many similarities, the VCE LOs lack the explicit emphasis on developing conceptual thought. Moreover, the VCE LOs include a statement about the types of attitudes students should develop which are not explicitly mentioned in the DP's learning outcomes, though the IB does cover this through its IB learner profile.

4.2.2 Content

This section compares and contrasts the content of the DP and VCE curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the chemistry content in the VCE is presented below in a diagram that shows the key topics and sub-topics included.

Figure 4: VCE chemistry content visualiser

Unit 1: How can the diversity of materials be explained?	Area of Study 1: How can knowledge of elements explain the properties of matter?	Elements and the periodic table	Metals	Ionic Compounds	Quantifying atoms and compounds
	Area of Study 2: How can the versatility of non-metals be explained?	Materials from molecules	Carbon lattices and carbon nanomaterials	Organic compounds	Polymers
	Area of Study 3: Research investigation	Options: The origin of the elements; The development of the periodic table; The lanthanoids and actinoids; Using light to solve chemical puzzles; Glass; Crude oil; Surfactants; Polymers and composite materials; Nanomaterials; The life cycle of a selected material or chemical.			
Unit 2: What makes water such a unique chemical?	Area of Study 1: How do substances interact with water?	Properties of water	Water as a solvent	Acid-base (proton transfer) reactions in water	Redox (electron transfer) reactions in water
	Area of Study 2: How are substances in water measured and analysed?	Water sample analysis	Measurement of solubility and concentration	Analysis for salts in water	Analysis for organic compounds in water
	Area of Study 3: Practical investigation	On completion of this unit the student should be able to design and undertake a quantitative laboratory investigation related to water quality, and draw conclusions based on evidence from collected data.			Analysis for acids and bases in water
Unit 3: How can chemical processes be designed to optimise efficiency?	Area of Study 1: What are the options for energy production?	Obtaining energy from fuels	Fuel choices	Fuel cells as a source of energy	
	Area of Study 2: How can the yield of a chemical product be optimised?	Rate of chemical reactions	Extent of chemical reactions	Production of chemicals by electrolysis	Rechargeable batteries
	Area of Study 3: School-based assessment	The student's level of achievement in Unit 3 is determined by School-assessed Coursework. Coursework tasks are completed mainly in class and within a limited timeframe.			
Unit 4: How are organic compounds categorised, analysed and used?	Area of Study 1: How can the diversity of carbon compounds be explained and categorised?	Structure and nomenclature of organic compounds	Categories, properties and reactions of organic compounds	Analysis of organic compounds	
	Area of Study 2: What is the chemistry of food?	Key food molecules	Metabolism of food in the human body	Energy content of food	
	Area of Study 3: Practical investigation	On completion of this unit the student should be able to design and undertake a practical investigation related to waves or fields or motion, and present methodologies, findings and conclusions in a scientific poster.			

4.2.2.1 Structure

In the VCE curriculum, there is one pathway, with students studying all high school science topics outlined. In contrast, the DP provides two routes for learning, SL and HL, with the HL chemistry content being more conceptually demanding and explored in greater depth.

The VCE chemistry course is arranged into four units spanning the course of two years. Within each unit, there are up to three areas of study, with Area of Study 1 focusing on acquisition of knowledge and subsequent areas featuring a greater emphasis on application of knowledge and practical investigations. These units are prefaced with the expected science skills and how students should communicate their understanding from investigations. Like the VCE chemistry course, DP chemistry provides guiding questions for each unit, in addition to this DP chemistry comprises six syllabus components that incorporate understandings, learning outcomes, and links to the 'Skills of the study of chemistry' and 'Nature of science'.

The main structural difference between the two courses lies in the order and extent to which content is typically taught. In the DP, topics taught at HL to some extent build on content covered in SL, whereas in the VCE chemistry there is less progression in terms of the content between units, with no prerequisite content from Unit 1 being required to take Units 2 and 3, for example.

4.2.2.2 Content Alignment

To complement the analysis on content alignment, the table below represents a simplified summary of the VCE's content alignment, at topic-level, with DP chemistry (SL and HL).

Table 8: Summary of content alignment between the DP chemistry topics and the VCE's chemistry curriculum

DP chemistry topics	SL presence in the VCE	AHL presence in the VCE
Structure 1. Models of the particulate nature of matter		
Structure 1.1 – Introduction to the particulate nature of matter		N/A
Structure 1.2 – The nuclear atom		
Structure 1.3 – Electron configurations		
Structure 1.4 – Counting principles by mass: The mole		N/A
Structure 1.5 – Ideal gases		N/A
Structure 2. Models of bonding and structure		
Structure 2.1 – The ionic model		N/A
Structure 2.2 – The covalent model		
Structure 2.3 – The metallic model		
Structure 2.4 – From models to materials		
Structure 3. Classification of matter		
Structure 3.1 – The periodic table: Classification of elements		
Structure 3.2 – Functional groups: Classification of organic compounds		
Reactivity 1. What drives chemical reactions?		
Reactivity 1.1 – Measuring enthalpy changes		N/A
Reactivity 1.2 – Energy cycles in reactions		
Reactivity 1.3 – Energy from fuels		N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A	
Reactivity 2. How much, how fast and how far?		
Reactivity 2.1 – How much? The amount of chemical change		N/A
Reactivity 2.2 – How fast? The rate of chemical change		
Reactivity 2.3 – How far? The extent of chemical change		

Reactivity 3. What are the mechanisms of chemical change?		
Reactivity 3.1 – Proton transfer reactions		
Reactivity 3.2 – Electron transfer reactions		
Reactivity 3.3 – Electron sharing reactions		N/A
Reactivity 3.4 – Electron-pair sharing reactions		
Experimental programme		

Key:

	<i>Strong presence of this topic in the VCE</i>		<i>Partial presence of this topic in the VCE</i>		<i>Little or no presence of this topics in the VCE</i>
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There is a high level of content alignment between the DP chemistry SL and the VCE chemistry. As can be seen above, the majority of DP chemistry SL topic areas is also covered in the VCE chemistry, with exception of energy cycles in reactions, electron sharing reactions, and electron-pair sharing reactions.

The VCE also offers coverage of approximately half of the AHL content in the DP chemistry HL, offering considerable coverage of a number of sub-topics, including periodicity, the metallic model, classification of organic compounds. However, differences in depth are apparent, for example, in thermochemistry, with no direct reference to coverage of Hess's Law and energy cycles in the VCE chemistry. Furthermore, although some coverage of bonding and energy diagrams is included in the VCE chemistry, bond enthalpies overall are not covered in comparable depth to the DP HL. Other DP HL areas not included in the VCE chemistry include entropy, hybridization, activation energy, Lewis acids and bases and pH curves.

There are also some areas covered in the VCE chemistry content which are not covered in the DP chemistry. Some of the most significant ones include Faraday's law calculations, Carbon 13 nuclear magnetic resonance (NMR), properties and analysis of water, key food molecules and metabolism in the human body (though the last three are covered in DP biology).

Table 9: VCE chemistry content which is not covered in the DP

Significant VCE chemistry content which is not included in the DP*
○ Properties and analysis of water ○ Carbon 13 nuclear magnetic resonance ○ Key food molecules ○ Metabolism of food in the human body ○ Faraday's law calculations ○ Option topics Unit 1 AOS 3 – Life cycle assessments, Nanoparticles, Surfactants, Synchrotron light, Lanthanoids and actinoids, The origin of elements, The development of the periodic table (NB: students only select one option).

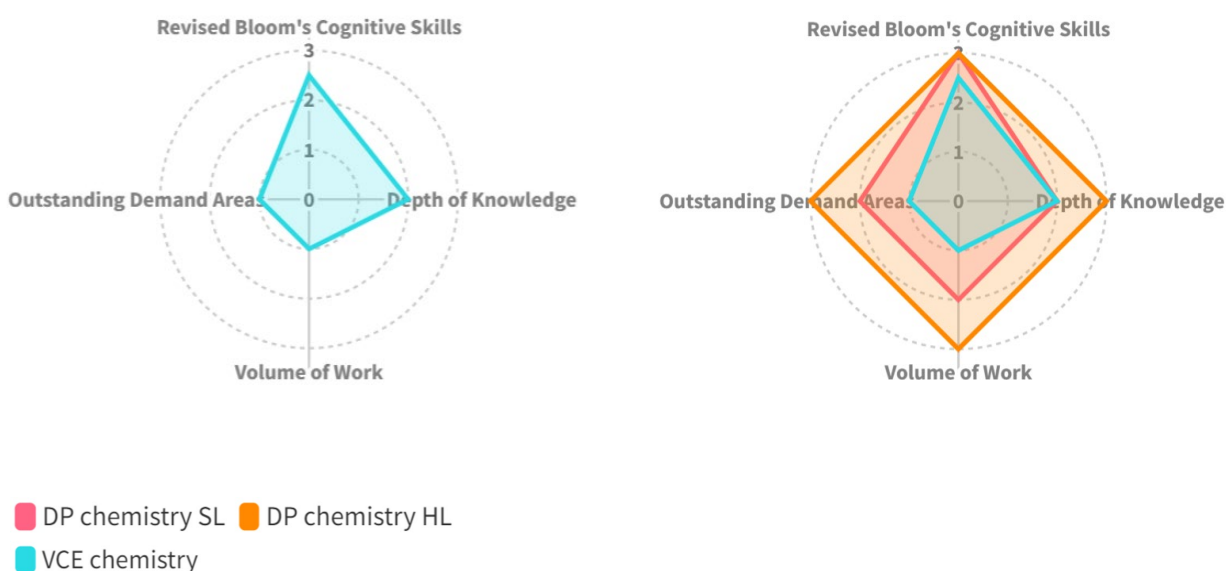
*Significant content mostly does not include topics which are typically studied *prior* to upper secondary

Overall, the VCE chemistry has a strong level of alignment with the DP chemistry SL, and some alignment with the DP chemistry HL, though a significant proportion of the AHL content is not covered.

4.2.3 Demand

The DP and VCE curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, and VCE chemistry. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing the profiles superimposed in one place, enabling immediate visual comparison.

Figure 5: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.
 - For VCE chemistry, a score of 2.5 was awarded, with Units 1 and 2 deemed to meet a score of 2 and Units 3 and 4 a score of 3. There was agreement that the learning outcomes featured a predominant focus on analysis and evaluation, methods and scientific models and that some synthesis and creation skills (in the form of investigation and research) were included too, though this was not deemed to be sufficient to meet a score of 3.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - For VCE chemistry, the cognitive complexity in the course, the (non-explicit) pre-requisites for accessing Units 1 and 2 and explicit pre-requisites for accessing Units 3 and 4, as well as a predominant focus on application of knowledge, were deemed to merit a score of 2.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.

- In contrast, the VCE chemistry course was attributed a score of 1 (moderate) due to the comparatively generous time allocation provided per topic studied.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - In VCE chemistry, the research investigation outlined in Unit 1 Area of Study 3 and the student-designed practical investigation on water quality outlined in Unit 2 Area of Study 3 were identified as areas of stretch, meriting a stretch score of 1.

4.3 Canada (Ontario)

The school system in the Canadian province of Ontario is overseen by the Ontario Ministry of Education. It is divided into primary school (grades 1-8) and secondary school (grades 9-12), with each grade being a year in duration.³¹

The Ontario Secondary School Diploma (OSSD) spans the last four years of Ontario's secondary school education, grades 9-12. Beginning in grade 9, students take courses to earn credits towards the OSSD, which is intended to grant access to higher education upon successful completion. There are several credit, and other, requirements, to gain the OSSD.

To earn a high school diploma in Ontario, students must:

- Earn a minimum of 30 credits, including 18 compulsory credits (see table below) and 12 optional credits selected from the courses listed as available in their school's programme and course calendar.
- Meet the provincial secondary school literacy requirement (i.e. usually, this means passing the Ontario Secondary School Literacy Test³²)
- Complete a minimum of 40 hours of community involvement activities (a requirement aimed to provide students the opportunity to develop awareness and understanding about civic responsibility).³³

Table 10: Compulsory credits for attaining the OSSD

Compulsory credits for attaining the OSSD (Total of 18)
• 4 credits in English (1 credit per grade) • 3 credits in mathematics (at least 1 credit in grade 11 or 12) • 3 credits for group 1, 2 and 3 courses (1 credit in each group) • 2 credits in science • 1 credit in Canadian history (grade 10) • 1 credit in Canadian geography (grade 9) • 1 credit in the arts • 1 credit in health and physical education • 1 credit in French as a second language • 0.5 credit in career studies • 0.5 credit in civics and citizenship

Courses are not only categorised by subject, but also by the stream within which they sit.

Types of courses available:

- Grades 9 and 10 – courses will be either 'Academic', 'Applied', or 'Open'. More recently, some subjects that were previously streamed in grade 9 have now been de-streamed.³⁴
- Grades 11 and 12 – courses will be either 'University Preparation', 'College Preparation', 'University/College Preparation', 'Workplace', or 'Open'.

³¹ Government of Ontario, Ministry of Education. (2020). *Education and Training*. Available from: <https://www.ontario.ca/page/educationand-training>

³² Education Quality and Accountability Office. (n.d.). *Ontario Secondary School Literacy Test (OSSLT)*. Available from: <https://www.eqao.com/the-assessments/osslt/>

³³ Government of Ontario, Ministry of Education. (2020). *High school graduation requirements*. Available from: <https://www.ontario.ca/page/high-school-graduation-requirements#section-3>

³⁴ Meaning that, for grade 9 core courses, students no longer choose between the Academic and Applied levels.

The analysis for Ontario focuses on the science courses offered in grades 9 and 10 and the chemistry grade 11 and grade 12 University Preparation (UP) courses. For content and demand, the analysis focuses on how grade 11 and grade 12 courses align with the DP, due to grades 9 and 10 being more typical of learning prior to upper secondary chemistry.

OSSD grades 9 and 10 science: Academic³⁵

Grades 9 and 10 are split into two streams, Academic and Applied. For the purposes of this report, the Academic stream and following courses will be the focus. The different areas of science are integrated at this grade to include concepts in chemistry, biology, physics, and earth and space science. The academic stream develops students' skills through the study of theory and abstract problems, whereas the applied stream emphasises practical applications. Students need to study the grade 10 Academic course to be able to access UP chemistry courses.

OSSD grades 11 and 12 chemistry: University Preparation³⁶

Grades 11 and 12 offer University Preparation, University/College Preparation, College Preparation, and Workplace courses. For the purposes of this report, the courses offered in University Preparation will be the focus. Chemistry is offered as a course from grade 11 and can be continued on to grade 12. These courses will prepare students for further study and are designed to satisfy university science programme requirements.

4.3.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of chemistry.

The learning outcome themes for chemistry were taken from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for physics, chemistry, and biology. Similarly, the OSSD sets out three goals which are the same for all science courses. These goals inform the three overall expectations found in each strand of a course; they also underlie assessment of student achievement.

The OSSD goals are the following:

- Goal 1. To relate science to technology, society, and the environment.
- Goal 2. To develop the skills, strategies, and habits of mind required for scientific investigation.
- Goal 3. To understand the basic concepts of science.

Each of the goals above had descriptions which were used for the analysis. Goal 2 was elaborated on in the section 'Developing Skills of Investigation and Communication', thus these details were also used.

³⁵ Government of Ontario, Ministry of Education. (2008). *The Ontario Curriculum Grades 9 and 10 Science*. Available from: [The Ontario Curriculum, Grades 9 and 10: Science, 2008 \(revised\) \(gov.on.ca\)](https://www.gov.on.ca/edu/ol308/science/science2008.pdf)

³⁶ Government of Ontario, Ministry of Education. (2008). *The Ontario Curriculum Grades 11 and 12 Science*. Available from: [The Ontario Curriculum, Grades 11 and 12: Science, 2008 \(revised\) \(gov.on.ca\)](https://www.gov.on.ca/edu/ol308/science/science2008.pdf)

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the OSSD chemistry curricula.

Table 11: Presence of the DP sciences learning outcome themes in the OSSD science/chemistry curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in Ontario's (OSSD) learning outcomes for science	
1. Conceptual understanding and making connections		Mostly present. Conceptual knowledge is referred to in Goal 3. Making connections is referred to in Goal 1, but with regard to the real-world, rather than within science
2. Acquisition and application of knowledge, methods, tools, and techniques that characterise science		Present. Goal 3 deals with acquisition of knowledge and theme is implied in other Goals
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present. Critical and creative thinking skills are focused on in Goal 2.
4. Skills for scientific inquiry		Present. Skills for scientific inquiry are the focus of Goal 2
5. Development of technological skills		Present. Goal 1 describes 'technical literacy'
6. Effective collaboration and communication		Mostly present. Communication is focused on in Goal 2; however, collaboration is not explicitly mentioned
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present. Relating science to technology, society and the environment is the focus of Goal 1

Key:

	<i>This theme is well-evidenced in the learning outcomes of the OSSD.</i>		<i>This theme is partially evidenced in the learning outcomes of the OSSD.</i>		<i>This theme is not evident in the learning outcomes of the OSSD.</i>
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Presence of the DP's Learning Outcome Themes

As can be seen from the table above, all the DP's learning outcome themes are present in the OSSD, with only a couple of small differences. Firstly, the DP's theme regarding global and local issues and scientific implications is strongly evident in the OSSD. Indeed, designed to emphasise scientific, environmental, and technological literacy, Goal 1 focuses on relating science to technology, society, and the environment. From references to 'technological literacy' it follows that another of the DP's themes, developing technological skills, is also present in Goal 1.

Furthermore, the OSSD places similar significance on skills for scientific inquiry through Goal 2, which includes 'Developing Skills of Investigation and Communication'. There are four broad areas in which these skills are developed, namely 'Interpreting and planning', 'Performing and recording', 'Analysing and interpreting', and 'Communication'. As well as combining to satisfy the DP's theme of scientific inquiry skills, some of these areas also evidence other themes. For example, 'Analysis and interpreting' and 'Interpreting and planning' detail skills such as

brainstorming, formulating hypotheses, making predictions, thinking critically and logically, evaluating and analysing data, solving problems, drawing and justifying conclusions, and synthesis – thus the DP's theme of creativity and critical thinking is well evidenced in the OSSD. Furthermore, the area of 'Communication' details skills such as attention to detail, applying correct terminology, and using various forms and formats to communicate scientific ideas, information and results, hence the DP's theme of effective communication is well evidenced here. However, it can be noted that collaboration is not explicitly mentioned in the OSSD outcomes, although there is reference to oral communication.

Additionally, the DP's theme of using and applying knowledge, methods, tools, and techniques is not an explicit outcome in the OSSD but is obviously implied throughout the Goals. Finally, Goal 3 refers to 'conceptual knowledge' students are expected to understand, which aligns with the DP's theme regarding conceptual understanding. Moreover, making connections is a feature within the OSSD's outcomes; however, emphasis is on connections to the real-world, rather than within and between scientific disciplines.

Other Themes in the OSSD

Although the OSSD sets out goals which are applicable to all science courses, unlike the DP it also presents specific overall expectations within each course. Each course is split into strands, each of which have three overall expectations, informed by the goals. When contextualising the goals with courses' overall expectations, one immediate difference which emerges is that the OSSD has a clear focus on Canadians' contributions to the field, and the recognition of indigenous peoples' knowledge and customs. This focus gives the OSSD science courses a more nationalistic rooted identity, whereas the DP outcomes are framed around global and international perspectives.

Furthermore, an overall expectation which is common to all science courses in the OSSD is 'identify and describe careers related to the fields of science under study to those fields', hence the OSSD outcomes explicitly expect students to show an understanding of the careers that study of science can relate/lead to. By contrast, the DP's learning outcomes do not make this explicit link to careers, thus the OSSD emphasises the movement between study and the workplace more. However, by the nature of the OSSD UP courses and the DP, both have a focus towards further tertiary study. This would be accessing university level courses majoring in chemistry or related disciplines such as engineering or other sciences.

Summary

The science learning outcomes of the DP and OSSD are highly aligned. The programmes contain very similar learning outcome themes for their science courses, with only small differences emerging.

4.3.2 Content

This section compares and contrasts the content of the DP and OSSD curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the chemistry content in the OSSD is presented below in diagrams that show the key topics and sub-topics included.

Figure 6: Ontario science grades 9-10 content visualiser

Science, grade 9, Academic	Biology	Ecosystems consist of a variety of components, including, in many cases, humans.	The sustainability of ecosystems depends on balanced interactions between their components.	Human activity can affect the sustainability of aquatic and terrestrial ecosystems.	
	Chemistry	Elements and compounds have specific properties that determine their uses.	The use of elements and compounds has both positive and negative effects on society and the environment.		
	Earth and Space Science	Celestial objects in the solar system and universe have specific properties that can be investigated and understood.	Technologies developed for space exploration have practical applications on Earth.		
	Physics	Electricity is a form of energy produced from a variety of non-renewable and renewable sources.	The production and consumption of electrical energy has social, economic, and environmental implications.	Static and current electricity have distinct properties that determine how they are used.	
Science, grade 10, Academic	Biology	Plants and animals, including humans, are made of specialized cells, tissues, and organs that are organized into systems.	Developments in medicine and medical technology can have social and ethical implications.		
	Chemistry	Chemicals react with each other in predictable ways.	Chemical reactions may have a negative impact on the environment, but they can also be used to address environmental challenges.		
	Earth and Space Science	Earth's climate is dynamic and is the result of interacting systems and processes.	Global climate change is influenced by both natural and human factors.	Climate change affects living things and natural systems in a variety of ways.	People have the responsibility to assess their impact on climate change and to identify effective courses of action to reduce this impact.
	Physics	Light has characteristics and properties that can be manipulated with mirrors and lenses for a range of uses.	Society has benefited from the development of a range of optical devices and technologies.		

Figure 7: Ontario chemistry grades 11-12 content visualiser

Chemistry, grade 11, University Preparation	Matter, Chemical Trends, and Chemical bonding	Every element has predictable chemical and physical properties determined by its structure.	The type of chemical bond in a compound determines the physical and chemical properties of that compound.	It is important to use chemicals properly to minimize the risks to human health and the environment
	Chemical Reactions	Chemicals react in predictable ways	Chemical reactions and their applications have significant implications for society and the environment.	
	Quantities in Chemical Reaction	Relationships in chemical reactions can be described quantitatively	The efficiency of chemical reactions can be determined and optimized by applying an understanding of quantitative relationships in such reactions.	
	Solutions and Solubility	Properties of solutions can be described qualitatively and quantitatively, and can be predicted.	Living things depend for their survival on the unique physical and chemical properties of water.	People have a responsibility to protect the integrity of Earth's water resources
	Gases and Atmospheric Chemistry	Properties of gases can be described qualitatively and quantitatively, and can be predicted.	People have a responsibility to protect the integrity of Earth's atmosphere.	
Chemistry, grade 12, University Preparation	Organic Chemistry	Organic compounds have predictable chemical and physical properties determined by their respective structures.	Organic chemical reactions and their applications have significant implications for society, human health, and the environment.	
	Structure and Properties of Matter	The nature of the attractive forces that exist between particles in a substance determines the properties and limits the uses of that substance.	Technological devices that are based on the principles of atomic and molecular structures can have societal benefits and costs.	
	Energy Changes and Rates of Reaction	Energy changes and rates of chemical reactions can be described quantitatively.	Efficiency of chemical reactions can be improved by applying optimal conditions.	Technologies that transform energy can have societal and environmental costs and benefits.
	Chemical Systems and Equilibrium	Chemical systems are dynamic and respond to changing conditions in predictable ways	Chemical systems are dynamic and respond to changing conditions in predictable ways	
	Electrochemistry	Oxidation and reduction are paired chemical reactions in which electrons are transferred from one substance to another in a predictable way.	The control and applications of oxidation and reduction reactions have significant implications for industry, health and safety, and the environment.	

4.3.2.1 Structure

The Ontario curriculum for grades 9 and 10 offers general science study split into academic and applied content. In grades 11 and 12, students can choose between specific subjects (e.g. biology, chemistry, physics, earth and space science) and, within those subjects, can choose between destination-related courses depending on their post high school ambitions (e.g. university preparation, university/college preparation, college preparation, and workplace preparation courses). There are prerequisites to have completed some of the grade 9 and 10 courses to progress to grade 11 and 12 courses, but these differ depending on the destination-related course a student chooses to study – e.g. completion of either the academic or the applied grade 9 course allows students to proceed directly to the grade 11 workplace preparation course. The Ontario courses outlined in the grades 9 to 12 science curriculum documents are designed as full-credit courses (100 hours of study). However, except for the grade 12 university preparation and university/college preparation courses, they may also be delivered as half-credit courses (50 hours of study).

By comparison, progression through DP chemistry is simpler – the only pre-requisite stated for DP study is to have covered SL content before progressing to HL content and, if a student wishes to study HL, it is advisable that they have some prior scientific knowledge.

Both courses emphasise, and provide opportunities for, investigation and experimentation. The DP chemistry course stipulates that students should show awareness of the purpose and practice of 13 chemistry techniques, outlined in Tool 1: Experimental Techniques, and OSSD chemistry shares coverage of the majority of those techniques, with exception of melting point determination, recrystallisation, paper chromatography, calorimetry, or drying to a constant mass.

Additionally, 30% of the final assessment in the OSSD courses is in the form of an examination, performance, essay, and/or other method of evaluation suitable to the course content and administered towards the end of the course, which could provide scope for an extended, self-directed investigation. However, the assessment method and scope vary from school to school and may not always, as a result, be comparable to the opportunities for investigation given to DP students through their IAs and collaborative sciences project.

4.3.2.2 Content Alignment

The rest of the chemistry analysis will focus on grades 11 and 12, rather than grades 9 and 10. Indeed, the studies in the first two years of the OSSD are more typical of learning *prior* to upper secondary, hence there is alignment with these grades and more meaningful comparisons to the DP can be drawn from the last two years of Ontario's secondary school education.

To complement the analysis on content alignment, the tables below represent a simplified summary of the OSSD's content alignment, at topic-level, with DP chemistry (SL and HL).³⁷

³⁷ The content of grades 9 and 10 was also mapped but is not represented in the table. Very little alignment was found with these grades due to their content being more typical of prior learning to upper secondary chemistry.

Table 12: Summary of content alignment between the DP chemistry topics and the OSSD chemistry grade 11 (university preparation)

DP chemistry topics	SL presence in the OSSD grade 11 chemistry	AHL presence in the OSSD grade 11 chemistry
Structure 1. Models of the particulate nature of matter		
Structure 1.1 – Introduction to the particulate nature of matter		N/A
Structure 1.2 – The nuclear atom		
Structure 1.3 – Electron configurations		
Structure 1.4 – Counting principles by mass: The mole		N/A
Structure 1.5 – Ideal gases		N/A
Structure 2. Models of bonding and structure		
Structure 2.1 – The ionic model		N/A
Structure 2.2 – The covalent model		
Structure 2.3 – The metallic model		
Structure 2.4 – From models to materials		
Structure 3. Classification of matter		
Structure 3.1 – The periodic table: Classification of elements		
Structure 3.2 – Functional groups: Classification of organic compounds		
Reactivity 1. What drives chemical reactions?		
Reactivity 1.1 – Measuring enthalpy changes		N/A
Reactivity 1.2 – Energy cycles in reactions		
Reactivity 1.3 – Energy from fuels		N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A	
Reactivity 2. How much, how fast, and how far?		
Reactivity 2.1 – How much? The amount of chemical change		N/A
Reactivity 2.2 – How fast? The rate of chemical change		
Reactivity 2.3 – How far? The extent of chemical change		
Reactivity 3. What are the mechanisms of chemical change?		
Reactivity 3.1 – Proton transfer reactions		
Reactivity 3.2 – Electron transfer reactions		
Reactivity 3.3 – Electron sharing reactions		N/A
Reactivity 3.4 – Electron-pair sharing reactions		

Table 13: Summary of content alignment between the DP chemistry topics and the OSSD chemistry grades 11 and 12 (university preparation)

DP chemistry topics	SL presence in the OSSD	AHL presence in the OSSD
Structure 1. Models of the particulate nature of matter		
Structure 1.1 – Introduction to the particulate nature of matter		N/A
Structure 1.2 – The nuclear atom		
Structure 1.3 – Electron configurations		
Structure 1.4 – Counting principles by mass: The mole		N/A
Structure 1.5 – Ideal gases		N/A
Structure 2. Models of bonding and structure		
Structure 2.1 – The ionic model		N/A
Structure 2.2 – The covalent model		
Structure 2.3 – The metallic model		
Structure 2.4 – From models to materials		
Structure 3. Classification of matter		
Structure 3.1 – The periodic table: Classification of elements		

DP chemistry topics	SL presence in the OSSD	AHL presence in the OSSD
Structure 3.2 – Functional groups: Classification of organic compounds		
Reactivity 1. What drives chemical reactions?		
Reactivity 1.1 – Measuring enthalpy changes		N/A
Reactivity 1.2 – Energy cycles in reactions		
Reactivity 1.3 – Energy from fuels		N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A	
Reactivity 2. How much, how fast and how far?		
Reactivity 2.1 – How much? The amount of chemical change		N/A
Reactivity 2.2 – How fast? The rate of chemical change		
Reactivity 2.3 – How far? The extent of chemical change		
Reactivity 3. What are the mechanisms of chemical change?		
Reactivity 3.1 – Proton transfer reactions		
Reactivity 3.2 – Electron transfer reactions		
Reactivity 3.3 – Electron sharing reactions		N/A
Reactivity 3.4 – Electron-pair sharing reactions		
Experimental programme		

Key:

	Strong presence of this topic in the OSSD		Partial presence of this topic in the OSSD		Little or no presence of this topic in the OSSD
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NB: Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

There is a high degree of content alignment between the OSSD and DP chemistry curricula, with the DP covering all of the significant OSSD chemistry topics and the OSSD covering all 21 SL sub-topics to either a partial or full extent. More specifically, there is similar coverage of the structure of matter and atomic structure, chemical bonding, chemical reactions/processes, and energy.

Some topics in the OSSD grade 12 chemistry course are covered in more depth than the core SL material in the DP course. However, the DP HL curriculum goes into greater depth than the OSSD curriculum in multiple areas, including the covalent model, electron pair-sharing reactions and classification of organic compounds. Furthermore, the HL course also covers the topic of entropy and spontaneity, which is entirely absent from the OSSD.

Overall, there is significant alignment between the DP and Ontario in terms of the main topics covered in the chemistry courses. Both spend a large proportion of their allotted time covering key areas of chemistry such as reactions, bonding, acids, and practical aspects of measuring chemical processes. The AHL content included within the DP curriculum exceed in depth and complexity some parts of the OSSD curricula.

Table 14: OSSD chemistry content which is not covered in the DP

Significant OSSD chemistry content which is not included in the DP*
○ All significant content is covered by DP chemistry.

* Significant content mostly does not include topics which are typically studied *prior* to upper secondary

4.3.3 Demand

The DP and OSSD curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, OSSD grade 11 chemistry, and OSSD grade 12 chemistry. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing the profiles superimposed in one place, enabling immediate visual comparison.

Figure 8: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.
 - A score of 2 was awarded to grade 11 chemistry due to the course's primary focus on analysis and application, as well as some (though limited) presence of evaluative skills. For grade 12 chemistry, though a considerable number of learning outcomes still focused on application, a more substantial focus on analysis was

observed – as a result, the course was judged to merit a 2.5 Bloom’s demand score.

- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - OSSD grade 11 chemistry was judged to merit a score of 1.5 due to the considerable prior knowledge required to access the course and the expectation that students conduct some analysis (compare and contrast) as well as demonstrate greater depth of understanding in certain topic areas. OSSD grade 12 chemistry, in turn, was given a score of 2 as, although many topics were found to be studied in higher detail, the primary focus of the course was found to be on knowledge application rather than more complex reasoning. The absence of clear opportunities for higher-order thinking prevented the course from achieving a score of 3.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - For Ontario grade 11 and grade 12 chemistry, a score of 2 was awarded. Both courses were seen to include added depth of content (when compared to their pre-secondary counterparts) and although students only study six units of work, the number of themes and concepts covered was judged to be typical to high and the time allocation per topic was considered standard.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - For Ontario grade 11 chemistry no obvious stretch areas were found. For grade 12 chemistry, the broad nature of the sample questions and the fact that some drew upon knowledge from multiple scientific subjects were seen to constitute a stretch area, awarding the course a score of 1 for this category.

4.4 Finland

The school system in Finland is overseen by the Finnish National Agency for Education (EDUFI).³⁸ Compulsory education is divided into Basic Education (years 1-9) and General Upper Secondary Education (GUSE). In Finland, students must study until they graduate from secondary education or reach the age of eighteen.³⁹ GUSE is typically three years in duration, yet students may complete the certificate in two or four years; as a result, the qualification is very fluid and there are no grade-specific classes.

An extensive reform to GUSE was launched in 2017, with changes to the Act on GUSE and the Government Decree on GUSE.⁴⁰ The aforementioned documents form the basis of the Finnish National Core Curriculum (FNCC), produced by EDUFI, with input from teaching staff, students, students' guardians, and relevant authorities. The FNCC underpins all local curriculum offerings.

In the FNCC/GUSE, each subject area is composed of different *subjects*, some of which contain different choices of *syllabi* – e.g. biology has only one syllabus, while mathematics offers two syllabi for student to choose from. Subjects/syllabi, in turn, contain *studies* (also referred to as 'modules'). There are *compulsory studies* and *national optional studies* – each study carrying different credit values.

In order to complete general upper secondary education, students must have 'passed the subject syllabi and completed the minimum scope of general upper secondary education studies, or 150 credits'.⁴¹ Of these 150 credits, a minimum of 20 must have been obtained from the completion of national optional studies. For reference, each credit is equivalent to fourteen hours and fifteen minutes of teaching, in addition to independent study.⁴²

Students must study the *compulsory credits* from all of the subjects listed in the table below.

Table 15: List of subjects and compulsory credits in the FNCC⁴³

Subjects and their compulsory credits in the FNCC
• mother tongue and literature (12 credits) • second national language, either Finnish or Swedish. (10 or 12 credits)* • foreign languages (12 credits) • mathematics (12 or 20 credits)* • biology (4 credits) • physics (2 credits) • chemistry (2 credits) • geography (2 credits) • philosophy (4 credits)

³⁸ Finnish National Agency for Education. (2022). Available from: <https://www.oph.fi/en>

³⁹ Ministry of Education and Culture, Finland. (2020). *Act on Compulsory Education (1214/2020)*. Available from: <https://www.finlex.fi/fi/laki/ajantasa/2020/20201214>

⁴⁰ Finnish National Agency for Education. (2019). *National Core Curriculum for General Upper Secondary Education*. p. 10.

⁴¹ Ibid. p. 62.

⁴² Ministry of Education and Culture, Finland. (2018). *Government Decree on General Upper Secondary Education (810/2018)*. Available from: <https://www.finlex.fi/fi/laki/alkup/2018/20180810>

⁴³ Finnish National Agency for Education. (2019). *National Core Curriculum (NCC) for General Upper Secondary Education*.

Subjects and their compulsory credits in the FNCC
• psychology (2 credits) • history (6 credits) • social studies (6 credits) • religion or worldview studies (4 credits) • health education (2 or 4 credits)* • physical education (4 credits) • music (4 credits) • visual arts (2 or 4 credits)* • guidance counselling (4 credits).
* Depending on the syllabus chosen.

As can be seen from the table above, students are required to study chemistry as part of the FNCC/GUSE.

FNCC chemistry⁴⁴

The Finnish National Agency for Education provides a framework on which local education establishments put together their curriculum. Each science discipline is composed of 'compulsory' and 'optional' studies (or modules). Students are required to study all compulsory studies, but they have free choice over which, if any, optional studies they take. Through the chemistry curriculum, students learn to understand the significance of chemistry for everyday life and society, and for solving environmental challenges. The curriculum develops students' curiosity about the study of chemistry and provides them with skills needed to succeed in further studies. Chemistry supports the understanding of concepts and phenomena in such a way that integrates their macroscopic, microscopic and symbolic levels. Observation and examination are key components in the teaching and learning of chemistry, and experimental work supports understanding and research skills.

4.4.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of chemistry.

The learning outcome themes for chemistry were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for chemistry, physics and biology. The FNCC outlines a 'task of the subject' section which provides overarching ideas about the intended development of students' knowledge and understanding in each subject. Additionally, the FNCC includes a section on 'general objectives of Instruction of chemistry' which is further broken down into three sub-sections: 'meaning, value and attitudes', 'research skills' and 'knowledge of chemistry and its use', each of which has its own objectives. An 'Assessment Framework' section is also included, providing general information regarding what skills students should be assessed on. Finally, the FNCC also includes a section on 'transversal competencies' which describes how the philosophical underpinnings of the FNCC are integrated within the instruction of chemistry as a subject – including societal competence, interaction competence, ethical and environmental competence, global and cultural competence, multidisciplinary and creative competence, as well as well-being. Notably, the FNCC as a whole has a holistic approach and puts particular emphasis on the

⁴⁴ Finnish National Agency for Education. (2019). *NCC for General Upper Secondary Education*.

integration of wider skills into their chemistry curriculum, and a lesser focus on subject content and subject-specific scientific knowledge.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the FNCC chemistry curricula.

Table 16: Presence of the DP sciences subject group learning outcome themes in the FNCC chemistry curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in FNCC	
1. Conceptual understanding and making connections		Present in all areas. FNCC describes how macroscopic, microscopic and symbolic understanding integrate themselves into a logical whole. The importance of chemistry in daily life, modern society, technology and the world of work is also highlighted.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present. The reference to students deepening their way of thinking that is typical for the natural sciences and understanding the character of natural sciences evidences the presence of this theme.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in all areas through the description of students formulating research questions, critically evaluating information and presenting arguments.
4. Skills for scientific inquiry		Present in task of the subject and general objectives. The FNCC puts the onus on the student to plan their own research and develop their own practical skills. They also utilise appropriate programs for expressing graphical solutions and results.
5. Development of technological skills		Present. In the transversal competencies, the mention of using information and communication technology to search for information, collect observations, process and interpret measurements shows the presence of this them.
6. Effective collaboration and communication		Present. The task of the subject and transversal competencies describes collaboration skills, project learning and group work, as well as joint decision-making and participating in social debates.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present. This is a strong theme of the FNCC, with emphasis on students developing a scientific worldview and understanding how chemistry is required for developing new solutions and ensuring human well-being locally, nationally and globally.

Key:

	<i>This theme is well-evidenced in the learning outcomes of the FNCC.</i>		<i>This theme is partially evidenced in the learning outcomes of the FNCC.</i>		<i>This theme is not evident in the learning outcomes of the FNCC.</i>
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Presence of the DP's Learning Outcome Themes

As can be seen in the table above, all learning outcome themes extracted from the DP are present in one or more areas of the FNCC. Conceptual understanding is evident from the emphasis placed by the general objectives on providing students with the skills needed to 'use and employ key concepts in chemistry' and 'know how to use different models to describe and

explain phenomenon and make forecasts'. Making inter-disciplinary connections, on the other hand, is implied in statements such as 'succeed in their further studies in natural sciences and other fields that apply' and 'obtain sufficient knowledge for further studies in natural sciences and fields that apply chemistry'. Notably, there is a more tenuous emphasis on making connections within the subject, as the FNCC appears to focus more on linkages between chemistry and areas outside of the subject itself (i.e. other sciences, and society at large).

The use and application of methods, tools and techniques that characterise science is evident in one of the general objectives, which requires students to 'understand the properties and development of knowledge of natural sciences and the scientific methods for producing knowledge collaboratively'. It is also mentioned under the 'Meaning, values and attitudes' sub-section, which refers to 'applying learning strategies in chemistry', and in the 'research skills' sub-section, which alludes to students being able to 'carry out experimental research using working methods typical of chemistry'.

Creativity and critical thinking are referenced throughout all strands of the FNCC chemistry learning outcomes, being reflected in statements such as: 'develop their overall research skills', 'meeting learning challenges, and applying learning strategies in chemistry', and 'process, interpret, and present research results and evaluate them and the whole research process'. There is further evidence from the general objectives, stating that students should formulate questions about the phenomena being observed and use these questions for research and problem-solving.

Mention of scientific inquiry is also present, with FNCC's objectives stating that students should 'develop their skills in experimental work towards the planning of their own research', and 'are able to carry out experimental research using working methods typical of chemistry'. Students should also be able to use computer programs to 'express numerical and graphical solutions and results'.

In addition to using computer programs to express solutions and results, technology is mentioned within the transversal competences as a tool to aid the search for information and to make observations, compose and present work, and model. The FNCC also states that 'computer-aided memory systems can [be used for] saving research data as images and videos'.

Communication and collaboration are also mentioned in the transversal competences and throughout the general objectives. Statements such as 'presenting information...develop their collaboration skills...working in groups...social debate and joint decision-making' demonstrate that this is a skill highly valued in the FNCC.

Finally, throughout all areas of the FNCC chemistry there is emphasis on awareness of local and global problems and the impact of science. Statements such as: based on 'the significance of chemistry for society and for solving environmental challenges [and] making social changes...chemistry is required for ensuring environmental well-being' exemplify how cross-cutting this theme is throughout the FNCC chemistry curriculum.

Other Themes in the FNCC

The FNCC emphasises the importance of collaboration with outside agencies to give students a more real-world experience of chemistry: ‘have opportunities to become familiar with the applications of chemistry through visits or collaboration with higher education institutions or workplaces at a local or international level’ – something that is not as explicitly mentioned in the DP.

Another general objective that is not explicitly encompassed within the learning outcomes of the DP relates to safe working. The FNCC states that students should be ‘familiar with safe working methods in chemistry’ and be able to ‘deal in an appropriate manner with any chemical waste that is produced’. This aligns closely with the emphasis Finland places on understanding the place of chemistry within society, as chemical waste is likely to become a global issue.

On a related note, it is worth mentioning that the Finnish learning outcomes generally provides more detail on potential considerations around the ethical, environmental and societal implications of technology and scientific investigation, as well as the importance of chemistry in developing a sustainable future, ensuring human and environmental welfare locally, nationally and globally. While these themes are mentioned in the DP, the learning outcomes of the latter are less specific as to the approach to covering them, allowing greater flexibility.

Summary

All learning outcome themes extracted from the DP are present to some extent in FNCC chemistry. The latter features several references to collaborative working and communication, as well as an awareness of the ‘bigger picture’ which aligns closely with the DP’s view that chemistry ‘often have impacts far beyond the boundaries of academic research’.⁴⁵

The FNCC takes a very skills-focused approach, emphasising conceptual understanding and linking chemistry to the outside world, but the idea of making connections within the subject is less apparent, as the FNCC places more emphasis on linkages between chemistry and areas outside of the subject itself (i.e. other sciences, and society at large). The FNCC also features fewer references to investigative techniques than the DP. These are referred to quite generally and are implicit within statements relating to ‘use of appropriate programs as tools for modelling and expressing numerical and graphical solutions and results’.

Overall, despite these differences, the FNCC chemistry aims to enable students to be able to contribute fully to society and have an appreciation of the importance of chemistry in many aspects of life – a very similar overall aim to that of the DP chemistry course.

4.4.2 Content

This section compares and contrasts the content of the DP and FNCC curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the chemistry content in the FNCC is presented below in a diagram that shows the key topics and sub-topics included.

⁴⁵ International Baccalaureate. (2023). *Chemistry guide*. p. 9.

Figure 9: FNCC chemistry content visualiser

Compulsory	KE1 Chemistry and I (1 credit)	KE2 Chemistry and a sustainable future (1 credit)		
Optional	KE3 Molecules and models (2 credits)	KE4 Chemical reaction (2 credits)	KE5 Chemical energy and the circular economy (2 credits)	KE6 Chemical equilibrium (2 credits)

4.4.2.1 Structure

The Finnish chemistry curriculum is constructed using the National Core Curriculum for GUSE for guidance, though the document provides substantial leeway for schools to create their own syllabus.⁴⁶ In fact, all education providers prepare a local curriculum based on the FNCC, with each drawing up a plan to organise the national core curriculum into the school year,⁴⁷ which impacts the amount of time and emphasis placed on subject content. Notably, the local curriculum is prepared in a way that allows students to make their own decisions about the subjects they focus on.

The DP and FNCC chemistry have very different structures. The content in DP chemistry is organised into two over-arching topics (structure and reactivity), each with various key areas within them. The FNCC chemistry consists of 'compulsory studies' and 'national optional studies' which are worth different numbers of credits towards the final 150 the student needs to earn. Students studying chemistry must complete the compulsory studies, but can choose which, if any, of the national optional studies to take. For the FNCC chemistry, there are two compulsory study units: KE1 and KE2, both worth one credit each. The national optional studies (KE3, KE4, KE5 and KE6), in turn, are worth two credits each. Each of the compulsory and national optional studies contains a bullet point list of 'core contents' and some general guidance on how the content could be investigated. However, as discussed above, the precise delivery of the contents is decided by the education provider.

4.4.2.2 Content Alignment

The table below represents a simplified summary of the FNCC's content alignment, at topic-level, with DP chemistry (SL and AHL).

Table 17: Summary of content alignment between the DP chemistry topics and the FNCC chemistry

DP chemistry topics	SL presence in FNCC	AHL presence in FNCC
Structure 1. Models of the particulate nature of matter		
1.1 Introduction to the particulate nature of matter		N/A
1.2 The nuclear atom		
1.3 Electron configurations		
1.4 Counting particles by mass: The mole		N/A
1.5 Ideal gases		N/A
Structure 2. Models of bonding and structure		
2.1 The ionic model		N/A
2.2 The covalent model		
2.3 The metallic model		
2.4 From models to materials		
Structure 3. Classification of matter		
3.1 The periodic table: Classification of elements		
3.2 Functional groups: Classification of organic compounds		
Reactivity 1. What drives chemical reactions?		
1.1 Measuring enthalpy changes		N/A
1.2 Energy cycles in reactions		
1.3 Energy from fuels		N/A
1.4 Entropy and spontaneity	N/A	

⁴⁶ Finnish National Agency for Education. (2019). *NCC for General Upper Secondary Education*. p.13.

⁴⁷ Ibid.

DP chemistry topics	SL presence in FNCC	AHL presence in FNCC
Reactivity 2. How much, how far and how fast?		
2.1 How much? The amount of chemical change		N/A
2.2 How fast? The rate of chemical change		
2.3 How far? The extent of chemical change		
Reactivity 3. What are the mechanisms of chemical change?		
3.1 Proton transfer reactions		
3.2 Electron transfer reactions		
3.3 Electron sharing reactions		N/A
3.4 Electron-pair reactions		
Experimental programme		

Key:

<i>Strong presence of this topic in the FNCC.</i>	<i>Partial presence of this topic in the FNCC.</i>	<i>Little or no presence of this topic in the FNCC.</i>	N/A	<i>This topic does not exist at the respective level.</i>
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The breadth of topics covered by the FNCC is somewhat less than DP chemistry, with substantial gaps in the coverage of certain topics. However, most of the SL topics are covered at least partially and there is strong alignment with the content in Structure 2 – Models of bonding and structure, particularly in the coverage of 2.2 – Covalent model, 2.3 – The metallic model and 2.4 – From models to materials. Nevertheless, there are considerable gaps in the coverage of Reactivity 3, with the FNCC chemistry syllabus including no explicit coverage of 3.1 – Proton transfers, 3.3 – Electron sharing reactions, 3.4 – Electron-pair reactions and only partial coverage of 3.2 – Electron transfer reactions.

When it comes to alignment with DP HL, there is strong coverage of Structure 2.4 – From models to materials, and partial coverage of Structure 1.2 – The nuclear atom; Structure 3.1 – The periodic table: classification of elements; Reactivity 1.2 – Energy cycles in reactions; Reactivity 2.3 – How far? The extent of chemical change; and Reactivity 3.4 – Electron-pair reactions. However, most topics are covered in less depth than the DP. Moreover, some DP AHL content is absent from all areas of FNCC chemistry, particularly that within Structure 2 and Reactivity 3. The DP's experimental programme is partially aligned with the FNCC chemistry curriculum. Within the FNCC task of the subject,⁴⁸ there is reference to 'experimentation in its different forms' in order for students to 'learn research skills and the understanding of the character of natural sciences'. This section also states that students will 'plan their own research...evaluate and present arguments about results'. Within the general objectives for chemistry⁴⁹ students will become capable of carrying out experimental research and presenting results from this. The FNCC includes, at the end of each module, a list of suggested practical experiments that students can undertake. Although the FNCC emphasises the importance of practical work in chemistry, there is not enough detail in the documentation to determine whether this is independent or collaborative work and the extent to which a written report of findings is created. This follows the style of the FNCC documentation, which provides guidance on which the local education establishments then build their curricula, allowing freedom of choice regarding the amount and type of practical work to be carried out.

⁴⁸ Finnish National Agency for Education. (2019). *NCC for General Upper Secondary Education*. p.312

⁴⁹ Finnish National Agency for Education. (2019). *NCC for General Upper Secondary Education*. p.314

As can be seen in the table below, there are also a few topics which are covered by FNCC chemistry but are absent from DP chemistry. The style of the FNCC makes it difficult to deduce how large these topics are, or how much detail they go in to. 'Sustainability', for example, could make up a very small part of the curriculum, but the title of the KE2 module (chemistry and a sustainable future) suggests that this is a rather large component. Using chemistry to solve health or environmental problems is a topic that is easily covered at a basic level, but could also be extended into more complex scenarios; however, the detail is not present in the FNCC documentation to ascertain this.

Table 18: FNCC chemistry content which is not covered in the DP

Significant FNCC content which is not included in DP chemistry*
- Sustainability - Using chemistry to solve a health or environmental problem

*Significant content does not include topics that are typically studied *prior* to upper secondary.

Summary

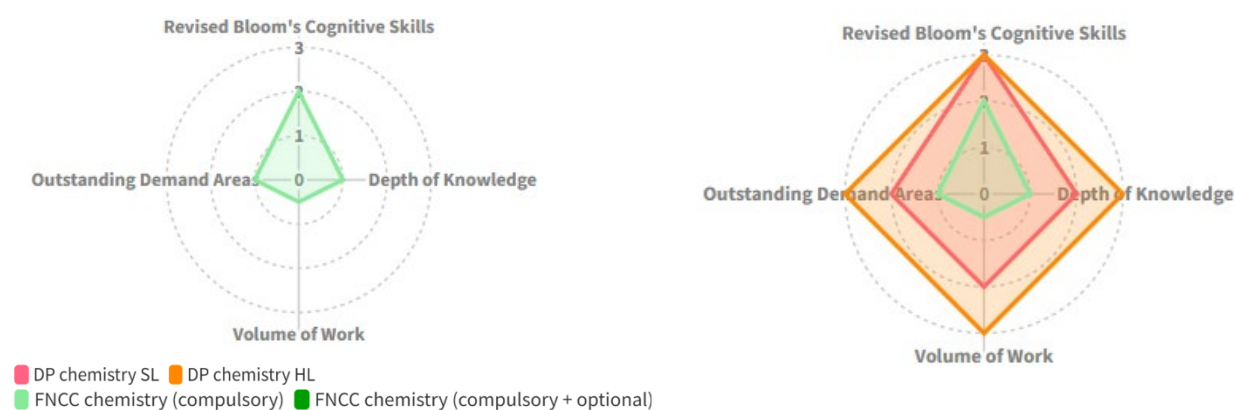
While there are similarities between the topic coverage of the FNCC and the DP, there is less alignment with regard to depth, as many of the sub-topics within the DP curriculum are absent from the FNCC. This is particularly the case for sub-topics within the DP's Reactivity 3. What are the mechanisms of chemical change?, which are almost entirely absent from the KHSCG chemistry syllabus.

However, these limitations in depth may be partially due to the FNCC's less prescriptive nature in regard to subject content. Notably, given that each education provider develops their own curriculum based on the FNCC, the fact that these sub-topics are not explicitly mentioned in the latter does not necessarily mean that they are altogether absent from the former.

4.4.3 Demand

The DP and FNCC curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, FNCC chemistry (compulsory), and FNCC chemistry (compulsory + optional). These demand profiles are presented below in the form of radar diagrams, with the last diagram showing the profiles superimposed in one place, enabling immediate visual comparison.

Figure 10: Visual representations of subject demand





The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.
 - Finland's compulsory chemistry was given a score of 2 for Bloom's due to the substantial focus of the subject's learning outcomes on application and analysis. Although references to higher order thinking skills such as evaluation, creation and problem solving are present, the opportunity to develop them within the limited time available for studying the compulsory modules impeded the award of a score of 3. For Finland's compulsory and optional chemistry combined, the score of 2.5 was given due to the higher-level thinking skills required for some aspects of practical and research work. However, opportunities for creation and synthesis, though present, were not judged to be the predominant focus, limiting the judgement to a 2.5.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - FNCC compulsory chemistry was judged to be a 1 due to the presence of skills and concepts above those of basic recall and reproduction. The design of the curriculum theoretically allows for a lot of independence from students, but there is limited evidence of how this is put into practice. Content is fairly skeletal in detail and some of it appears to be typical of pre-upper secondary level; it therefore warranted a score of 1. The score of 2.5 was given for compulsory and optional studies for the FNCC chemistry. As students in Finland are very much in control of which courses they study and how many, this affects the depth of knowledge they can obtain in each subject. However, given the advanced research skills targeted in the curriculum, if students study both the compulsory courses and the optional courses, their experience of the subject is likely to include considerable strategic and extended thinking.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - The FNCC compulsory chemistry was given a score of 0.5. The amount of time devoted to the compulsory modules is generous and the content covered in

these appears to be of a level expected prior to upper secondary education. However, since there is evidence that some time is spent on conceptually complex thinking (e.g. there is some emphasis on conceptual understanding and self-directed learning), a score of 0.5 was agreed upon. For FNCC chemistry's compulsory and optional courses combined, a score of 1.5 was given based on the increased complexity of the content covered in some of the optional courses, and the moderate number of themes in total for the respective allocated time.

- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - Both FNCC compulsory chemistry and compulsory and optional chemistry combined were given a score of 1 due to the strong emphasis on research and experimental skills. The latter provide opportunities for students' learning and understanding to be stretched appropriately for their individual strengths, amounting to an area of outstanding subject demand.

4.5 Singapore

The school system in Singapore is overseen by the Ministry of Education (MOE). It is divided into primary school (six years/grades) secondary school (four to five years/grades), and post-secondary/pre-university education (two to three years/grades).⁵⁰ This report focuses on the Singaporean GCE A Level (SGA) curriculum taught at junior colleges (JCs) and the Millennia Institute (MI), leading to the GCE A Level examination and qualification⁵¹ and represents the most common route to higher education.

The SGA curriculum is taught over two to three years (two years in JCs and three in MI) and organises courses into three main groups:

- Life skills: co-curriculum activities, character and citizenship education, physical education, and values in action
- Knowledge skills: general paper, knowledge and inquiry, and project work
- Content-based subjects: various courses offered within the subject areas of:
 - languages
 - humanities and the arts
 - mathematics and sciences.⁵²

Life skills are not assessed in the GCE A Level examinations.

Each content-based and 'knowledge skills' subject will be described by a level. The three possible levels of study are the following:⁵³

- Higher 1 (H1) level
- Higher 2 (H2) level
- Higher 3 (H3) level.

H2 is double the size of H1 in terms of curriculum time and thus enables a greater breadth and depth of content to be studied.⁵⁴ The syllabi are designed such that students study **either** H1 or H2, they do not study both. In contrast, H2 is a requirement to study H3, as H3 is designed to build on the content of H2 and offers diverse learning opportunities for in-depth study. However, not all subjects are offered at H1, H2 and H3 levels – e.g. the General Paper is only offered as H1.

In order to sit their GCE A Level examinations, students must complete 10 to 12 academic units (AU) of study, where:

- each H1 subject carries 1 AU
- each H2 subject carries 2 AU

⁵⁰ MOE, Singapore. (2022). *Post-secondary Education Booklet*. Available from: post-secondary-education-booklet-2022.ashx (moe.gov.sg)

⁵¹ SEAB. (2022). *GCE A Level*. Available from: www.seab.gov.sg/home/examinations/gce-A-Level

⁵² MOE, Singapore. (2022). *A Level curriculum and subject syllabuses*. Available from: www.moe.gov.sg/post-secondary/A-Level-curriculum-and-subject-syllabuses

⁵³ Ibid.

⁵⁴ MOE, Singapore. (2015). *The 'A' Level Experience. Levels of Study*. Available from: [Ministry of Education Singapore: New 'A' Level Curriculum 2006](https://www.moe.gov.sg/files/Assets/Images/2015/07/A_Level_Experience_Levels_of_Study.pdf) (archive.org)

- each H3 subject carries 1 AU (as it is taken in addition to the H2 subject); and
- the total number of AU should not exceed 12.⁵⁵

In practice, this typically means that students take:

- at least four content-based subjects, usually:
 - three H2 content-based subjects
 - one H1 content-based subject
- H1 Mother Tongue Language (MTL) (or MT syllabus B in some circumstances⁵⁶)
- H1 General Paper, or H2 Knowledge and Inquiry in lieu – the latter counting as a fourth H2 subject.⁵⁷
- H1 Project Work.

It is required that at least one of the four content-based subjects is from a contrasting discipline.

Hence, the SGA does not require students to study chemistry, but for those wishing to do so, the following courses are offered and have been used in the analysis:

SGA H1 chemistry⁵⁸

H1 chemistry is designed to offer a science education that develops knowledge of core scientific ideas and an understanding of scientific inquiry. This will enable students to make decisions on science-related issues and challenges. H1 chemistry broadens students' learning and develops their scientific literacy by using real-world contexts, putting less emphasis on handling equipment and carrying out laboratory experiments, and instead focusing on developing scientific knowledge. The aim of the H1 syllabus is to enable students to become scientifically literate consumers who are able to make informed choices concerning science-related issues.

SGA H2 chemistry⁵⁹

The H2 chemistry curriculum aims to prepare students well for university, work and life by laying a strong foundation of knowledge, skills and attitudes. Upon completing H2 chemistry, all students will be well-equipped to make informed decisions based on scientific knowledge, but H2 also caters for students who wish to pursue chemistry further. It gives students a deeper grasp of scientific knowledge and is designed to give students a more coherent and integrated understanding of science rather than a compartmentalised view of knowledge. Application is also a key component of the H2 chemistry curriculum; students are provided with real-world contexts in order to strengthen their understanding and deepen their scientific knowledge.

⁵⁵ SEAB. (2022). *2022 Singapore-Cambridge GCE A Level Examinations - Registration Information for School Candidates*. Available from: [2022 Instructions For School Candidates \(seab.gov.sg\)](https://seab.gov.sg/2022-Instructions-For-School-Candidates)

⁵⁶ Students should sit the Year-End mother tongue syllabus B examination if they did not obtain at least D7 in GCE O Level MTL or take MTL Syllabus B at GCE O Level.

⁵⁷ SEAB. (2022). *2022 Singapore-Cambridge GCE A Level Examinations - Registration Information for School Candidates*.

⁵⁸ MOE, Singapore. (2020). *Chemistry Syllabus. Pre-University Higher 1. Syllabus 8873*. Available from: [pre-university-h1-chemistry-syllabus.ashx \(moe.gov.sg\)](https://pre-university-h1-chemistry-syllabus.ashx(moe.gov.sg))

⁵⁹ MOE, Singapore. (2019). *Chemistry Syllabus. Pre-University Higher 2. Syllabus 9729*. Available from: [preuniversity_h2_chemistry_syllabus.ashx \(moe.gov.sg\)](https://preuniversity_h2_chemistry_syllabus.ashx(moe.gov.sg))

SGA H3 chemistry⁶⁰

H3 chemistry is designed to build on and extend students' knowledge and understanding gained from H2 chemistry. Catering to students with a keen interest and strong ability in chemistry, there is a strong emphasis on independent and self-directed learning, and it aims to provide greater depth and rigour. H3 is designed for students who wish to pursue further studies in chemistry-related fields by providing them with a greater appreciation of the practice, value and rigour of chemistry, as well as deepening the knowledge, skills and attitudes gained through the study of H2.

4.5.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of chemistry.

The learning outcome themes for chemistry were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for physics, chemistry, and biology. Similarly, the SGA sets out learning outcomes which apply to all sciences, known as the 'Practices of Science' (PoS). The PoS are split into three components – 'A. Understanding the nature of scientific knowledge', 'B. Demonstrating scientific inquiry skills', and 'C. Relating science and society'. In addition to these, the SGA outlines specific 'syllabus aims', which are specific to the science (physics, chemistry or biology) and the course (H1, H2, or H3). Within each science, H1 and H2 have the same aims, but the aims for H3 are slightly different. H3 builds on and extends knowledge and skills acquired in H2 – the expectation being that students fully grasp the core ideas and learning outcomes of H2 before deepening and extending this understanding through H3.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the SGA chemistry curricula.

⁶⁰ MOE, Singapore. (2021). *Chemistry Syllabus. Pre-University Higher 3. Syllabus 9813*. Available from: [2021-preu-h3-chemistry.ashx \(moe.gov.sg\)](https://www.moe.gov.sg/preu-h3-chemistry.ashx)

Table 19: Presence of the DP sciences subject group learning outcome themes in the SGA chemistry curricula.

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the SGA	
1. Conceptual understanding and making connections		Present throughout PoS and aims. Students should connect between the sub-microscopic, macroscopic and symbolic levels, as well as build attitudes for further study in related fields.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present throughout PoS and aims. Descriptions of science as evidence-based and model-building, as well as constructing explanations based on evidence support the presence of this theme.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present throughout PoS and aims. SGA describes the analysis and interpretation of data, as well as using scientific principles to understand, analyse and evaluate systems.
4. Skills for scientific inquiry		Present. Found in PoS through statements concerning the planning and conducting of experimental procedures and obtaining and organising data appropriately.
5. Development of technological skills		Absent. Not found in PoS or H1, H2, or H3 aims.
6. Effective collaboration and communication		Partially present. Scientific communication is referenced in PoS in relation to communicating scientific knowledge and findings appropriately, but collaborative competence is not explicitly mentioned.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present throughout PoS and aims from the mention of scientific knowledge and problem-solving being influenced by economic, social, environmental and ethical factors.

Key:

	<i>This theme is well-evidenced in the learning outcomes of the SGA.</i>		<i>This theme is partially evidenced in the learning outcomes of the SGA.</i>		<i>This theme is not evident in the learning outcomes of the SGA.</i>
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Presence of DP's Learning Outcome Themes

The DP's learning outcome themes one to four, six and seven are found to be present in the aims and PoS for chemistry H1, H2 and H3. Many statements throughout the PoS imply conceptual understanding and making connections: 'use appropriate models to explain concepts, solve problems and make predictions, 'make decisions based on evaluation of evidence, processes, claims and conclusions'. The aims of H1 and H2 also reflect this theme: 'connecting between the sub-microscopic, macroscopic and symbolic levels of representations'. Demonstrating, using and applying knowledge that characterises science is found throughout PoS and aims. PoS statements that refer to this include: 'understand that science is an evidence-based, model-building enterprise', 'use appropriate models to explain concepts, solve problems and make predictions', 'understand, analyse and evaluate real-world systems as well as generate solutions for problem solving'. Terminology within the aims include: 'understanding the nature of science enquiry skills', 'develop the way of thinking to explain phenomena, approach and solve problems in chemical systems'.

Creativity and critical thinking are also seen throughout the PoS and aims. 'Understand that the use of both logic and creativity is required in the generation of scientific knowledge' can be found in the PoS, as can 'make decisions based on evaluation of evidence, processes, claims and conclusions'. The aims within H3 are worded 'develop [...] the skills to analyse chemical issues, and to apply relevant concepts and techniques to solve problems'.

The application of skills in order to carry out insightful and ethical investigations is covered in the PoS through 'identify scientific problems, observe phenomena and pose scientific questions/hypotheses', 'plan and conduct investigations' and 'obtain, organise and represent data in an appropriate manner'.

Communicating and collaborating effectively is only evident in two statements from the PoS: 'scientific knowledge is generated from consensus within the community of scientists through critical debate and peer review' and 'communicate findings and information using appropriate language and terminology'. Hence, whilst communication is present, collaboration is not explicitly mentioned in the SGA chemistry curricula.

The awareness of local and global problems and ethical, environmental, cultural and social impacts on science is referenced through the PoS, for example: 'science is [...] connected with the natural world', 'recognise that [...] problem-solving could be influenced by other considerations such as economic, social, environmental and ethical factors' and 'demonstrate an understanding of the benefits and risks associated with the application of science to society'. H1 and H2 aims discuss the importance of this theme through 'scientifically literate citizens who are well-prepared for the challenges of the 21st century [...] relating science to society'.

The focus of H1, H2 and H3 aims is on conceptual understanding and making connections, as well as the wider considerations of social, economic, global and environmental issues. Within the chemistry syllabus, it is explained that 'chemistry is often seen to play a central role in science' and this expanded-upon by explaining how it is built on understanding of the laws of physics and provides a basis for studying reactions in biological systems. This links with the DP focus on conceptual understanding and making connections within, and across, subjects. Alongside this, there is a lot of similarity to the DP collaborative sciences project of addressing real-world problems and integrating knowledge. Singapore has a strong focus on developing 21st Century Competencies (21CC) in students to enable outcomes of students becoming self-directed learners, confident people, concerned citizens and active contributors. These are overarching themes that should be embedded within science lessons and influence the learning outcomes.

Finally, within the SGA learning outcomes, there is no direct reference to technology, hence this DP theme of developing technological skills is not well-evidenced in the SGA.

Other Themes in the SGA

Although the vast majority of learning outcomes in the Singaporean curriculum feature similar themes to those found in the DP, the former places greater explicit emphasis on providing students with the necessary skills to continue studying the subject, or related subjects. This is explicitly mentioned in the first aim within H2 and H3, which highlights the intention for these syllabi to build the 'knowledge, skills and attitudes necessary for further studies in related

fields'.⁶¹ In this way, the Singaporean curriculum makes specific reference to future studies and to students having the ability to deepen their learning with further study, while the DP's learning outcomes, while also designed to prepare students for higher education, take a more implicit approach.

Summary

Like the DP, the Singaporean chemistry curriculum is heavily focused on conceptual learning and developing skills that allow for the use of science to solve problems at a global level. The outcomes are centred around the students being capable of linking multiple ideas, thinking critically to investigate issues and how science can impact and be affected by global issues. Whilst these themes are present in the DP, the DP goes into further detail with regard to the importance of developing technological skills and working collaboratively, while the Singaporean curriculum seems to place greater emphasis on further study. Overall, however, the learning outcomes in the Singaporean chemistry curriculum are closely aligned with those of the DP, sharing predominantly similar themes and focuses.

4.5.2 Content

This section compares and contrasts the content of the DP and SGA curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the chemistry content in the SGA is presented below in a diagram that shows the key topics and sub-topics included.

⁶¹ MOE, Singapore. (2019). *Chemistry syllabus. Pre-University Higher 2*. p.3

Figure 11: SGA chemistry content visualiser

H1 chemistry	Core Idea 1: Matter	1 Atomic Structure	2 Chemical Bonding			
	Core Idea 2: Structure and Properties	2 Chemical Bonding	3 Theories of Acids and Bases	4 Periodic Table		
	Core Idea 3: Transformation	5 The Mole Concept and Stoichiometry	6 Chemical Energetics: Thermochemistry	7 Reaction Kinetics	8 Chemical Equilibria	
	Extension Topic	9 Materials				
H2 chemistry	Core Idea 1: Matter	1 Atomic Structure				
	Core Idea 2: Structure and Properties	2 Chemical Bonding	3 The Gaseous State	4 Theories of Acids and Bases	5 The Periodic Table	
	Core Idea 3: Transformation	6 The Mole Concept and Stoichiometry	7 Chemical Energetics: Thermochemistry and Thermodynamics (Gibbs Free Energy and Entropy)	8 Reaction Kinetics	9 Chemical Equilibria	
	Extension Topics	10 Chemistry of Aqueous Solutions 10.1 Acid-Base Equilibria 10.2 Solubility Equilibria	11 Organic Chemistry 11.1 Introduction 11.2 Isomerism			
H3 chemistry	Additional Content 1: Spectroscopic Techniques	1.1 Basic Principles of Spectroscopy	1.2 Ultraviolet/visible Spectroscopy	1.3 Infra-red (IR) Spectroscopy	1.4 Nuclear Magnetic Resonance (NMR) Spectroscopy	1.5 Mass Spectroscopy
	Additional Content 2: Further Organic Matter	2.1 Molecular Stereochemistry	2.2 Basic Physical Organic Chemistry	2.3 Nucleophilic Substitution	2.4 Elimination	

4.5.2.1 Structure

DP chemistry is taught over two years, whereas the Singaporean curriculum is designed to be completed over two or three years, depending on the type of institution the student attends. Students choose to study H1 or H2 depending on their ability, interest and potential future careers. H1 is 'designed to broaden students' learning that will support the development of scientific literacy'. The H1 syllabus is focused on equipping students with the skills they need to make 'informed decisions based on sound scientific knowledge and principles' so that they become citizens that can contribute positively to society. The H2 curriculum is intended to suit students who enjoy science and are capable of studying it at a deeper level than H1, laying 'a strong foundation of knowledge, skills and attitudes' in order to 'prepare students well for university, work and life in the future'.⁶² For students who wish to extend their science skills and deepen their understanding, they may study H3 in addition to H2. The H3 syllabus is 'designed to build on and extend the knowledge, understanding and skills' acquired from the H2 chemistry syllabus', catering to 'students of strong ability and keen interest in chemistry', and being 'designed with a strong emphasis on independent and self-directed learning'.⁶³ As such, the H3 syllabus goes into more depth than H1 and H2 and is intended to be a more challenging subject.

The DP organises chemistry content into two over-arching themes of 'Structure' and 'Reactivity', with each theme containing three main topics. The curriculum is further subdivided into smaller topics within these three sections. Somewhat similarly, the H1 and H2 syllabi each have three overarching themes, referred to as 'Core Ideas', which are 'Matter', 'Structure and Properties', and 'Transformation', as well as 'Extension Topics'. The SL and HL content within the DP are clearly defined and separated, with entire sub-topics only studied if students are studying HL. Due to the design of the SGA, instead of offering one course with SL and AHL content, SGA offers three subjects which each have a separate syllabus. It is expected that students will cover all content of whichever subject(s) they choose to study. Moreover, the DP outlines suggested teaching time to be allocated to both SL and HL content, while all SGA curricula do not contain this information. This may be due to the flexibility within the SGA, where students may spend either two or three years studying this course (depending on what type of institution they study in) and therefore the time devoted to each topic may vary.

While, in terms of overarching topics, the DP is subdivided into 'Reactivity' and 'Structure', each with multiple topics within, H3 is divided into 'Spectroscopic Techniques' and 'Further Organic Mechanisms', each of which also consists of multiple sub-topics. Due to the design of the SGA, all H3 content is compulsory, and students offering H3 must offer H2, meaning that all H2 content is also covered. There are no distinct 'extension topics' within the H3 syllabus; rather, the subject is designed in such a way that certain topics covered in H2 are extended into different contexts. For example, 'the concepts of chemical bonding and the periodic table is extended to the [...] transition metals'.⁶⁴ Although the SGA H3 chemistry structure appears somewhat more simplistic than the DP, it has a stronger focus on applications, allowing students to 'apply relevant concepts and skills from H2 to tackle a more

⁶² MOE, Singapore. (2019). *Chemistry syllabus. Pre-University Higher 2*. p.1.

⁶³ MOE, Singapore. (2021). *Chemistry syllabus. Pre-University Higher 3*. p.3

⁶⁴ Ibid. p.7.

diverse range of problems'.⁶⁵ Higher level thinking skills are encouraged through analysis, synthesis and application of knowledge in order to broaden students' ability in chemistry.

4.5.2.2 Content Alignment

To complement the analysis, the table below represents a simplified summary of the SGA's content alignment, at topic-level, with DP chemistry (SL and AHL content). Following this table is a table highlighting significant SGA content that is not in the DP.

Table 20: Summary of the content alignment the SGA chemistry H1, H2 and H3 has with the main topics of the DP chemistry

DP chemistry topics	SL presence in H1	AHL presence in H1	SL presence in H2	AHL presence in H2	SL presence in H3	AHL presence in H3
Structure 1 Models of the particulate nature of matter						
1.1 Introduction to the particulate nature of matter		N/A		N/A		N/A
1.2 The nuclear atom						
1.3 Electron configurations						
1.4 Counting particles by mass: The mole		N/A		N/A		N/A
1.5 Ideal gases		N/A		N/A		N/A
Structure 2 Models of bonding and structure						
2.1 The ionic model		N/A		N/A		N/A
2.2 The covalent model						
2.3 The metallic model						
2.4 From models to materials						
Structure 3 Classification of matter						
3.1 The periodic table: Classification of elements						
3.2 Functional groups: Classification of organic compounds						
Reactivity 1 What drives chemical change?						
1.1 Measuring enthalpy changes		N/A		N/A		N/A
1.2 Energy cycles in reactions						
1.3 Energy from fuels		N/A		N/A		N/A
1.4 Entropy and spontaneity	N/A		N/A		N/A	
Reactivity 2 How much, how far and how fast?						
2.1 How much? The amount of chemical change		N/A		N/A		N/A
2.2 How fast? The rate of chemical change						
2.3 How far? The extent of chemical change						
Reactivity 3 What are the mechanisms of chemical change?						
3.1 Proton transfer reactions						
3.2 Electron transfer reactions						
3.3 Electron sharing reactions		N/A		N/A		N/A
3.4 Electron-pair reactions						
Experimental programme						

* Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

⁶⁵ Ibid. p.8.

Key:

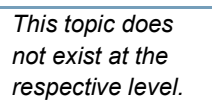
 Strong presence of this topic in the SGA.	 Partial presence of this topic in the SGA.	 Little or no presence of this topic in the SGA.	 N/A	 This topic does not exist at the respective level.
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Table 21: SGA chemistry content which is not covered in the DP

Significant SGA content which is not included in DP chemistry*		
H1	H2	H3**
- Nanomaterials - Trends and variations of oxides and chlorides - Half-life and first order reactions - Elimination	- Trends and variations of oxides and chlorides - Half-life and first order reactions - Homogeneous and heterogeneous catalysis - Solubility equilibria - The Faraday constant - Elimination	- Molecular stereochemistry - Elimination

*Significant content mostly does not include topics that are typically studied *prior* to upper secondary

**Content listed in this column is specific to H3. As H2 is always studied alongside H3, all topics in the H2 column should be considered in addition to the topics in this column

H1 Chemistry

At both SL and HL, the H1 chemistry curriculum has strong alignment with the DP in terms of the number of topics covered and, to a lesser extent, the depth of these topics. There are very few DP topics and sub-topics that are completely absent from H1, making the breadth of the H1 curriculum very similar to that of the DP. At SL, only two areas of the DP's Reactivity 3 topics (3.2 – Electron transfer reactions and 3.3 – Electron sharing reactions) are not present in H1 chemistry, and while Structure 1.5 – Ideal gases and Reactivity 1.3 – Energy from fuels are also absent, all other areas of the DP were found to have some alignment with the H1, even if only partial.

When comparing the AHL content of the DP with H1 chemistry, however, there are evident gaps in topic coverage. There are many partial alignments across the AHL content and H1; for example, Structure 1.3 – Electron configurations and Structure 2.2 – The covalent model. As well as Reactivity 3.1 – Proton transfer reactions, which is the only sub-topic within Reactivity 3 to have any alignment to the DP AHL content. This is to be expected, as H1 aims to provide a firm foundation of chemistry understanding, with H2 and H3 designed to cover content at greater depth than H1.

H2 Chemistry

As seen in the content alignment summary table above, the topic coverage in the H2 curriculum has strong alignment with the content of the DP at both SL and HL. There is only one area at SL (Structure 2.4 – From models to materials) where no alignment was found. Most other areas were found to have strong alignment, reflecting a similarity of breadth between the H2 chemistry syllabus and the DP.

Most of the DP AHL content is also covered in H2, although, interestingly, the AHL content of Structure 2.2 – The covalent model – is absent from H2, despite being partially covered in H1. In addition to this, only one other DP area is entirely not present in H2 chemistry, Structure

3.2 – Electron transfer reactions. Overall, the content of the H2 chemistry curriculum shows relatively strong alignment with the DP HL.

H3 Chemistry

There is strong alignment between H3 chemistry and both the SL and AHL aspects of the DP curriculum. The breadth of the H3 curriculum is highly aligned to the DP, with only one subtopic (Structure 2.4 – From models to materials) showing little or no alignment. All other areas show partial or high levels of alignment. The depth of the H3 syllabus is highly aligned to the DP AHL content, with all areas aligned to either a partial or high extent. Both the breadth and depth of the H3 syllabus is more aligned to the DP than H1 and H2.

Summary

Overall, the SGA chemistry curricula, as a whole, is strongly aligned with the DP chemistry syllabus, as both their breadth and depth of content are similar. There are some areas where content does not align – for instance, within the Structure section, SL content from 2.4 – From models to materials, and AHL content from 3.2 – Functional groups. However, taking into account the number of shared content areas and depth of coverage in those areas, the level of content alignment between all H1, H2 and H3 chemistry courses and the DP is high. The experimental programme of the DP is highly aligned with all SGA curricula, within the section of the curriculum entitled ‘demonstrating science inquiry skills’⁶⁶ it describes in detail how students are expected to plan and conduct investigations, obtain, analyse and evaluate their data and then communicate their findings. Although it is not explicit whether this is collaborative or independent work, the principles of the experimental programme are clearly within H1, H2 and H3 SGA chemistry.

4.5.3 Demand

The DP and SGA curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, SGA H1 chemistry, H2, and H3. These demand profiles are presented below in the form of radar diagrams, with superimposed diagrams also being featured to enable immediate visual comparison.

⁶⁶ MOE, Singapore (2020). *Chemistry syllabus. Pre-University Higher 1*. p.4; MOE, Singapore (2019). *Chemistry syllabus. Pre-University Higher 2*. p.5; MOE, Singapore (2021). *Chemistry syllabus. Pre-University Higher 3*. p.5

Figure 12: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.

- A score of 2 was given to H1 chemistry as, while there is some evidence of analysis and synthesis in the learning outcomes, the predominant focus of both outcomes and assessment objectives is on knowledge and understanding and applying and evaluating. H2 chemistry was given a score of 2.5 as it features more higher order thinking, with some opportunities for analysis and synthesis, yet these were still not the predominant feature. For H3 chemistry, a score of 3 was awarded given the numerous references to higher order thinking skills, including problem solving and synthesis.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - H1 chemistry was given a score of 1 due to the majority of content being focused on foundational concepts and requiring lower-level thinking skills, such as 'identify, state, define and outline'. For H2, a score of 2 was awarded to reflect the extended nature of the curriculum, where greater detail is observed. Finally, H3 chemistry, studied in addition to H2, covers topics in great detail and features multiple areas requiring extended thinking within and across topics, being awarded a score of 3.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - H1 chemistry was awarded a score of 1 as the content is relatively simple and having two-three years of teaching time to cover it suggests that a lot of time can be spent on each topic. H2 curriculum provides more challenge for students as it is designed to take students' learning further. H2 is studied over a longer period of time – two-three years – but it features a higher number of challenging topics and skill development; hence the score of 2. H3 chemistry received a score of 3 as students must study it concurrently with H2; therefore, within the same two-three-year timeframe, students are not only covering a higher number of topics, but also doing so at a greater depth, making the volume of work high.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - H1 chemistry was given a score of 1. This score was reached based on the extension topics 9.1 Nanomaterials and 9.2 Polymers, which feature some elements of advanced content and potential for students to explore and extend their understanding. For H2 chemistry, a score of 1 was given due to the inclusion of the K_{sp} topic as well as the references to real-life applications of knowledge. The design of the H3 chemistry curriculum is intended to extend and deepen students' knowledge across multiple topics, therefore the areas of outstanding subject demand are not from specific topics, but from the ethos of the route of study. This was deemed to deserve a score of 1.

4.6 South Korea

The school system in South Korea is overseen by the Ministry of Education (MOE – 교육부).⁶⁷ It is divided into primary school (grades 1-6, typically from ages 6 to 12), middle school or lower secondary school (grades 7-9, typically from ages 12 to 15), and high school or upper secondary education (grades 10-12, typically from ages 15-18).⁶⁸

High school education is offered by several different types of schools, including:

- General high schools
- Vocational high schools
- Special purpose high schools
- Autonomous high schools.⁶⁹

The focus of this report is on the curriculum offered by general high schools and leading to the High School Certificate of Graduation (KHSCG); other routes will not be discussed in depth.

The KHSCG curriculum spans the three years of South Korea's upper secondary education. Beginning in grade 10, students select courses which earn them units towards the KHSCG, which is intended to grant access to higher education upon successful completion. The high school curriculum is comprised of common courses, electives, and what is referred to as 'creative experiential activities' (CEA), consisting of 'discretionary activities, club activities, community services, and career-related activities'.⁷⁰

Common courses are mandatory courses studied by all students. All students completing a KHSCG must study the common courses in: Korean Language, Mathematics, English, Korean History, Integrated Social Studies, Integrated Science, Scientific Investigation. Students must also study courses in Physical Education, Arts, and Life/Liberal Arts (i.e. Technology, Home Economics, Second Foreign Language, Classical Chinese or Liberal Arts).

Electives are non-compulsory courses selected by students according to their aptitudes and career plans. They are divided into general electives and career-related electives.

To successfully complete the KHSCG, students must study a minimum of 204 units (i.e. 2,890 hours) over the course of three years, of which:

- 180 units (i.e. 2,550 hours) are typically earned through successful completion of common courses and elective courses and/or specialised courses combined. Notably, all units studied from the 'Foundation' subject group may not exceed the 50% of the total number of units in the programme.⁷¹
- At least 24 units (i.e. 340 hours) must be earned through the completion of CEA.

⁶⁷ MOE, Republic of Korea. (2018). *Education in Korea*. Available from: <http://english.moe.go.kr/boardCnts/viewRenewal.do?boardID=282&boardSeq=80324&lev=0&searchType=null&statusYN=W&page=1&s=english&m=0502&opType=N>

⁶⁸ Ibid.

⁶⁹ MOE, Republic of Korea. (2022). *Secondary Education*. Available from: english.moe.go.kr/sub/infoRenewal.do?m=0303&page=0303&s=english

⁷⁰ Ibid.

⁷¹ Ibid.

Each unit in the KHSCG is equivalent to 17 lessons of 50 minutes each.⁷² The following table provides a summary of the unit allocation per subject cluster:

Table 22: Unit requirements of the KHSCG

Subject areas	Subject clusters	Minimum required units per subject cluster (units from the common courses)	Electives and/or specialised courses
Foundation	Korean Language	10 units Korean Language (8 units)	Selected subjects from general electives, career-related electives, or specialised subjects*
	Mathematics	10 units Mathematics (8 units)	
	English	10 units English (8 units)	
	Korean History	6 units Korean history (6 units)	
Inquiry	Social Studies (including History/ Moral Education)	10 units Integrated social studies (8 units)	
	Science	12 units Integrated science (8 units) Scientific investigation (2 units)	
Physical Education/ Arts	Physical Education	10 units	
	Arts	10 units	
Life/Liberal Arts	Life/Liberal Arts (i.e. Technology/ Home Economics/ Second Foreign Language/ Classical Chinese/Liberal Arts)	16 units	
Sub-total		94 units	86 units
Creative experiential activities (CEA)			
Discretionary activities, club activities, community services, and career-related activities			24 units
Total		204	
<i>NB: Units assigned to common courses can be reduced up to 2 units, except for Korean History, where the full 6 units are required.</i> ⁷³			

As seen in the table above, students are required to study the 'Integrated Science' and 'Scientific Investigation' courses as part of the curriculum, though the study of chemistry is optional.

⁷² MOE, Republic of Korea. (2015). *The National Curriculum for the Primary and Secondary Schools*. p. 20

⁷³ Ibid. p.19.

KHSCG Integrated Science⁷⁴

Integrated Science is taken by all students in the KHSCG, and has, therefore, been considered in this report as complementary to other science subjects. It has a strong emphasis on scientific inquiry and problem-solving skills through the study of various aspects of physics, chemistry and biology. Earth and space, the characteristics of matter, life and the environment make up some of the topics within the curriculum. Integrated Science also contains a lot of investigation and experiments through which students can gather results and apply their understanding. Collecting data, analysing and evaluating this data and then communicating it to others is a large part of this subject.

KHSCG Scientific Investigation⁷⁵

As well as Integrated Science, students in the first year of high school will also take the common course of Scientific Investigation. This subject looks at past experiments and discoveries, research methods and ethics, and the process of scientific inquiry. Students' interest and curiosity will be developed as they learn how science is linked to sport, art and culture, technology, and the development of products. During this subject, students will plan and conduct their own scientific inquiries, inspired by problems that they themselves have discovered.

KHSCG chemistry⁷⁶

The chemistry subject consists of Chemistry I and Chemistry II and aims to provide essential understanding of chemical reactions, particles and the usefulness of chemistry in the real world. Chemistry I provides a foundation level of understanding as to how chemistry can be applied to the 21st century; providing students with the ability to research, think, and solve problems scientifically. Logical reasoning and using evidence to formulate an argument are strong themes within Chemistry I so that students become better communicators and lifelong learners. Chemistry II contains more content and goes to a slightly deeper level, but still emphasises the importance of using investigative skills and evidence to solve scientific problems.

4.6.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of chemistry.

The learning outcome themes for chemistry were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for chemistry, physics and biology. For the purposes of mapping and comparisons with the DP, the learning outcomes for KHSCG chemistry were extracted from the 'character' and 'objectives' sections of the Chemistry I and Chemistry II subjects. The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the KHSCG chemistry curricula.

⁷⁴ MOE, Republic of Korea. (2015). *Science Curriculum*

⁷⁵ Ibid.

⁷⁶ Ibid.

Table 23: Presence of the DP sciences subject group learning outcome themes in the KHSCG chemistry curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the KHSCG	
1. Conceptual understanding and making connections		Present in both the 'character' and 'objectives' sections. The KHSCG discusses the links between multiple aspects of its curriculum and how the contents of chemistry have close connections with other subjects.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present in both the 'character' section. Students are expected to understand that scientific knowledge is based on logical reasoning and discovery through observation and exploration.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in both the 'objectives' and 'character' sections. There is reference throughout these to problem solving and critical consideration.
4. Skills for scientific inquiry		Present in both the 'character' and 'objectives' sections which discuss the collection of data, research activities and selecting and organising data.
5. Development of technological skills		Present in both the 'character' and 'objectives' sections. Computers, the use of various media and information technology is referred to throughout the KHSCG curriculum.
6. Effective collaboration and communication		Present in both the 'character' and 'objectives' sections through mention of students' ability to advocate their own ideas, understand others and use various forms of communication to express scientific information.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present in both the 'character' and 'objectives' sections. The KHSCG encourages students to become lifelong learners and pay attention to social issues of science and technology.

Key:

 This theme is well-evidenced in the learning outcomes of the KHSCG.	 This theme is partially evidenced in the learning outcomes of the KHSCG.	 This theme is not evident in the learning outcomes of the KHSCG.
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Presence of the DP's Learning Outcome Themes

As can be seen from the table above, all learning outcome themes extracted from the DP are present in one or more areas of the KHSCG curriculum. Conceptual understanding is evident in statements such as 'understand the core concepts of chemistry by exploring natural phenomena in daily life' in the objectives for Chemistry I, or 'enjoying learning advanced chemistry concepts and inquiry methods' in the 'character' section of Chemistry II. Making connections between subjects, too, is present in statements such as 'recognise the interrelationship between science, technology and society as a basis for knowledge as a democratic citizen' and the fact that the 'content composition of 'Chemistry II' is closely related to the chemistry concepts contained in 'Integrated Science', 'Scientific Investigation' and 'Chemistry I', implying linkages within the sciences and chemistry subjects.

The use and application of methods, tools and techniques that characterise science is evident throughout all areas, in statements such as 'ability to collect, interpret, and evaluate evidence through various methods', 'enjoying learning advanced chemistry concepts and inquiry

methods' and 'ability of scientific inquiry...includes a scientific world view and view of nature, scientific knowledge and methods' in the 'character' section of Chemistry II, or 'enjoying learning chemistry concepts and exploring methods through natural phenomena or situations related to daily experience' in the 'character' section of Chemistry I. Similar statements are dotted throughout the curriculum, illustrating that this theme is of great focus in the KHSCG curriculum.

Within the creativity and critical thinking theme, problem solving is referenced throughout the curriculum and is reflected in statements such as 'cultivate science and core abilities such as...scientific problem-solving ability', 'use scientific knowledge and scientific thinking to solve personal or public problems' and 'solve scientific problems and obtain new scientific knowledge or construct meaning'. The 'creativity' aspect is also prominent in the curriculum, in statements such as 'cultivate the scientific literacy of solving individual and social problems scientifically and creatively'.

The application of skills to carry out insightful and ethical investigations is also strongly evident throughout all areas of the curriculum. Statements such as 'collect, interpret, and evaluate evidence through various methods such as experiments, investigations, and discussions in order to solve scientific problems and obtain new scientific knowledge or construct meaning', 'scientific inquiry skills and knowledge, and scientific thinking' all demonstrate the prominence of this theme in the KHSCG curriculum.

Technology is another major focus throughout the KHSCG curriculum and is repeatedly referred to in all subjects, in statements such as 'recognise the interrelationship between science, technology and society'; 'understand and express scientific and technical information through various media such as computers and audio-visual equipment'.

Communication and collaboration, too, are repeatedly mentioned in both the character and the objectives sections of the Chemistry I and Chemistry II curriculum. Examples of instances where this is explicitly mentioned include: 'scientific communication ability, scientific participation', 'the ability to collect, interpret, and evaluate evidence through...discussions' and 'the ability to advocate one's own ideas, understand others' ideas, and adjust them in order to share and develop the process and results of solving scientific problems within the community'. Various means of communication are even explicitly mentioned: 'various forms of communication such as speech, words, pictures and symbols, the ability to understand and express scientific and technical information through various media'.

Finally, the awareness of local and global problems is also strongly evident throughout all areas of the curriculum and an understanding of the impact of science for society is clearly a priority concept for students to grasp. This is nicely illustrated by the following quotes: 'the ability to keep learning as a member of the community in order to act reasonably and responsibly, pay attention to social issues of science and technology, participate in the decision-making process, and adapt to new scientific and technological environments'; 'recognise the interrelationship between science, technology and society as a basis for knowledge as a democratic citizen', and 'explore the role of chemistry in contributing to future society'.

Other Themes in the KHSCG

There are no main learning outcomes in the KHSCG curriculum that are not present or related to the DP themes.

Summary

There is a strong level of alignment between the learning outcomes of the DP chemistry and those of KHSCG chemistry, with all themes extracted from the DP being strongly evidenced in the KHSCG. The Korean chemistry curriculum aims to create well-rounded, curious students who have an appreciation for science as a whole and its place in the world. This aligns well with the DP's intentions of developing learners who are 'curious...and show enthusiasm about the world around them',⁷⁷ as well as students who care for the environment and act to 'improve the lives of others'.⁷⁸

4.6.2 Content

This section compares and contrasts the content of the DP and KHSCG curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the chemistry content in the KHSCG is presented below in a diagram that shows the key topics and sub-topics included.

⁷⁷ International Baccalaureate. (2023). *Chemistry guide*. p. 12

⁷⁸ International Baccalaureate. (2023). *Chemistry guide*. p. 13

Figure 13: KHSCG science/chemistry content visualiser

Common Subject	Integrated Science	Substance and regularity	Regularity and Combination of Substances	Components of Environment	Life systems
		System and interaction	Dynamic systems	Earth systems	
		Change and diversity	Chemical changes	Biodiversity and sustainability	
		Environment and division energy	Ecosystem and environment	Development of renewable energy	
	Scientific Investigation	Scientific experiments in history	Nature of science	Research methods	
		Scientific experiments in daily life	Approach to scientific experiments	Scientific inquiry process	
		High-tech scientific experiments	Application of science		
General elective	Chemistry I	Structure of matter	Components of matter	Chemical combinations	
		Change of matter	Chemical reactions	Energy inflows and outflows	
Career-related electives	Chemistry II	Properties of matter	States of matter		
		Change of matter	Chemical reactions	Energy inflows and outflows	

4.6.2.1 Structure

While DP chemistry is taught over two years, the chemistry curriculum in the KHSCG is designed to be completed in three years. The KHSCG curriculum is referred to as ‘electives-centred’ and runs from the first grade to the third grade.⁷⁹ Science is a ‘common subject’ in the curriculum; hence all students must take the common courses of ‘Integrated Science’ and ‘Scientific Investigation’. The number of required science units is 12, with the common courses making up 10 of these units. Following the common courses, students are offered electives to choose from. The elective courses are divided into two categories: general electives (Physics I, Chemistry I, Biology I and Earth Science I) and career-related electives (Physics II, Chemistry II, Biology II, Earth Science II, Science and History, Life and Science, and Convergence Science). For reference, the KHSCG curriculum states that schools should ‘guide all students to take more than three career-related elective courses’,⁸⁰ and that they should organise a school curriculum ‘appropriate for their circumstances and based on national guidelines’.⁸¹

As to the structure of the chemistry curriculum in particular, the DP splits it into two overarching themes of ‘Structure’ and ‘Reactivity’, each covering three large topics. Similarly, the KHSCG splits the curricula of its chemistry electives, Chemistry I and Chemistry II, into two large overarching themes that have clear parallels with those of the DP – ‘Structure of matter’ and ‘Change of matter’ (another term for reactivity). As can be seen in the figure above, each of these overarching themes covers between one and two large topics.

4.6.2.2 Content Alignment

The table below represents a simplified summary of the KHSCG’s content alignment, at topic-level, with DP chemistry (SL and AHL).

Table 24: Summary of content alignment between the DP chemistry topics and the KHSCG chemistry

DP chemistry topics	SL presence in KHSCG	AHL presence in KHSCG
Structure 1. Models of the particulate nature of matter		
1.1 Introduction to the particulate nature of matter		N/A
1.2 The nuclear atom		
1.3 Electron configurations		
1.4 Counting particles by mass: The mole		N/A
1.5 Ideal gases		N/A
Structure 2. Models of bonding and structure		
2.1 The ionic model		N/A
2.2 The covalent model		
2.3 The metallic model		
2.4 From models to materials		
Structure 3. Classification of matter		
3.1 The periodic table: Classification of elements		
3.2 Functional groups: Classification of organic compounds		
Reactivity 1. What drives chemical reactions?		
1.1 Measuring enthalpy changes		N/A
1.2 Energy cycles in reactions		
1.3 Energy from fuels		N/A

⁷⁹ MOE, Republic of Korea. (2015). *The National Curriculum for the Primary and Secondary Schools*. p. 7.

⁸⁰ Ibid. p. 44.

⁸¹ Ibid. p. 50.

DP chemistry topics	SL presence in KHSCG	AHL presence in KHSCG
1.4 Entropy and spontaneity	N/A	
Reactivity 2. How much, how far and how fast?		
2.1 How much? The amount of chemical change		N/A
2.2 How fast? The rate of chemical change		
2.3 How far? The extent of chemical change		
Reactivity 3. What are the mechanisms of chemical change?		
3.1 Proton transfer reactions		
3.2 Electron transfer reactions		
3.3 Electron sharing reactions		N/A
3.4 Electron-pair reactions		
Experimental programme	Within the 'Scientific Investigation' course	

Key:

	Strong presence of this topic in the KHSCG.		Partial presence of this topic in the KHSCG.		Little or no presence of this topic in the KHSCG.	N/A	This topic does not exist at the respective level.
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NB: Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

The topic coverage of the KHSCG curriculum is strongly aligned with that of the DP chemistry, with only two of the DP's topics not being present in the KHSCG curriculum. These are Structure 3.2 – Functional groups: Classification of organic compounds and 3.4 – Electron-pair reactions. All other topics are covered to some extent by the KHSCG chemistry curriculum, mostly showing high levels of alignment, particularly with SL topics. Regarding AHL content, there are a number of areas – such as the nuclear atom, classification of elements in the periodic table, energy cycles in reactions, and proton transfers – that are covered to similar depth. However, some areas are covered only partially – such as electron configurations, the covalent model, entropy and spontaneity, and electron transfer reactions – while some are completely absent, such as classification of organic compounds and the metallic model. Thus, KHSCG surpasses the content of SL with regard to depth, though not HL. The experimental programme of the DP is partially covered within Chemistry I and Chemistry II, through references to experimental research and project work, and further alignment is found in the 'Scientific Investigation' common course. Within this, students carry out an investigation from a topic of their choice; planning, obtaining and analysing results and then completing a small write-up of this. Therefore, the DP's experimental programme is fully aligned with the KHSCG.

Notably, the KHSCG curriculum also covers some areas and concepts which are absent from the DP curriculum. The properties of water, for instance, is present in KHSCG chemistry but the DP covers this in its biology curriculum. The KHSCG also contains the concepts of half-life and first order reactions which are not found in the DP chemistry. The KHSCG chemistry also differs from the DP in that it features an underlying theme of the importance of chemistry for everyday life – while links to the real world are made in the DP curriculum, the 'everyday life' aspect is much more prominent on the KHSCG, where these links are deeply embedded in numerous content areas. For example, Chemistry I covers cases where chemistry has contributed to solving food problems, clothing problems, and housing problems – an approach that is not found in the DP.

Table 25: KHSCG chemistry content which is not covered in the DP

Significant KHSCG content which is not included in DP chemistry*
- The properties of water & its importance in everyday life - General theme of 'real life' importance: e.g. importance of buffers in vivo, fermentation in real life, examples of catalysts in life/industry, altering freezing/boiling points - Half-life and first order reactions

*Significant content does not include topics that are typically studied *prior* to upper secondary

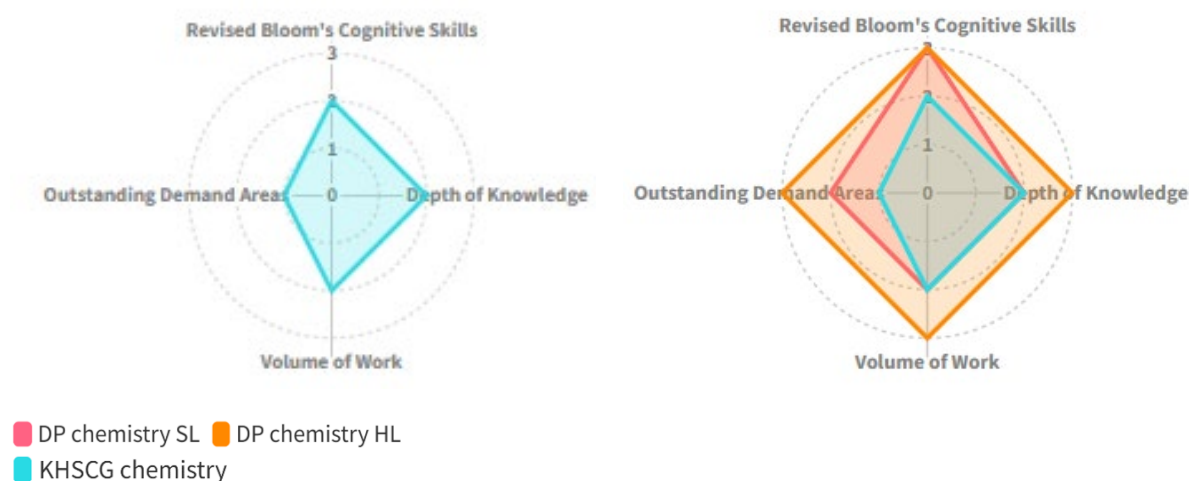
Summary

In general, the KHSCG chemistry curriculum is highly aligned with the DP, with very few topic areas in one that are not covered by the other. The KHSCG curriculum has a more limited coverage of the mechanisms of chemical change, lacking content on electron transfer and electron-pairing reactions, and classification of organic compounds. Instead, it features coverage of the properties of water, half-life and first order reactions, and an overall emphasis on the importance of chemistry in everyday life, which make up a smaller focus in the DP. Overall, the focus, breadth and depth of the curricula are similar, though the KHSCG is somewhat surpassed in content size by DP HL.

4.6.3 Demand

The DP and KHSCG curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, and KHSCG chemistry. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing the profiles superimposed in one place, enabling immediate visual comparison.

Figure 14: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.

- The score of 2 was given to the KHSCG chemistry curriculum due to the presence of higher order thinking skills in the learning outcomes, such as 'problem solve, analyse and develop original ideas'. However, the focus is not predominantly on these aspects, hence the judgement of 2.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - The KHSCG chemistry received a score of 2 due to the strong emphasis on inquiry, and the linking across multiple topics and subjects. The threshold for a score of 3 was judged not to be met as the inquiry and linking processes do not appear to be complexly drawn out over a long period of time.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - A score of 2 was given to KHSCG chemistry as the amount of content covered and time allocation per theme are relatively standard, and most themes are covered in considerable detail, going beyond basic conceptual depth.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - No specific subject content areas within KHSCG chemistry were regarded as outstanding in terms of demand. However, the consistent theme of scientific inquiry and the linking of multiple concepts provides significant opportunity for stretching students' understanding, hence the score of 1.

4.7 United States

The NGSS are a set of standards, developed in 2013, outlining the scientific and engineering practices, crosscutting concepts, and core ideas within science that all K-12 students' education should be tailored around in applicable states.⁸² They were developed with the intention of aligning current scientific curriculum demands with more contemporary understandings of science, and modern understandings of best teaching practice.⁸³

The NGSS were developed in a collaborative, state-led process by science supervisors from 26 states, consulting teachers, scientists, and education workers, who drafted the standards based on the National Research Council's document 'A Framework for K-12 Science Education'.⁸⁴ Overall, the NGSS promote 'student-centred' learning that encourages collaboration, communication, and problem solving.⁸⁵ The standards propose five innovations for teaching, designed to enhance the quality of content and learning when delivering science education:

Table 26: Five innovations for teaching developed within the NGSS.⁸⁶

Innovations for teaching	
Three-dimensional learning	There are three equally important, distinct dimensions to learning science included in the NGSS: Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. The NGSS connect all three dimensions. To prepare students for success in college and 21st century careers, the NGSS also connect scientific principles to real-world situations, allowing for more engaging and relevant instruction to explore complicated topics.
All three dimensions build coherent learning progressions	The NGSS provide students with continued opportunities to engage in and develop a deeper understanding of each of the three dimensions of science. Building on the knowledge and skills gained from each grade – from elementary through high school – students have multiple opportunities to revisit and expand their understanding of all three dimensions by the end of high school.
Students engage with phenomena and design solutions	In instructional systems aligned to the NGSS, the goal of instruction is for students to be able to explain real-world phenomena and to design solutions using their understanding of the Disciplinary Core Ideas. Students can achieve this goal by engaging in the Science and Engineering Practices and applying the Crosscutting Concepts.
Engineering and the Nature of Science is integrated into science	Some unique aspects of engineering (e.g., identifying problems) are incorporated throughout the NGSS. In addition, unique aspects of the nature of science (e.g. how theories are developed) are also included throughout the NGSS as practices and crosscutting concepts.
Science is connected to math and literacy	The NGSS not only provide for coherence in science instruction and learning but the standards also connect science with mathematics and English Language Arts. This meaningful and substantive overlapping of skills and knowledge affords all students equitable access to the learning standards.

⁸² NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Developing the Standards*. Available from: <https://www.nextgenscience.org/developing-standards/developing-standards>

⁸³ NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Factsheet*. Available from: <https://www.nextgenscience.org/sites/default/files/resource/files/NGSSFactsheet2016revised.pdf>

⁸⁴ National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Available from: <https://doi.org/10.17226/13165>

⁸⁵ NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Factsheet*.

⁸⁶ Ibid.

As can be seen above, they prioritise the development of students who are prepared to enter university and the 21st-century workforce. They do so particularly by emphasising linkages and connections between the scientific disciplines taught and the real world, building students' ability to engage with the latter and design solutions for real-world situations.

Notably, the standards do not dictate teaching methods or curriculum design, but rather set out goals upon which teachers are to devise their curriculum and lesson plans, allowing for flexibility and tailored delivery. The implementation of the standards is decided at state and local levels, allowing for flexibility and different approaches of their implementation alongside any other state-specific goals.⁸⁷

In this study, the NGSS Physical Sciences standards were used as the comparison point against the DP chemistry.

NGSS Physical Sciences^{88, 89}

The NGSS high school standards apply from grades 9 to 12 and are split into Physical Sciences (PS), Life Sciences (LS), Earth and Space Sciences, and Engineering - with PS covering topics relating directly to physics alongside chemistry topics. The high school standards build upon the concepts taught and included in the middle school standards, so there is a natural progression from grade 8, the final year of middle school and high school where the content goes into greater depth and allows for further cross cutting themes to be explored across physical, life and earth and space sciences. NGSS PS include topics on chemistry, which overlap in some areas with those relevant to physics. These topics of direct relevance to chemistry include the structure and properties of matter and in particular, chemical reactions.

4.7.1 Learning Outcomes

The learning outcome themes for chemistry were taken from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for physics, chemistry, and biology. The NGSS for grades 9-12 are made up of performance expectations, which were developed using three elements – science and engineering practices, disciplinary core ideas, and cross-cutting concepts. For the analysis of learning outcomes, the science and engineering practices are the most relevant, however the cross-cutting concepts and performance expectations are also reviewed to add context. It is important to note that the NGSS performance expectations used in the analysis apply across all grades 9-12, rather than individual years of study.

The following table demonstrates the learning outcome themes that were extracted from the DP sciences subject group and indicates if and where they were judged to have presence within the learning outcomes of the NGSS PS.

⁸⁷ Ibid.

⁸⁸ NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Understanding the Standards*. Available from: [Understanding the Standards | Next Generation Science Standards \(nextgenscience.org\)](https://www.nextgenscience.org/understanding-the-standards)

⁸⁹ NGSS Lead States. (2013). *Read the standards*. Available from: [Read the Standards | Next Generation Science Standards \(nextgenscience.org\)](https://www.nextgenscience.org/read-the-standards)

Table 27: Presence of the DP sciences subject group learning outcome themes in the NGSS PS

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the NGSS	
1. Conceptual understanding and making connections		Not present. No explicit reference to developing conceptual understanding or making connections.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present. The science and engineering practices imply that students will have the knowledge and ability to apply it in various ways. Furthermore, some performance expectations explicitly refer to application of knowledge.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, and synthesis)		Present. This is a strong theme of the science and engineering practices.
4. Skills for scientific inquiry		Present. This is a strong theme of the science and engineering practices.
5. Development of technological skills		Present. The science and engineering practices frequently refer to using technology. Furthermore, how science and technology influence each other, society and the environment is a theme present in the NGSS.
6. Effective collaboration and communication		Present. Collaboration is referred to in the context of carrying out investigations. The science and engineering practices also expect that students are able to communicate in various formats.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Somewhat present. In the science and engineering practices, the impact of science is considered in context of carrying out investigations, and solving real-world problems is also stated. Also, how science, technology, society and the environment relate to one another is a theme in the NGSS, however only a limited number of performance expectations include this element.

Key:

<i>This theme is well-evidenced in the learning outcomes of the NGSS.</i>	<i>This theme is partially evidenced in the learning outcomes of the NGSS.</i>	<i>This theme is not evident in the learning outcomes of the NGSS.</i>
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Presence of the DP's Learning Outcome Themes

The demonstration of understanding and application as a theme is well reflected across the NGSS topic areas. Although the NGSS performance expectations are predominantly skills-focused, it is clear that students would need to acquire significant fundamental knowledge and understanding of the key facts and underpinning theories and concepts in order to acquire the stated competencies. This is evident from the introductory statement of each performance expectation 'students who demonstrate understanding can:', implying that developing an understanding is a precursor to the application of knowledge in practice. The NGSS 'disciplinary core ideas' include the key content students are expected to understand. For example, in the topic on forces and interactions, core disciplinary ideas include forces and motion, types of interactions and definitions of energy. Furthermore, a large proportion of the NGSS performance expectations involve applying knowledge across a range of different

contexts and topic areas in the PS. Some make direct reference to 'apply', whereas others use other command words which similarly invoke the application of knowledge and skills. However, there is no explicit reference to students developing conceptual understanding or making connections within chemistry or to other science disciplines and subjects. That said, the cross-cutting concepts are designed to help students understand core ideas, new phenomena, and science and engineering practices. Therefore, conceptual understanding and making connections are implicitly present in the design of the standards and likely to be needed to achieve the performance expectations

The science and engineering practices evidence numerous other DP themes. For example, 'Planning and carrying out investigation' aligns with the DP's themes of investigation skills, collaboration, and awareness of scientific implications – as it states that students should 'plan and conduct investigations independently and collaboratively' and that this should be done in a 'safe and ethical manner including considerations of environmental, social, and personal impacts'. Furthermore, as well as providing detail on the design and implementation skills, the science and engineering practices also provide detail on the sub-skills involved in undertaking investigations. For instance, 'Obtaining, Evaluating and Communicating Information' details how students should be able to communicate scientific information and ideas in multiple formats. Additionally, the DP's theme of creative and critical thinking skills is strongly present in the science and engineering practices, which include these skills both in reference to investigations, and generally. Indeed, the science and engineering practices explain that students should be able to analyse data (using various techniques). 'Analysing and Interpreting Data' explains that students should be able to analyse data, construct evidence-based arguments, justify reasoning, evaluate and critique information, create and revise models, critically read scientific literature, and design solutions to real-world problems.

The DP's theme of developing technological skills is also present in the science and engineering practices, as they detail how students are expected to select and appropriately use technological tools for observing, measuring, recording, and analysing data – including for using models and performing statistical analysis. Furthermore, the ability to understand and consider the influence of science, engineering and technology on society and the environment as a whole is a cross-cutting theme within the NGSS. Therefore, it follows that there is some alignment with the DP's theme of the social and environmental implications of science. However, performance expectations which include this theme are few in the PS and LS standards.

Other Themes in the NGSS

A couple of outcome themes emerge as receiving greater emphasis in the NGSS when compared to the DP. The ability to use computational thinking is one area which appears to be more prominent in the NGSS performance expectations and in particular, the science and engineering practices. The performance expectations refer to using mathematical representations of physical models to solve problems, whilst the science and engineering practices make explicit reference to using computational simulations. Moreover, the science and engineering practices place more emphasis than is perhaps evident in the DP themes on understanding and applying scientific models. Indeed, in one such practice area students are expected to 'develop and use a model based on evidence to illustrate the relationships between systems or between components of a system'.

Summary

Learning outcomes from the NGSS PS standards compare well to the themes extracted from the DP's sciences subject group. Acquiring and applying knowledge of ideas, theories and concepts in chemistry is evident across a number of the performance expectations in the topic areas relevant to chemistry in the NGSS PS. For example, in the topic on chemical reactions, students are expected to 'Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties'. Furthermore, application of scientific knowledge is also indicated by a range of NGSS performance expectations, particularly those that specify the command words 'use', 'construct' and 'apply'. However, conceptual understanding and making connections is not explicitly referenced the NGSS – though will likely be needed to achieve the performance expectations.

Furthermore, the science and engineering practices align with numerous DP themes. Indeed, 'Planning and conducting investigations', 'Analysing and interpreting data', 'Constructing explanations and designing solutions', and 'Engaging with argument from evidence' all align with the DP's themes of developing scientific inquiry skills and using creative and critical thinking. Another DP theme, effective communication and collaboration, is addressed in 'Obtaining, evaluation and communicating information' and 'Planning and conducting investigations'. Reference to using technological tools appears in several practices, hence the DP's theme of developing technical skills is also satisfied. As well as conceptual understanding, a lesser present theme is that of the ethical, environmental, economic, cultural and social impact of science. Though the relationship between science, technology, society and the environment is a theme in the NGSS, it is not present in many performance expectations.

Finally, the NGSS learning outcomes place more emphasis on computational thinking and using and applying models than the DP does in its learning outcomes.

4.7.2 Content

This section compares and contrasts the content of the DP and NGSS curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the chemistry content in the NGSS is presented below in a diagram that shows the key topics and sub-topics included.

Figure 15: NGSS PS (chemistry focus) content visualiser⁹⁰

Core	PS1: Matter and its Interactions	PS1.A: Structure and Properties of Matter	PS1.B: Chemical Reactions	PS1.C: Nuclear Processes	
	PS2: Motion and Stability: Forces and Interactions				
	PS3: Energy	PS3.A: Definitions of Energy	PS3.B: Conservation of Energy and Energy Transfer		PS3.D: Energy in Chemical Processes and Everyday Life
	PS4: Waves and their Applications in Technologies for Information Transfer			PS4.C: Information Technologies and Instrumentation	
Crosscutting concepts	Patterns				
	Cause and effect: Mechanism and explanation				
	Scale, proportion, and quantity				
	Systems and system models				
	Energy and matter: Flows, cycles, and conservation				
	Structure and function				
	Stability and change				
Scientific and Engineering Practices	Asking questions (for science) and defining problems (for engineering)				
	Developing and using models				
	Planning and carrying out investigations				
	Analyzing and interpreting data				
	Using mathematics and computational thinking				
	Constructing explanations (for science) and designing solutions (for engineering)				
	Engaging in argument from evidence				
	Obtaining, evaluating, and communicating information				

⁹⁰ NB: only chemistry-focused units of work from the physical sciences standards have been included. Units pertaining to other scientific disciplines are included in the relevant subject's section. For example, PS2 and PS3.C relate to physics and therefore do not appear in this figure.

4.7.2.1 Structure

Unlike the DP chemistry course, the NGSS chemistry topics are integrated into the physical science standards, which cover both chemistry and physics topics. Moreover, the content is spread across four grade levels (9-12), as opposed to the two years for the DP chemistry course. In the NGSS there is one pathway, with students studying all high school science topics outlined. In contrast, the DP provides two routes for learning; standard level (SL) and higher level (HL), with the HL chemistry content being more conceptually demanding and explored in greater depth.

The structure of DP chemistry is intended to promote conceptual teaching and learning, with the course being organised around two overarching concepts – structure and reactivity. The order of the syllabus is, thus, designed to show that structure leads to reactivity, which then alters structures. Teachers and students can use the guiding inquiry questions provided or design their own to lead the learning within each subtopic. The NGSS science curricula have been designed to allow standards to be taught in any order within the high school grade levels. In this sense, both programmes have in-built flexibility.

There are some clear structural differences between the DP and NGSS that stem from their overarching design principles. For example, the DP highlights clear links to approaches to learning, the nature of science, and study skills in chemistry at topic level. The NGSS, on the other hand, are more focused on the subject-specific objectives which are required to be met. While the NGSS do make reference to ‘connections to the nature of science’, they do so in a more general way rather than being topic-specific, which could limit the impact of this strand within teaching and learning.

The DP chemistry subject offers more opportunities for practical work, through 40 assigned hours comprising the collaborative science project and scientific investigation. The DP chemistry course also stipulates that students should show awareness of the purpose and practice of 13 chemistry techniques, outlined in Tool 1: Experimental techniques. In contrast, the NGSS contain much less emphasis on practical chemistry techniques, making explicit reference to only two of the 13 techniques required in the DP: melting point determination and molecular modelling.

Overall, despite some structural similarities, the DP chemistry course has a significantly more defined content structure than the NGSS, with student experiences of those studying the latter likely varying significantly.

4.7.2.2 Content Alignment

To complement the analysis on content alignment, the table below represents a simplified summary of the NGSS’s content alignment, at topic-level, with DP chemistry (SL and HL).

Table 28: Summary of the content alignment between the DP chemistry topics and the NGSS PS (chemistry) standards.

DP chemistry topics	SL presence in the NGSS	AHL presence in the NGSS
Structure 1. Models of the particulate nature of matter		
Structure 1.1 – Introduction to the particulate nature of matter		N/A
Structure 1.2 – The nuclear atom		
Structure 1.3 – Electron configurations		
Structure 1.4 – Counting principles by mass: The mole		N/A
Structure 1.5 – Ideal gases		N/A
Structure 2. Models of bonding and structure		
Structure 2.1 – The ionic model		N/A
Structure 2.2 – The covalent model		
Structure 2.3 – The metallic model		
Structure 2.4 – From models to materials		
Structure 3. Classification of matter		
Structure 3.1 – The periodic table: Classification of elements		
Structure 3.2 – Functional groups: Classification of organic compounds		
Reactivity 1. What drives chemical reactions?		
Reactivity 1.1 – Measuring enthalpy changes		N/A
Reactivity 1.2 – Energy cycles in reactions		
Reactivity 1.3 – Energy from fuels		N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A	
Reactivity 2. How much, how fast and how far?		
Reactivity 2.1 – How much? The amount of chemical change		N/A
Reactivity 2.2 – How fast? The rate of chemical change		
Reactivity 2.3 – How far? The extent of chemical change		
Reactivity 3. What are the mechanisms of chemical change?		
Reactivity 3.1 – Proton transfer reactions		
Reactivity 3.2 – Electron transfer reactions		
Reactivity 3.3 – Electron sharing reactions		N/A
Reactivity 3.4 – Electron-pair sharing reactions		
Experimental programme		

Key:

<i>There is strong presence of this topic in the NGSS</i>	<i>There is partial presence of this topic in the NGSS</i>	<i>There is little or no presence of this topic in the NGSS</i>
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As illustrated by the tables above, the depth and breadth of content for chemistry in the DP, both at SL and HL, exceed that of the chemistry topics in the NGSS PS. Across all NGSS, only two out of sixteen units studied focus on chemistry topics, a very small number which likely results in very limited time being dedicated to chemistry overall.

There is, however, some partial coverage of some DP chemistry topics in the NGSS, with the latter partially covering approximately three-quarters of the SL chemistry course. Topics covered include periodicity, the mole concept, bonding, rates of reaction, and the nuclear atom. The generous time allocation and broad learning objectives provide flexibility for teachers to extend learning in some topics if they choose to do so. However, the framework provides clear assessment boundaries, which teachers should not exceed. An example of this is within the sub-topic of equilibrium, where the assessment boundary states equilibrium constants and concentrations should not be calculated. In contrast, DP chemistry encourages sub-topics to be explored in greater depth and poses no limit to the scope of the curriculum.

Overall, there is limited alignment between the DP and NGSS, with several key DP chemistry sub-topics being fully absent from the NGSS PS, including: electron configurations, ideal gases, classification of organic compounds, proton transfer, electron sharing, and transfer reactions. Additionally, some of the SL sub-topics are covered in less depth, such as concentrations in Structure 1.4 - shapes of molecules and bond polarity in Structure 2.2 - and both electron transfers and electrochemical cells in Structure 3.2 (the latter not being referenced anywhere in the NGSS).

Table 29: NGSS content which is not covered by DP chemistry

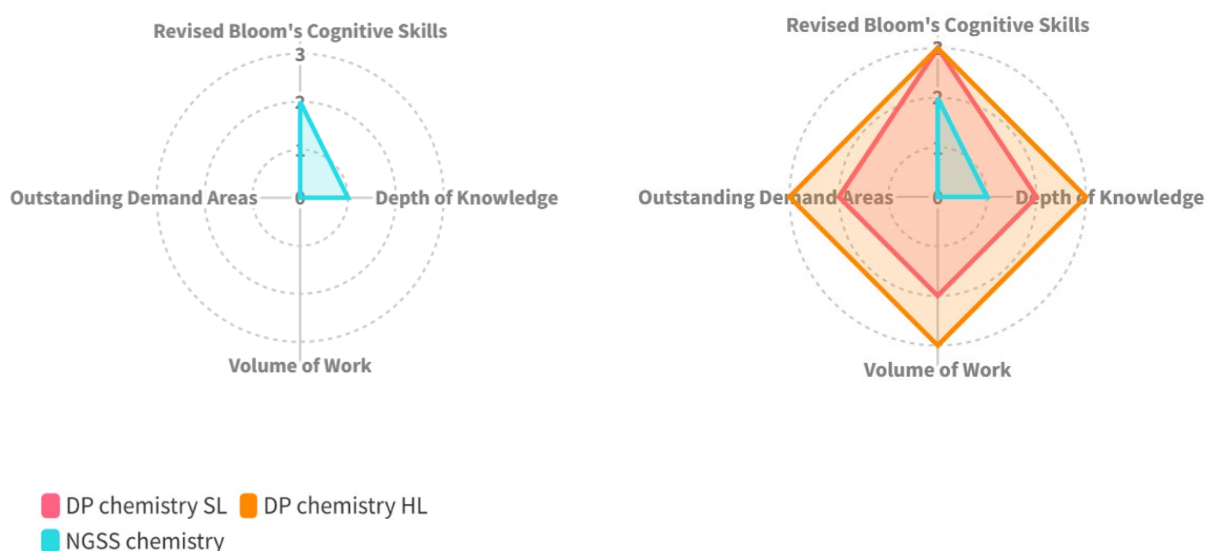
Significant NGSS content which is not included in DP chemistry*	
○	None – there is a very limited number of chemistry topics covered in the NGSS.

* Significant content does not include topics which are typically studied *prior* to upper secondary

4.7.3 Demand

The DP and the NGSS curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, and the NGSS Physical Sciences standards. These demand profiles are presented below in the form of radar diagrams, with the last diagram showing the profiles superimposed in one place, enabling immediate visual comparison.

Figure 16: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.
 - For the NGSS, a Bloom's score of 2 was deemed appropriate given a predominant focus on knowledge acquisition and application, with some presence (though limited) of higher-order thinking skills, such as analysis and interpretation of data, and emphasis on cross-curricular links. It was noted by the panel that there are

good examples of individual states providing more detail on how to apply the standards effectively, though this detail is absent from the NGSS themselves.

- Regarding the scores for **Depth of Knowledge:**
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - For the NGSS, the depth of knowledge was seen to meet a score of 1 due to the key pre-requisite requirements and some reference to calculations and analysis, though the level to which these are applied is unclear from the standards themselves.
- Regarding the scores for **Volume of Work:**
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - In contrast, the NGSS received a score of 0 for volume of work due to the apparently light depth and detail of knowledge and skills evidenced in the documentation. However, it was noted that the real breadth and depth of content, as well as time allocation per theme, may vary significantly from state to state or even school to school, depending on how the standards are applied.
- Regarding the scores for **Outstanding Areas of Subject Demand:**
 - DP chemistry SL received a score of 2 and HL received a score of 3.
 - As to the NGSS, a score of 0 was awarded as no clear areas of outstanding demand were identified – it was noted that the emphasis on cross-curricular linkages could provide opportunities for potential stretch, but that it was not possible to clearly infer this from the NGSS documentation.

4.8 France

The school system in France is overseen and regulated by the Ministry for National Education and Youth.⁹¹ Secondary education in France is divided into two cycles – lower and upper secondary education. Upper secondary education lasts three years and is provided to students between the ages of 15 and 18 years old. It is the last three years of upper secondary education that constitutes the *Baccalauréat* (FB).⁹²

The general pathway (resulting in the *baccalauréat général*) is the main focus of this study; however, students can also choose:

- the technological pathway, resulting in the *baccalauréat technologique* and;
- the professional pathway, resulting in the *baccalauréat professionnel*.

Study in upper secondary is organised into three years and two pedagogical cycles, namely:

- 1st year: *Seconde* (Grade 10: students aged 15 to 16 years old)
- 2nd year: *Première* (Grade 11: students aged 16 to 17 years old)
- 3rd year: *Terminale* (Grade 12: students aged 17 to 18 years old).

Students begin the general pathway in the *Première* year, after completion of the *Seconde* year. The *Seconde* provides an opportunity for students to consolidate and develop their foundational knowledge and skills in order to facilitate a successful transfer from lower to upper secondary education. In the general pathway, students study:

- six common subjects
- three specialty subjects in *Première* and;
- two of these speciality subjects in the *Terminale* year.

Alongside their common and speciality subjects, students can choose one optional subject in the *Première* year and an additional optional subject in the *Terminale* year.

FB physics-chemistry is offered as a speciality subject in the general pathway and this was the focus of the chemistry subject analysis.

FB physics-chemistry

Physics-chemistry is a specialty subject on the FB *général*. It is a combined subject, where physics and chemistry are taught alongside one another, and is designed as a two-year subject – studied at *Première* and *Terminale* years – though students in the FB may choose to drop it in their second year. The subject aims to provide students with the appropriate knowledge and skills to prepare them for higher education in the fields of experimental sciences, medicine, technology, engineering, computer science, or mathematics. When both *Première* and *Terminale* years are studied, the subject places significant emphasis on promoting experimental practice and modelling, requiring students to draw on every day, real-life examples as well as forming links between different themes, and different subjects.

⁹¹ Government of France, Ministry for National Education and Youth. (2023). *Let's build a committed education system together!* Available: <https://www.education.gouv.fr/let-s-build-committed-education-system-together-100037>

⁹² Ibid.

4.8.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of physics.

The learning outcome themes for chemistry were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for biology chemistry and physics.

As, in the FB, chemistry is studied as part of the FB physics-chemistry combined subject, the learning outcomes of the FB physics-chemistry subject have been mapped against both the DP chemistry and DP physics subjects.

The FB physics-chemistry curriculum outlines specific “skills developed as part of scientific research”, of which there are five:

- S'approprier – this directly translates as “to appropriate” which means that students will be expected to ‘take ownership’ of something
- Analyser/Raisonner – to analyse/reason
- Réaliser – the direct translation of this results in “to realise”, which, in this context, would be where students are expected to create something, or make something happen.
- Valider – to validate
- Communiquer – to communicate

These skills characterise the FB’s scientific approach and “aim to structure the learning and assessment of students,⁹³ being a key focus throughout students’ studies. Alongside these, the FB also provides some examples of associated capabilities. Finally, some additional skills are also discussed in the ‘Preamble’ section of the FB’s documentation. As such, the FB’s ‘skills developed as part of scientific research’, the associated capabilities, and the skills extracted from the Preamble have all been considered when mapping against the DP’s learning outcome themes.

Once commencing the general pathway, all students will follow a common curriculum, as well as choose three speciality subjects. FB physics-chemistry is one of the speciality subjects that students may choose to pursue; however, after completing the first year (*Première*) of the subject, they have the option of ceasing their studies by dropping one speciality subject. Therefore, it may be the case that not all students will complete the full two-years of study in FB physics-chemistry. However, the skills outlined in the curricula for both the *Première* and *Terminale* years of FB physics-chemistry are the same; as such, these skills will be developed in all students, regardless of whether they choose to continue to study the subject in the *Terminale* year.

Since the FB physics-chemistry course has been used for comparison to the DP physics and chemistry courses, the ‘skills developed’ in the FB are the same. This means that the results

⁹³ Ministry of Education, France. (2019). *Programme de physique-chimie de première générale*. Available from: <https://eduscol.education.fr/1648/programmes-et-ressources-en-physique-chimie-voie-gt>

of the learning outcomes comparison analysis are the same for chemistry as they are for physics.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the FB chemistry curricula.

Table 30: Presence of the DP sciences subject group learning outcome themes in the FB physics-chemistry curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in FB	
1. Conceptual understanding and making connections		Not present in skills, though the fundamental concept is briefly discussed in the Preamble.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present in four out of the five skills.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in the 'appropriate', 'analyse/reason' and 'validate' skills.
4. Apply skills necessary to carry out insightful and ethical investigations (planning, collecting data, organising, following ethical guidelines)		Present in three of the five skills.
5. Development of technological skills		Not present in skills but discussed in the Preamble of the course.
6. Effective collaboration and communication		Present in the 'communication' skill.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Not present in skills, but some aspects are briefly discussed in the Preamble.

Key:

	<i>This theme is well-evidenced in the learning outcomes of the FB.</i>		<i>This theme is partially evidenced in the learning outcomes of FB.</i>		<i>This theme is not evident in the learning outcomes of the FB.</i>
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Presence of the DP's Learning Outcome Themes

As seen in the table above, only four of the seven DP's learning outcome themes are explicitly found within the skills of the FB physics-chemistry subject. The three remaining skills are present to an extent in the Preamble of the physics-chemistry curriculum, but as discussed below, these are not expressed to the same level of detail as that featured in the DP.

1. Conceptual understanding and making connections

This theme is not evident in the skills section of the FB physics-chemistry curriculum; however, the 'making connections' aspect of this theme is discussed in the 'Preamble' section. This outlines how the curriculum is organised into four themes, and then describes how this approach "makes it possible to draw on many situations of daily life and to contribute to a fruitful dialogue with other scientific disciplines".⁹⁴ This shows that there will be a focus on students' learning involving real-life scenarios and contexts, therefore students will have to

⁹⁴ Ibid, p.2.

make connections between what they learn in class and how this applies to the real world around them. However, due to there not being any explicit reference to conceptual understanding, the theme is only partially evidenced in the FB physics-chemistry curriculum.

2. Use and application of knowledge, methods, tools, and techniques that characterise science

This theme is clearly emphasised across many of the FB physics-chemistry skills. The ‘appropriate’ skill describes how students will “state a problem” and then “research and organise information related to that problem”.⁹⁵ The following three skills (analyse/reason, realise and validate) then cover many aspects of scientific study, including formulating hypotheses, justifying and developing their choice of protocol, performing common procedures, identifying errors and comparing a model to experimental results. The aspects encompass all methods, tools and techniques that characterise science, and show that this theme is strongly prevalent in the FB physics-chemistry curriculum.

3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)

Three out of the five skills in the FB documentation demonstrate the importance of this theme within the FB physics-chemistry curriculum. The ‘appropriate’ skill outlines that students will state a problem and research information relating to this problem; these are the first steps of problem-solving. Developing, and justifying, a resolution strategy (as stated in the ‘analyse/reason’ skill) requires creativity and evaluation. The ‘validate’ skill reflects the ‘synthesis’ component of this DP theme where it details “propose possible improvements to the approach or model”.⁹⁶ These aspects fully cover the DP’s creativity and critical thinking theme, showing the importance of this theme throughout the FB physics-chemistry curriculum.

4. Apply skills necessary to carry out insightful and ethical investigations

Some aspects of the skills within the FB physics-chemistry curriculum overlap between the third theme above (critical thinking and creativity) and this theme regarding insightful and ethical investigations. For example, the ‘analyse/reason’ skill outlines the importance of formulating hypotheses, proposing a strategy and developing a protocol. The ‘realise’ skill includes this theme as it describes “Perform common procedures (collection of data). Implement an experimental protocol”.⁹⁷ Although this theme is present in so far as there are references to students applying their skills to carry out investigations in a problem-solving capacity, there is no specific reference to the ‘ethical and insightful’ component of these investigations; an aspect which is emphasised in the DP.

5. Development of technological skills

The skills outlined in the FB physics-chemistry curriculum do not specifically mention technology. However, in the ‘Preamble’ section of the course, technology is discussed within the ‘organisation of the program’ section. Here, it is stated that there is the opportunity to bring out cross-cutting notions, for example “experimental and digital devices (sensors, measuring instruments) [and] digital sciences (programming, simulation etc.)”.⁹⁸ This demonstrates that students will be interacting with technology during their course and will be guided in its use within physics and chemistry; nonetheless, technology is not highlighted as a key skill in the curriculum in the same way as it is presented in the DP.

⁹⁵ ibid

⁹⁶ ibid

⁹⁷ ibid

⁹⁸ ibid

6. Effective collaboration and communication

Although only one skill within the FB physics-chemistry outlines this theme, the skill is further described within the 'Preamble' section of the curriculum. The skill states that students will "use appropriate vocabulary and choose appropriate modes of representation";⁹⁹ it then further states the "exchange between peers" and how these aspects are used both orally and in writing.

The 'Preamble' section provides further detail on this skill, describing how students will develop their skills of argumentation; "explaining one's reasoning in a way as to convince".¹⁰⁰ The FB physics-chemistry subject outlines how this will be important for all students, but particularly those wishing to pursue further study or careers based around teaching. This highlights that, although only one skill within the FB physics-chemistry references communication, it is an important area and therefore it is implied that it would be emphasised throughout the curriculum.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

The skills outlined in the FB physics-chemistry curriculum do not specifically mention an awareness of global and local problems, and the impact of science; therefore, this theme is not present within the skills. However, in the 'Preamble' section of the course, some of these aspects are discussed within the accompanying write-up of the skills section. Here, it is described how the FP physics-chemistry subject must be implemented in a way that allows for the opportunity to discuss the "individual and collective responsibility, safety for oneself and others, the environmental education and sustainable development".¹⁰¹ This demonstrates that students will be coming across aspects of this theme during their course, but it is not highlighted as a key skill in the curriculum in the same way, or to the extent that, it is presented in the DP.

Other Themes in the FB

Whilst it is not described as a 'skill', within the Preamble of the FB physics-chemistry curriculum there is reference to students linking their theoretical understanding to the wider world through the use of models: "the modelling process occupies a central place...to train students to establish a link between objects, experiences, facts and that of models and theories".¹⁰² This is somewhat in line with the DP's use of models throughout its curriculum content in order to enhance students' understanding of concepts, though is more explicitly emphasised in the FB.

Summary

As described above, all DP learning outcome themes are at least partially evidenced within the FB physics-chemistry curriculum. Some themes, such as techniques that characterise science and creativity and critical thinking, are clearly outlined and covered thoroughly. Others, such as the development of technological skills and the awareness of the wider impact of science, are more subtle and nuanced than they are in the DP. Certain aspects of these themes are clearly present, such as environmental impact, whereas others, such as the development of technology skills, can be inferred from other references within the 'Preamble' section of the curriculum.

⁹⁹ *ibid*, p. 3.

¹⁰⁰ *ibid*

¹⁰¹ *ibid*

¹⁰² *ibid*, p. 1.

4.8.2 Content

This section compares and contrasts the content of the DP and FB curricula falling within the category of chemistry. The FB chemistry curriculum is presented below in diagrams which show the key topics and subtopics included in each.

Figure 17: FB physics-chemistry content visualiser

Physics-chemistry Première	Constitution and Transformations of Matter	1. Monitoring the evolution of a system, seat of a transformation	2. From the structure of entities to the physical properties of matter	3. Physico-chemical properties, synthesis and combustion of chemical organic species	
	Movement and Interactions	1. Fundamental interactions and introduction to the notion of field	2. Description of a fluid at rest	3. Movement of a system	
	Energy: conversions and transfers	1. Energetic aspects of electrical phenomena	2. Energetic aspects of mechanical phenomena		
	Waves and Signals	1. Mechanical Waves	2. Light: images and colours, wave and particle models		
Physics-chemistry Terminale	Constitutions and Transformations of Matter	1. Determine the composition of a system by physical and chemical methods	2. Modeling the temporal evolution of a system, seat of a transformation	3. Predicting the final state of system, the site of chemical transformation	4. Develop strategies in organic synthesis
	Movement and Interactions	1. Describe a movement	2. Link the actions applied to a system to its movement	3. Model the flow of a fluid	
	Energy: conversions and transfers	1. Describe a thermodynamic system: example of the perfect gas model	2. Carry out energy balances on a system: the first principle of thermodynamics		
	Waves and Signals	1. Characterise wave phenomena	2. Forming images, describing light by a flux of photons	3. Study the dynamics of an electrical system	

4.8.2.1 Structure

Both DP chemistry and FB physics-chemistry are designed as two-year subjects, with both offering the opportunity for students to study chemistry at different levels – i.e. the FB by allowing students to choose whether to continue to study the FB physics-chemistry subject in the *Terminale* year; the DP by offering students the opportunity to study DP chemistry at either SL or HL.

One notable difference between the structure of the chemistry subject area in the DP and FB is that in the latter chemistry is taught as part of the FB physics-chemistry subject. In contrast, chemistry and physics content are covered in separate subjects in the DP – i.e. DP chemistry and DP physics, respectively.

Like the DP chemistry subject, FB physics-chemistry is divided into overarching themes of study. In the latter's case, the subject is divided into four themes that cover both chemistry and physics content, namely: Constitution and Transformations of Matter, Movement and Interactions, Energy: Conversions and Transfers, and Waves and Signals. These themes are designed to promote a transdisciplinary approach and encourage real-life application.

In turn, the DP chemistry subject is designed through a concept-based approach and organised into two overarching, discipline-specific topics – Structure and Reactivity. Each of these topics covers various key areas within them and is further divided into subtopics. Overall, DP chemistry SL consists of 22 subtopics, while the DP chemistry HL extends learning in 13 of the 22 subtopics and contains one additional HL-only subtopic.

The FB physics-chemistry subject builds on the prerequisite scientific understanding obtained in the *Seconde* year of study. In contrast, the two routes through DP chemistry do not detail specific knowledge prerequisites, allowing students from a variety of backgrounds to access both DP chemistry SL and HL; however, in the case of the latter, students are recommended to have 'some previous exposure to formal science education', either through having 'undertaken the IB Middle Years Programme (MYP) or studied an equivalent national science qualification or a school-based science course'.¹⁰³

4.8.2.2 Content Alignment

The table below represents a simplified summary of the FB's content alignment, at topic-level, with DP chemistry (SL and HL).

¹⁰³ International Baccalaureate (2023) *Chemistry Guide* p.18

Table 31: Summary of content alignment between the DP chemistry topics and the FB physics-chemistry

DP chemistry topics	SL presence in FB physics-chemistry	AHL presence in FB physics-chemistry
Structure 1. Models of the particulate nature of matter		
Structure 1.1 – Introduction to the particulate nature of matter		N/A
Structure 1.2 – The nuclear atom		
Structure 1.3 – Electron configurations		
Structure 1.4 – Counting principles by mass: The mole		N/A
Structure 1.5 – Ideal gases		N/A
Structure 2. Models of bonding and structure		
Structure 2.1 – The ionic model		N/A
Structure 2.2 – The covalent model		
Structure 2.3 – The metallic model		
Structure 2.4 – From models to materials		
Structure 3. Classification of matter		
Structure 3.1 – The periodic table: Classification of elements		
Structure 3.2 – Functional groups: Classification of organic compounds		
Reactivity 1. What drives chemical reactions?		
Reactivity 1.1 – Measuring enthalpy changes		N/A
Reactivity 1.2 – Energy cycles in reactions		
Reactivity 1.3 – Energy from fuels		N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A	
Reactivity 2. How much, how fast and how far?		
Reactivity 2.1 – How much? The amount of chemical change		N/A
Reactivity 2.2 – How fast? The rate of chemical change		
Reactivity 2.3 – How far? The extent of chemical change		
Reactivity 3. What are the mechanisms of chemical change?		
Reactivity 3.1 – Proton transfer reactions		
Reactivity 3.2 – Electron transfer reactions		
Reactivity 3.3 – Electron sharing reactions		N/A
Reactivity 3.4 – Electron-pair sharing reactions		
Experimental programme		

Key:

Strong presence of this topic in the FB.	Partial presence of this topic in the FB.	Little or no presence of this topic in the FB.	N/A	This topic does not exist at the respective level.
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NB: Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

As mentioned above, the DP chemistry SL consists of 22 subtopics. The FB physics-chemistry subject covers the large majority (19) of these subtopics in similar depth and detail, including Models of bonding and structure and Classification of matter.

There are three subtopics that are not covered in the same level of detail as that found in DP chemistry SL, which are: Structure 2.4 – From models to materials, Reactivity 1.2 – Energy cycles in reactions and Reactivity 3.3 – Electron sharing reactions. For 2.4 – From models to materials, the FB physics-chemistry covers polymers, but, unlike the DP, does not include coverage of alloys. For Reactivity 1.2 – Energy cycle in reactions, energy requirements for bond making and breaking are covered, but Hess's law is not covered to the same extent. Finally, for Reactivity 3.3 – Electron sharing reactions, the FB does cover electron sharing reactions, but does not cover free radical substitution, which is present in the DP.

As for comparison to DP chemistry HL, the FB physics-chemistry subject covers four AHL subtopics in similar depth and detail; these are: Structure 2.3 and 2.4, Reactivity 2.3 and 3.1. FB physics-chemistry also partially covers seven HL subtopics – Structure 1.2, 2.2, 3.1, 3.2 and Reactivity 2.2, 3.2 and 3.4 – but features less depth and detail in its coverage of these. For example, the DP chemistry HL covers Rate constants and the Arrhenius equation, which is not present in the FB physics-chemistry curriculum.

There are three DP chemistry AHL topics that are not covered in the FB physics-chemistry subject: Structure 1.3, Reactivity 1.2, Reactivity 1.4. FB physics-chemistry does not cover any additional chemistry content that is not included in the DP chemistry subject.¹⁰⁴

FB physics-chemistry subject has similar subject breadth to the DP chemistry SL, though it lacks depth in four subtopics. It has notably less subject depth than the DP chemistry HL, with seven AHL topics having only a partial presence in the FB physics-chemistry. There is greater subject breadth in DP chemistry HL, as there are three subtopics that are altogether absent from the FB physics-chemistry subject.

Table 32: FB physics-chemistry content which is not covered in the DP

Significant FB chemistry content which is not included in the DP*
There is no significant chemistry content in the FB that is not included in the DP.

*The FB physics-chemistry subject also contains physics content – see section 5.2.1. Notably, 'significant content' does not include topics which are typically studied *prior* to upper secondary.

In summary, when comparing the chemistry content covered by FB physics-chemistry in both *Première* and *Terminale*, they align to a similar breadth and depth as that found in DP chemistry SL. The main difference is that the chemistry content in FB physics-chemistry is taught in combination with physics, whereas physics and chemistry are taught as discrete subjects with the DP.

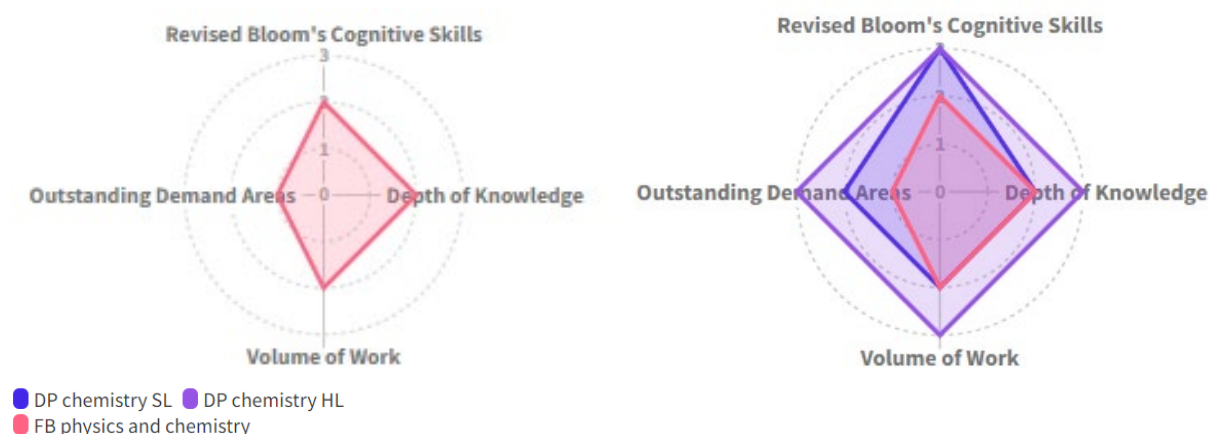
When compared to DP chemistry HL, there is considerably less depth and breadth in the chemistry content of the FB physics-chemistry, with seven AHL subtopics being covered in less depth and detail and three topics being fully absent.

4.8.3 Demand

The DP and FB curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL and FB physics-chemistry. The FB demand profile is presented below in the form of a radar diagram, beside another radar diagram showing all DP and FB profiles superimposed in one place, enabling immediate visual comparison.

¹⁰⁴ As a combined subject, FB physics-chemistry does include additional physics topics which align with the DP physics subject instead – see Physics Subject Report.

Figure 18: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.
 - For FB physics-chemistry, a score of 2 was given. This was due to the presence of critical thinking and a large amount of analysis within the skills of the FB, as well as the mention of students making predictions, and revising experimental procedures as necessary. However, there was not enough evidence of a strong presence of evaluation and synthesis to warrant a judgement of 3.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and DP HL received a score of 3.
 - The FB physics-chemistry course was given a score of 2 for the depth of knowledge category. The reasoning behind this was that FB requires students to use some complex reasoning, and some content (electromagnetic and gravitational fields) allows for challenging and abstract thinking. However, insufficient evidence of extended thinking and problem-solving was found to warrant a score of 3.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and DP HL received a score of 3.
 - A score of 2 was given to FB physics-chemistry. There is a relatively high number of themes covered in the course, and due to the coverage of both physics and chemistry together, this results in a short time allocation per theme. This also means that some amount of time is dedicated to content beyond basic conceptual depth, warranting a score of 2.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a score of 3.
 - The FB physics-chemistry was given a score of 1 for outstanding areas of demand. The transdisciplinary approach to teaching and coverage of thermodynamics were considered to make up 1 or 2 stretch areas, awarding it a score of 1.

4.9 Spain

The school system in Spain is overseen by the Ministry of Education and Vocational Training, but is decentralised into 17 autonomous regions. As such, while the Ministry oversees the core curriculum and assessment, the regions can determine specific procedures and dictate some subjects within the overall selection.

Overall, the Spanish system is divided into primary school, lower secondary education, and upper secondary education. Upper secondary education is non-compulsory and lasts for two years, being attended by students between the ages of 16 and 18 years old.¹⁰⁵ During upper secondary, students can take the Spanish *Bachillerato* (SB).

The SB is offered through four different streams (i.e. modalities), which students can choose from, in line with their specific interests and career plans:

- the Arts modality (includes two pathways);
- the Sciences and Technology modality;
- the Humanities and Social Sciences modality; and
- the General modality.

Students from all modalities study a range of subjects from different categories, including:

- **Common subjects:** these are subjects taken by all students regardless of their modality.
- **Modality subjects:** these are subjects taken by students in the same modality.
- **Elective subjects:** these are optional subjects that students can choose to study.

In addition to the common and modality subjects above, students in the SB also study elective subjects. The specific subjects offered are determined by the Spanish regional educational authorities but should include at least one second foreign language.¹⁰⁶

The mathematics studied as part of the Science and Technology modality is the main focus of the mathematics comparison analysis. The below table displays the subjects within this modality:

Table 33: Subjects offered in the Science and Technology modality

Modality	Year of study	Subjects
Science and Technology	Year 1	Mandatory subject: Mathematics I
		Two subjects to be chosen from: • Biology, geology and environmental sciences • Technical drawing I • Physics and chemistry Technology and engineering I

¹⁰⁵ Government of Spain, Ministry of Education and Vocational Training (n.d). Compulsory Secondary Education, <https://educagob.educacionyfp.gob.es/enseanzas/secundaria.html> ; Government of Spain, Ministry of Education and Vocational Training (n.d). Bachiller Certificate, <https://educagob.educacionyfp.gob.es/enseanzas/bachillerato.html>

¹⁰⁶ Government of Spain, Ministry of Education and Vocational Training (n.d). General information of the Bachillerato. Elective subjects. <https://educagob.educacionyfp.gob.es/enseanzas/bachillerato/informacion-general/organizacion.html>

	Year 2	Mandatory subject: Mathematics II or Mathematics Applied to Social Sciences II
		Two subjects to be chosen from: • Biology • Technical drawing II • Physics • Geology and environmental sciences • Chemistry Technology and engineering II

The following subjects from the Science and Technology Modality were used in the chemistry subject comparisons.

SB physics and chemistry¹⁰⁷

Physics and chemistry is a one-year modality subject that students may opt to study on the first year of the Science and Technology modality of the SB. The subject combines physics and chemistry content, building on prior scientific knowledge and skills acquired during lower secondary education. It intends to provide a strong foundation for further physics and/or chemistry study in the following year.

SB chemistry¹⁰⁸

Chemistry is a one-year modality subject that students may opt to study on the second year of the Science and Technology modality of the SB. It builds on the SB physics and chemistry subject offered in the SB's first year, aiming to provide the appropriate foundation of knowledge and skills required for further scientific study at higher education level. Students must have completed the first-year SB physics and chemistry in order to take SB chemistry in their second year.

4.9.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of chemistry.

For the DP, the learning outcome themes for chemistry were extracted from the aims and assessment objectives of the Sciences subject group, hence the themes are the same for biology chemistry and physics.

The learning outcomes for the SB were drawn from the 'Specific Competences' (SCs) of both the SB physics and chemistry and the SB chemistry subjects. While there are some minor differences between the SCs of both SB subjects, these did not affect the level of alignment with the DP learning outcome themes; as such, most of the analysis applies to both subjects, flagging the slight differences observed when appropriate.

¹⁰⁷ Ministry of Education, Spain. (2023). *Physics and chemistry*. Available from: <https://educagob.educacionyfp.gob.es/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/materias/fisica-quimica/competencias-especificas.html>

¹⁰⁸ Ministry of Education, Spain. (2023.). *Chemistry*. Available from: <https://educagob.educacionyfp.gob.es/ca/curriculo/curriculo-lomloe/menu-curriculos-basicos/bachillerato/materias/quimica/desarrollo.html>

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the SB chemistry curricula.

Table 34: Presence of the DP sciences subject group learning outcome themes in the SB chemistry curricula

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the SB	
1. Conceptual understanding and making connections		Present in both sets of SCs
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Present in both sets of SCs
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in both sets of SCs
4. Skills for scientific inquiry		Somewhat present in the SB chemistry SCs, and SB physics and chemistry competences.
5. Development of technological skills		Absent from SB chemistry SCs, but present within the SB physics and chemistry competences.
6. Effective collaboration and communication		Present in both sets of SCs
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Present in both sets of SCs.

Key:

	<i>This theme is well-evidenced in the competences of the SB</i>		<i>This theme is partially evidenced in the competences of the SB</i>		<i>This theme is not evident in the competences of the SB.</i>
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Presence of the DP's Learning Outcome Themes

As can be seen in the table above, all learning outcome themes extracted from the DP are present to some extent in the SB chemistry curricula. The below write-ups provide a summary of the extent to which each DP theme is present in the SB.

1. Conceptual understanding and making connections

Many of the SB chemistry SCs demonstrate the importance of conceptual understanding and making connections (within the subject, and with other science subjects). For example, specific competence 2 states that students will be “studying the properties of material systems”¹⁰⁹. Specific competence 3 describes how students will use chemical nomenclature, units and equations “as a basis for adequate communication between different scientific communities”¹¹⁰. Specific competence 6 shows this theme most prominently when it describes students being required to highlight the relationship that chemistry has “with other sciences and fields of knowledge”, promoting a “holistic approach” to scientific knowledge¹¹¹. This provides evidence of the conceptual understanding and making connections theme within the SB.

¹⁰⁹ ibid

¹¹⁰ ibid

¹¹¹ ibid

This theme is further evidenced through the more detailed description of specific competence 2, where the SB acknowledges that students should not only learn chemical laws, theories and experimental observations of chemistry, but that they must also interact with a “coherent model of nature...through contact with everyday situations”.¹¹²

2. Use and application of knowledge, methods, tools, and techniques that characterise science

There are many SCs within the SB chemistry curriculum that link closely with this theme. Specific competence 1 describes how students must understand, describe and apply the “fundamentals of the most important chemical processes”.¹¹³ Specific competence 2 enhances this with students adopting the “accepted models and laws of chemistry”,¹¹⁴ and specific competence 3 further shows the presence of this theme when it references the “codes of chemical language” and their use as a “fundamental tool in the research of this science”.¹¹⁵

3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)

The theme of problem-solving is well-evidenced through the SB chemistry SCs.¹¹⁶ Three of these discuss the requirement of students to “help overcome the negative connotations that are often attributed to the word “chemical””, which would require both problem solving and creative thinking. Specific competence 5 describes the need for “logical-mathematical reasoning in the resolution of chemistry problems” and specific competence 6 further reflects this theme through asking students to “recognise and analyse chemistry”.

The specific competences of the SB physics and chemistry curriculum also include problem-solving aspects; such as SC 1: “solve problems and situations related to physics and chemistry, applying the appropriate scientific laws and theories”.¹¹⁷

The SB features a lighter focus on the evaluation and synthesis aspect of this theme, but there are many references to analysis, problem-solving and critical thinking, showing that this theme is present within SB chemistry.

4. Skills necessary for insightful and ethical investigations

Within the chemistry SCs, only specific competence 5 relates to this DP theme: “apply work techniques typical of experimental sciences...in the resolution of chemistry problems”.¹¹⁸ It can be inferred that ‘work techniques’ of experimental sciences would involve carrying out practical procedures and investigations; however, there is no explicit reference to this in the SCs.

The more detailed description of specific competence 6 references that students will “develop their learning through experimental study and observation”,¹¹⁹ but there is no further description of the exact nature of the ‘experimental study’. Thus, while the DP strongly emphasises the importance of practical work and experimental techniques, this theme is less apparent in the SB.

¹¹² *ibid*

¹¹³ *ibid*

¹¹⁴ *ibid*

¹¹⁵ *ibid*

¹¹⁶ *ibid*

¹¹⁷ Ministry of Education, Spain. (2023). *Physics and chemistry*.

¹¹⁸ Ministry of Education, Spain. (2023). *Chemistry*.

¹¹⁹ *ibid*

5. Development of technological skills

None of the SCs within the SB chemistry curricula cover this DP theme of technology skills. The only reference to it is within the first-year SB physics and chemistry course, where specific competence 4 states that students will use digital platforms and varied resources to create materials in various formats. This mention of 'digital platforms' is the only reference to technology found, meaning the DP theme is only somewhat present in the SB.

6. Effective collaboration and communication

Only specific competence 5 out of all SB chemistry's SCs references communication skills, stating that students should "value the importance of cooperation".¹²⁰ However, within the SB physics and chemistry SCs, the theme of communication and collaboration is more prominent. Specific competence 3 states that students should manage "different registers of communication",¹²¹ and "individual and teamwork"¹²² is mentioned in specific competence 4. Specific competence 5 really highlights the presence of this theme by detailing that students are to "work collaboratively in diverse teams, applying coordination, communication, and balanced responsibility skills".¹²³ There is also an element of communication within specific 6 of the SB physics and chemistry, which mentions that students "become active agents of the dissemination of scientific thought".¹²⁴

The more detailed description of specific competence 5 further emphasises the importance of collaboration. Students will recognise the importance of working as a team, and how collaboration between individuals is fundamental to achieving scientific progress.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

This DP theme regarding global and local problems is evident in many SCs of the SB chemistry. Specific competence 2 discusses how students are to "infer general solutions to everyday problems related to...chemistry and its repercussions on the environment". Specific competence 4 encourages students to recognise why responsible use of chemical products is important, and specific competence 5 states that students should work towards the "resolution of chemistry problems...and to value the role of chemistry in a society based on ethical and sustainable values".

The SCs in the SB physics and chemistry curriculum further enhance the presence of this theme in the SB. Specific competence 5 describes that students are to "predict the consequences of scientific advances and their influence on...health and sustainable environmental development". Specific competence 6 explains how students will participate in the "construction of scientific knowledge, in its daily and close environment" and goes on to say that students should preserve "the environment and public health [and] economic development".

Although there is less evidence of the 'culture' aspect of this DP theme, the strong presence of the environmental, ethical and social aspects show similarity to the SB.

Other Themes in the SB

No additional learning outcome themes were found in the SB chemistry and SB physics and chemistry curriculum that were not present in the DP. However, in SB physics and chemistry

¹²⁰ ibid

¹²¹ Ministry of Education, Spain. (2023). *Physics and chemistry*.

¹²² ibid

¹²³ ibid

¹²⁴ ibid

there is a heavy emphasis on utilising cognitive skills through the interconnection of physics and chemistry, with specific competence 1 discussing the importance of problem-solving and understanding physicochemical phenomena, analysing interactions in the light of physicochemical laws and theories. This merging of physics and chemistry is unsurprising given the design of the subject, but the mention of 'physicochemical phenomena' and its strong presence in the SCs constitutes a difference with the DP. Although the theme of linking concepts across multiple subjects is evident in the latter, the DP's is defined more broadly, without the same specific focus being given to physics and chemistry in particular.

The SB also provides a more detailed description than the DP of the communication and collaboration skills that it targets. While the SB encompasses the DP's theme of 'collaboration and communication', the SB specifically describes the importance of working collaboratively and in diverse teams as a way of developing other skills, such as reading, writing, speaking, technology and mathematics. Whilst all these skills are present within the DP, they are not so clearly linked to the communication and collaboration theme as they are in the SB.

In the second year SB chemistry subject, the SB places a strong emphasis on understanding the way chemistry and chemicals are perceived in the media. Specific competence 4 highlights the importance of understanding how chemical products are used responsibly, but also describe the importance of overcoming and negative connotations of the word 'chemical'. The way that the SB requires students to not only understand that the media can portray a negative image of chemicals, but to then overcome these negative influences is something that is not as heavily evidenced in the DP.

Summary

Whilst all learning outcome themes from the DP have been found in the SB, the detail in which they are described varies. Conceptual understanding and making connections, techniques that categorise science and creativity and critical thinking are all themes that are strongly present throughout the SCs of the SB. Nonetheless, investigative skills and the development of technology skills are less apparent themes in the SB. These skills are briefly mentioned or can be inferred from the SC statements or descriptions; however, they are not as clearly defined as they are within the DP. The final two themes (communication and collaboration, and the awareness of global and local problems) differ in terms of which aspects of them are particularly emphasised. Collaboration is a very prevalent theme in the SB, however, the communication aspect of this skill is mentioned in a much more subtle way than in the DP. There are references to the importance of communication, but not the same level of explicit description of students developing specific skills associated with communication. The awareness of global problems is strong in the SB in the context of the environment and sustainability, however, in the SB there is less reference to the ethical and cultural elements of this theme.

4.9.2 Content

This section compares and contrasts the content of the DP and SB curricula falling within the category of chemistry. In order to support visual comparison at-a-glance, the DP and SB chemistry curricula are presented below in diagrams which show the key topics and subtopics included in each.

Figure 19: SB physics and chemistry content visualiser

SB physics and chemistry ¹²⁵	A. Chemical Bonding and Structure	The Periodic Table	Electronic structure of atoms	Atoms, ions and bonds	Nomenclature of simple substances	
	B. Chemical Reactions	Laws of Chemistry	Classification of chemical reactions	Quantities of matter calculations	Stoichiometry of chemical reactions	
	C. Organic Chemistry	Physical and Chemical properties	IUPAC rules for formulating and naming compounds			
	<i>D. Kinematics</i>	<i>Kinematic variables</i>	<i>Rectilinear and circular movement</i>	<i>Trajectory</i>		
	<i>E. Static and Dynamic</i>	<i>Static and dynamic particle behaviour</i>	<i>Vector mechanics</i>	<i>Momentum and Mechanical Impulse</i>		
	<i>F. Energy</i>	<i>Work and Power</i>	<i>Energies of a simple system</i>	<i>Thermodynamic variables of a system</i>		
SB chemistry	A. Chemical Bonding and Structure	1. Atomic spectra	2. Quantum principles of atomic structure	3. Periodic Table and properties of atoms		
	B. Chemical Reactions	1. Chemical Thermodynamics	2. Chemical Kinetics	3. Chemical Equilibrium	4. Acid-Base reactions	5. Redox Reactions
	C. Organic Chemistry	1. Isomerism	2. Organic Reactivity	3. Polymers		

¹²⁵ Physics topics have been greyed out for the combined SB physics and chemistry subject as they were not considered in the chemistry content comparisons.

4.9.2.1 Structure

The DP and SB programmes are both taught over two years of study, with both offering the opportunity for students to study chemistry at different levels – i.e. the SB offers a combined SB physics and chemistry subject in the first year, with the option to take the specialist SB chemistry subject in the second year; the DP offers students the opportunity to study DP chemistry at either SL or HL.

One notable difference between the structure of the chemistry subject area in the two programmes is the combined nature of the SB's first-year physics and chemistry subject. In the DP, chemistry and physics content is taught in separate subjects, i.e. DP chemistry and DP physics, respectively.

The DP chemistry subject is designed through a concept-based approach and organised into two over-arching, discipline-specific topics – Structure and Reactivity. Each of these topics covers various key areas within them and is further divided into subtopics. Overall, DP chemistry SL consists of 22 subtopics, while DP chemistry HL extends learning in 13 of the 22 subtopics and contains one additional HL-only subtopic. SB physics and chemistry is structured into six blocks of learning: three for physics and three for chemistry. The chemistry blocks of learning are: A. Chemical Bonding and Structure of Matter, B. Chemical Reactions, and C. Organic Chemistry. SB chemistry, which is the optional second-year modality subject, consists of the same three blocks of learning, which build on the chemistry understanding from the SB physics and chemistry subject taught in the first year.

4.9.2.2 Content Alignment

The table below represents a simplified summary of the SB's content alignment, at topic-level, with DP chemistry (SL and HL).

Table 35: Summary of content alignment between the DP chemistry topics and SB chemistry

DP chemistry topics	SL presence in SB physics and chemistry	AHL presence in SB physics and chemistry	SL presence in SB chemistry	AHL presence in SB chemistry
Structure 1. Models of the particulate nature of matter				
Structure 1.1 – Introduction to the particulate nature of matter		N/A		N/A
Structure 1.2 – The nuclear atom				
Structure 1.3 – Electron configurations				
Structure 1.4 – Counting principles by mass: The mole		N/A		N/A
Structure 1.5 – Ideal gases		N/A		N/A
Structure 2. Models of bonding and structure				
Structure 2.1 – The ionic model		N/A		N/A
Structure 2.2 – The covalent model				
Structure 2.3 – The metallic model				
Structure 2.4 – From models to materials				
Structure 3. Classification of matter				
Structure 3.1 – The periodic table: Classification of elements				
Structure 3.2 – Functional groups: Classification of organic compounds				
Reactivity 1. What drives chemical reactions?				
Reactivity 1.1 – Measuring enthalpy changes		N/A		N/A
Reactivity 1.2 – Energy cycles in reactions				
Reactivity 1.3 – Energy from fuels		N/A		N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A		N/A	
Reactivity 2. How much, how fast and how far?				
Reactivity 2.1 – How much? The amount of chemical change		N/A		N/A
Reactivity 2.2 – How fast? The rate of chemical change				
Reactivity 2.3 – How far? The extent of chemical change				
Reactivity 3. What are the mechanisms of chemical change?				
Reactivity 3.1 – Proton transfer reactions				
Reactivity 3.2 – Electron transfer reactions				
Reactivity 3.3 – Electron sharing reactions		N/A		N/A
Reactivity 3.4 – Electron-pair sharing reactions				
Experimental programme				

Key:

	Strong presence of this topic in the SB.		Partial presence of this topic in the SB.		Little or no presence of this topic in the SB.	N/A	This topic does not exist at the respective level.
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NB: Where applicable, content alignments found in pre-requisite subjects are carried forwards and combined with new alignments to represent the cumulative content covered.

As mentioned above, DP chemistry SL consists of 22 subtopics. SB physics and chemistry subject covers eleven of these subtopics in similar depth and detail, including the nuclear atom and the ionic, covalent and metallic models. There are two DP chemistry SL topics that are not covered in the same level of detail: 'Structure 3. Classification of Matter' and 'Reactivity 2. How Much, How Fast and How Far?'. For Structure 3, SB physics and chemistry covers '3.2 Functional Groups: classification of organic compounds' but does not include coverage of '3.1 The Periodic Table: classification of elements', which is covered by the DP. For 'Reactivity 2 How Much, How Fast and How Far?', SB physics and chemistry covers '2.1 – How much? The amount of chemical change' but does not cover '2.2 How fast? The rate of chemical change' and '2.3 How far? The extent of chemical change'. SB physics and chemistry also does not cover two DP chemistry SL topics: 'Reactivity 1 What Drives Chemical Reactions' and 'Reactivity 3. What are the Mechanisms of Chemical Change?'.

As to comparison with DP chemistry HL, SB physics and chemistry covers only one of the 13 AHL subtopics in similar depth and detail – i.e. 'Structure 1.3 electron configurations'. It also partially covers 'Structure 2.2 the covalent model'.

In turn, SB chemistry covers 20 of the 22 DP chemistry SL subtopics in similar depth and detail, including proton transfer reactions and measuring enthalpy changes. There is partial presence of the remaining two subtopics, which are: 'Reactivity 1.3 – Energy from fuels' and 'Reactivity 3.3 – Electron sharing reactions'. For Reactivity 1.3, SB chemistry covers combustion reactions but does not cover the advantages and disadvantages of fossil fuels and biofuels, which is covered in DP chemistry. In Reactivity 3.3, electron sharing reactions may be covered in SB chemistry, however, free radical substitution reactions are not specifically referenced.

Comparing to DP chemistry HL, SB chemistry covers 9 of 13 AHL subtopics and the HL-only topic of 'Reactivity 1.4 – Entropy and spontaneity'. There are also three DP chemistry HL subtopics that are partially present in SB chemistry: 'Reactivity 2.2 – How fast? The rate of chemical change', 'Reactivity 3.2 – Electron transfer reactions', 'Reactivity 3.4 – Electron-pair sharing reactions'. SB chemistry does not cover the AHL 'Structure 3.2 – Functional groups: Classification of organic compounds', but it does cover polymers in greater depth than the DP, by including their applications, properties and associated environmental risks.

Table 36: SB chemistry content which is not covered in the DP

Significant SB chemistry content which is not included in the DP*	
○	Polymers applications, properties and associated environmental risks

*This is only content pertaining to chemistry, the SB physics chemistry subject also contains physics content – see section 5.2.2.

Overall, SB physics and chemistry has less subject depth and breadth than DP chemistry SL, as two topics are entirely absent (Reactivity 1. What drives chemical reactions? and Reactivity 3. What are the mechanisms of chemical change) and a further two topics are only partially present (Structure 3. Classification of matter and Reactivity 2. How much, how fast, how far?).

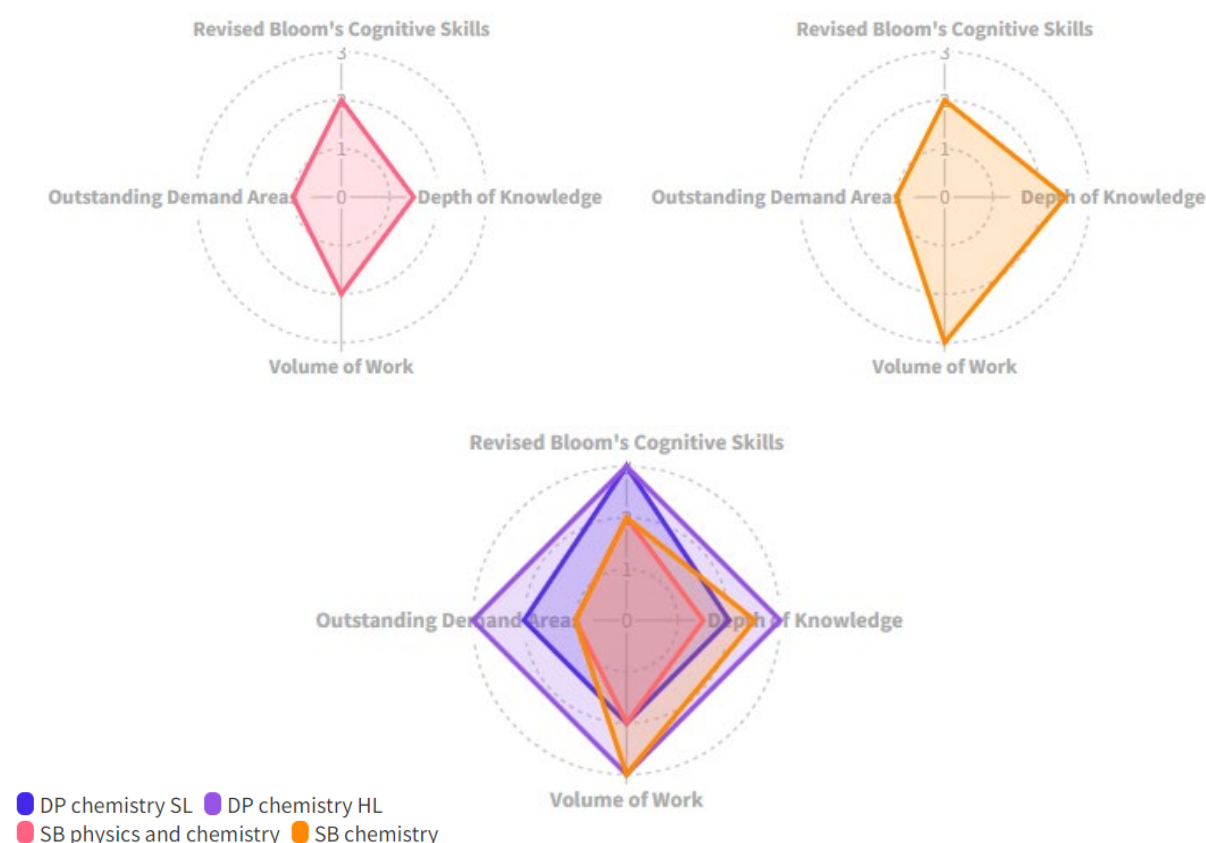
Overall, SB physics and chemistry has limited alignment with the DP chemistry HL, with only two subtopics being partially present.

In turn, SB chemistry covers most of the content in DP chemistry SL and more; it aligns more closely with DP chemistry HL in both breadth and depth, with most HL subtopics being covered. Although the DP chemistry AHL subtopic 'Structure 3.2 – Functional groups: Classification of organic compounds' is not covered in SB chemistry, SB chemistry includes slightly more depth in other areas of organic chemistry, such as polymers.

4.9.3 Demand

The DP and SB curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, SB physics and chemistry and SB chemistry. The SB demand profiles are presented below in the form of radar diagrams, along with a radar diagram showing all DP and SB profiles superimposed in one place, enabling immediate visual comparison.

Figure 20: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.

- For SB physics and chemistry, a score of 2 was given due to the presence of a wide range of skills in SB. However, a score of 3 was not warranted because there was not a predominant focus on evaluation and creation/synthesis within the SB. Although elements of these skills are present, they are not emphasised enough to merit a score of 3.
- A score of 2 was also awarded to the SB chemistry course. Although the subject also covers a range of skills, and there is some evidence of synthesis, analysis and evaluation, this was not found to be the predominant focus of the SCs, and therefore a score of 3 was not judged to be appropriate.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a 3.
 - SB physics and chemistry was awarded a score of 1.5. Although the content covered does not itself necessarily warrant a score above 1, when considered in light of the skills students are required to develop, there is more potential for depth of knowledge. This did not conduce a confident judgement of 2, but was deserving of a score higher than 1, therefore a score of 1.5 was agreed upon.
 - SB chemistry was given a score of 2.5. This is due to the greater depth of content covered, in addition to the skills-based approach taken by the subject. The subject was not given a score of 3 as there was not enough evidence of extended thinking that required complex reasoning over an extended period of time.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a 3.
 - SB physics and chemistry subject was given a score of 2 for the volume of work category. This is because the coverage of physics and chemistry together means that a short amount of time is devoted to each content area. This transdisciplinary approach results in a short time allocation per theme, therefore a score of 2 was deemed appropriate.
 - SB chemistry was given a score of 3 for the volume of work category. There is a large amount of content covered in just 87.5 hours, and therefore a very short time allocation per theme.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a 3.
 - For SB physics and chemistry, a score of 1 was given. There were no specific content areas that showed outstanding areas of subject demand; however, the project work that is described in the specific competences (working collaboratively, applying entrepreneurship, predicting consequences of scientific advances and how these advances might influence the community and environment) may provide a significant area of stretch to students.
 - The SB chemistry course was judged to be a 1 for outstanding areas of subject demand. The transdisciplinary approach to learning and the real-life applications within the course provide stretch areas for students, but in a limited capacity, therefore there are not enough opportunities for stretch areas to warrant a score of 2.

4.10 Brazil

The education system in Brazil is overseen by the Ministry of Education (*Ministério da Educação*, MoE). Broadly, the Brazilian education system is divided into basic education (*educação básica*) and higher education (*ensino superior*). Basic education is compulsory and spans three stages: early childhood education (*ensino infantil*); elementary school (*ensino fundamental*), which encompasses both primary and lower secondary; and high school (*ensino médio*).

The upper secondary stage of education, the *ensino médio*, takes place over three years (grades 1-3) and is delivered in general or technical institutions.¹²⁶ This stage acts as a continuation from primary education, and as a preparatory stage prior to higher education or vocational training.

The *National Guidelines for High School Education*, *National Common Curricular Base (BNCC)*, and *Curricular References for the Preparation of Formative Itineraries* are key to the organisation and structure of high school education in Brazil and are referred to collectively here as the Brazilian High School Curriculum (BHSC).

As part of the BHSC, the BNCC describes the essential learning and minimum standards to be achieved for all pupils. At school level, the curriculum is set by the state education secretariats and municipal education authorities. Providing they meet the standards outlined in the BNCC, educational institutions and networks may construct their curriculum as they feel is pertinent to their context. The BNCC thus underpins all curriculum offerings, but rather than being a curriculum in itself, it provides guidance for content planning, allowing for flexibility at the state and school-level.¹²⁷

Learning in the BHSC is structured into basic general education and formative itineraries. Basic general education is guided by the BNCC, which arranges the essential learning into the four areas of knowledge below:

- Language and Technology (including Portuguese)
- Mathematics and Technology.
- Natural Sciences and Technology.
- Applied Human and Social Sciences.¹²⁸

The other component of the BHSC is the formative itineraries, which schools may offer based on regional and local needs, interests and resources. Formative itineraries focus on deepening and expanding learning in one of the areas of knowledge, or on technical and professional training.¹²⁹ Integrated itineraries may also be offered which combine the study of one area of knowledge with another area, or with technical and professional training.

¹²⁶ OECD. (2021). *Education Policy Outlook in Brazil: With a focus on national and subnational policies*. OECD Education Policy Perspectives, No. 38. OECD Publishing, Paris. Available from: [Education Policy Outlook in Brazil: With a focus on national and subnational policies | OECD](#)

¹²⁷ OECD. (2021). *Education in Brazil: An International Perspective. The Brazilian education system*. OECD Publishing, Paris.

¹²⁸ Ministry of Education. National Education Council. Basic Education Chamber. (2018). *Resolution No.3, of November 21, 2018*. p. 5-6 (art.11).

¹²⁹ Ministry of Education. National Education Council. Basic Education Chamber. (2018). *Resolution No.3, of November 21, 2018*. p. 7 (art.12)

As such, the analysis uses the following subjects for comparison to DP chemistry.

BHSC Natural Sciences and Technology (Basic General Education) – BHSC NST (BGE)

In the BHSC, Natural Sciences and Technology (NST) is a compulsory area of knowledge for the basic general education (BGE) component of high school. NST encompasses multiple science disciplines (physics, chemistry and biology) and aims to build on the learning of elementary school, deepening students' knowledge in the themes of Matter and Energy, Life and Evolution, and Earth and Universe. Students are also expected to become more aware of the social, historical and cultural contextualization of science and technology; and of research process and practices. BHSC NST (BGE) is based upon the specific competencies and skills prescribed by the BNCC for NST.¹³⁰ To support the content analysis, the Rio de Janeiro Referential Curriculum (RJRC) was consulted to gain further insights into the physics, chemistry, and biology topics covered in BHSC NST (BGE).¹³¹

BHSC Natural Sciences and Technology (Formative Itinerary) – BHSC NST (FI)

In the BHSC, Natural Sciences and Technology is an area of knowledge that students may choose to specialise in for the formative itinerary (FI) component of high school. Formative itineraries are curricular units which are designed for students to deepen their knowledge and prepare for further studies or careers. BHSC NST (FI) is based upon the 'Curricular References for the Preparation of Formative Itineraries', which guide the development of this subject by each state.¹³² Again, the RJRC is consulted to provide further insights into the type of content covered in BHSC NST (FI).¹³³

4.10.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of science. The learning outcomes articulated by the DP and BHSC are the same for all sciences, therefore these are considered for the science subject area as a whole in this section.

The DP learning outcome themes for science were extracted from the aims and assessment objectives of the DP sciences subject group. BHSC Natural Science and Technology (NST) learning outcomes are presented as specific competencies and specific skills. For formative itineraries specifically, additional skills are given, which are based on the formative itinerary structuring axes. Moreover, the BHSC also articulates general competencies for high school education which have also been considered when relevant here.

The following summary table demonstrates the learning outcome themes that were extracted from DP sciences and indicates if and where they were judged to have presence within the learning outcomes of BHSC Natural Sciences and Technology (NST).

¹³⁰ Brazil, Ministry of Education. (2018). 5.3.1. *The area of Natural Sciences and their Technologies: Specific competencies and skills*. BNCC. Available from: [National Common Curricular Base - Education is the Base \(mec.gov.br\)](https://ncc.mec.gov.br)

¹³¹ Rio de Janeiro State Government, Department of Education. (2022). *Natural Sciences and Technology*. High School Referential Curriculum for the State of Rio de Janeiro. p. 81-91. Available from:

¹³² Brazil, Ministry of Education. (n.d.). *Curricular References for the Preparation of Formative Itineraries*.

¹³³ Rio de Janeiro State Government, Department of Education. (2022). *Curricular Organisation of Formative Itineraries*. Available from: [Trails \(educacao.rj.gov.br\)](https://educacao.rj.gov.br).

Table 37: Presence of the DP sciences learning outcome themes in BHSC Natural Sciences and Technology (NST)

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in BHSC Natural Sciences and Technology (NST)	
1. Develop conceptual understanding and make connections		Presence can be inferred from the specific competencies and skills for BHSC NST, though there is less evidence of conceptual understanding or to making connections between science subjects.
2. Use and apply the knowledge, methods, tools, and techniques that characterise science		Present in the specific competencies and skills for BHSC NST, particularly competency 3.
3. Use creative and critical thinking (problem-solving, analysis, evaluation, synthesis)		Present in the specific competencies and skills for BHSC NST, many of which include problem solving, analysis, evaluation and synthesis.
4. Develop skills for scientific inquiry		Scientific inquiry is present in the specific competencies and skills for BHSC NST, though there is limited mention of specific experiments.
5. Develop technological skills		The development of technological skills is implied in the specific competencies and skills for BHSC NST.
6. Collaborate and communicate effectively		Communication skills are present in the specific competencies and skills for BHSC NST, though there is less mention of collaborative skills.
7. Be aware of global and local problems and the environmental, ethical, cultural, and social impact of science		Well-evidenced in the specific competencies and skills for BHSC NST, particularly competence 1.

Key:

 This theme is well-evidenced in the learning outcomes of BHSC NST.	 This theme is partially evidenced in the learning outcomes of BHSC NST.	 This theme is not evident in the learning outcomes of BHSC NST.
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Presence of the DP's Learning Outcome Themes

There is strong alignment between the learning outcomes of DP sciences and BHSC Natural Sciences and Technology (NST). Indeed, all DP learning outcomes themes for sciences are represented either completely or partially in the BHSC NST specific competencies and specific skills and are further evidenced in the additional skills for the formative itinerary (FI). The extent to which each DP theme is present in BHSC NST is discussed in more detail below.

1. Develop conceptual understanding and make connections

The ability to develop conceptual understanding and make connections is partially evidenced within BHSC NST. Indeed, the specific competencies include higher order skills such as analysis, synthesis and evaluation – all of which require strong conceptual understanding. With regards to making connections, there is evidence that this is expected between science subjects in BHSC NST. For instance, specific skill EM13CNT203 refers to evaluating and predicting the effects of interventions in an ecosystem on organisms, in respect to transformations of matter and energy.¹³⁴ This would require students to understand and relate knowledge within and between science subjects. The general competencies also include

¹³⁴ Brazil, Ministry of Education. (2018). 5.3.1. *Natural Sciences and Technology in High School: Specific competencies and skills*. BNCC.

utilising knowledge from different areas, though this does not specifically refer to making connections between science subjects.

Furthermore, within the FI skills, conceptual understanding is also partially evident, as students are expected to identify and explain issues related to physical, chemical and/or biological phenomena. However, there are no explicit references to conceptual understanding, or to making connections between or within science subjects. In summary, as there are no explicit references to conceptual understanding or to making connections amongst science subjects, this DP theme is only partially present in BHSC NST.

2. Use and apply the knowledge, methods, tools, and techniques that characterise science

Using and applying the knowledge, methods, tools, and techniques that characterise science is evident across BHSC NST. The specific skills refer to using procedures and languages typical of natural sciences and of scientific investigation. It is likewise described that students should develop explanations, make predictions, interpret results, analyse models, theories and laws; and recognise the explanatory limits of science; which encompasses many elements of scientific study. This theme is further evidenced by specific skill EM13CNT301 which outlines how students will not only create hypotheses, use measuring instruments and generate data, but also justify the conclusions they reach from a scientific perspective.¹³⁵

Moreover, multiple FI skills describe mobilising knowledge and resources related to Natural Sciences, which implies an application of scientific knowledge and methods. There is therefore strong evidence of this theme within BHSC NST.

3. Use creative and critical thinking (problem-solving, analysis, evaluation, synthesis)

The DP theme of creativity and critical thinking is evident within BHSC NST. For example, students are expected to propose appropriate solutions to identified problems, whilst considering local and global contexts. Moreover, students are expected to evaluate the applications of scientific knowledge, analyse natural phenomena, recognise the explanatory limits of science, and to build strategies for selecting reliable sources of information such that they can evaluate and justify conclusions.

Additionally, within the FI skills, students are expected to utilise creative resources related to Natural Sciences to solve real environmental and societal problems, exploring and contrasting different sources of information. As such, there is evidence that problem solving, analysis, evaluation and synthesis are present in BHSC NST. However, it can be noted that the DP places more emphasis on evaluation, particularly on the evaluation of experimental procedures.

4. Develop skills of scientific inquiry

The DP theme of applying skills to conduct insightful investigations is present within BHSC NST. As described previously, BHSC NST refers to using procedures and languages typical of Natural Sciences, and of scientific investigation. Students are expected to investigate issues, and more specifically students should be able to: come up with questions, hypotheses, predictions and estimates; use measuring instruments; represent and interpret models, data

¹³⁵ Ibid.

and experimental results; as well as to evaluate and justify conclusions.¹³⁶ Ethical considerations are also referred to in general, and it can be inferred that this would be applied to conducting investigations.

Furthermore, the FI skills include taking part in a project involving the formulation of concrete proposals, which is suggestive of planning and organising an investigation. There are no specific references to experimental procedure, but it is implied that students will be able to carry out investigations.

There is therefore overall strong evidence of scientific investigation in BHSC NST. However, the DP science curriculum includes a greater amount of detail with regards to the specific experiments and procedures that students should be aware of, which is not the case for the BHSC NST.

5. *Develop technological skills*

There is clear evidence that the DP theme of developing technological skills is present in BHSC NST. It is described that students should be able to use and communicate through different technologies and evaluate their applications. Moreover, BHSC NST refers to students using digital devices in many different contexts and areas of science. In addition, the FI skills include multiple skills that require students to consider available technologies when proposing solutions to real problems. As such, it is clear that students are required to develop technology skills in a scientific context in BHSC NST.

6. *Collaborate and communicate effectively*

The DP's theme of effective communication is evident in BHSC NST, as students are expected to communicate to varied audiences and in different contexts. Multiple specific competencies also refer to participating in debate, from which communication skills such as expressing arguments or ideas can be inferred. Moreover, interpreting information from varied sources, distinguishing between different points of view, as well as expressing conclusions are included – all of which relate to effective communication.

There is less evidence of collaborative skills in BHSC NST. However, general competencies for high school education in the BHSC refer to exercising cooperation and respect for others, which is suggestive of collaboration. Moreover, as mentioned previously, the FI skills refer to students taking part in a project, which would potentially involve elements of individual or group work. Overall, as collaboration does not seem to be an explicit focus, this theme is partially evidenced in BHSC NST.

7. *Be aware of global and local problems and the environmental, ethical, cultural, and social impact of science*

The DP's theme regarding awareness of global and local problems and the environmental, ethical, cultural, and social impact of science is evident in BHSC NST. Indeed, BHSC NST expects students to demonstrate an awareness of prominent issues within science as they participate in and/or promote debates in topics of scientific relevance. Awareness of identified problems among the more local context of Brazilian society is likewise shown, as well as

¹³⁶ Brazil, Ministry of Education. (2018). 5.3.1. *Natural Sciences and Technology in High School: Specific competencies and skills*. BNCC.

knowledge of the contemporary experiences and challenges of young people. Furthermore, there are multiple references made to the social, cultural, and environmental impacts of science. There are fewer references to the ethical impact of science, though students must debate using ethical and responsible arguments, as well as discuss the misuse of knowledge from Natural Sciences.

Moreover, the FI skills describe that students demonstrate their ability to identify and explain sociocultural and environmental issues and to solve real environmental and societal problems which, although not specified, is suggestive of an awareness of issues that are present in either the local or global context. Students must also evaluate how knowledge and resources related to natural science can be used and the socioenvironmental impacts of this. Overall, there is therefore strong evidence of the DP theme in BHSC NST.

Other Themes in BHSC NST Learning Outcomes

Most of the themes and skills described BHSC NST are in the DP; however, it can be noted that there are few aspects that are highlighted more specifically.

Indeed, the BHSC learning outcomes specifically highlight that students will learn the historic contextualisation of scientific discoveries and discuss models, theories and laws proposed in different times. The DP learning outcomes do not specifically identify historical context of scientific discoveries; however, teachers may explore these with students during the course. In addition, the BHSC NST learning outcomes specifically highlight that students should learn about the *misuse* of knowledge regarding natural science in different social and historical contexts. While misuse of knowledge is not specifically mentioned in the DP learning outcomes, considering the impact of scientific knowledge is a key theme and this will likely include exploring negative impacts and unethical practices.

Furthermore, BHSC NST learning outcomes include a larger emphasis on the engagement with scientific literature than the DP sciences learning outcomes. For example, the specific skill EM13CNT303 and the FI skill EMIFCNT03 each state that students should interpret scientific texts.¹³⁷ The latter specifies that students should be able to select information from scientific texts such as studies and/or research (bibliographic, exploratory, field, experimental, etc.). The DP does refer to the ability to analyse, evaluate and synthesize scientific information and claims, but does not make specific reference to engaging with scientific texts. The extended essay (EE) in the DP core would provide opportunity for a similar engagement with literature as part of the high-level research. Although EE may be focused on subjects other than science. Likewise, scientific texts may be reviewed as part of the DP's internally assessed science investigation. Therefore, there is scope for students to engage with scientific literature in the DP curriculum, but there is less emphasis specifically on literature within the learning outcomes for science.

Summary

Overall, there is strong alignment between DP sciences and BHSC NST with regards to learning outcomes. The DP learning outcome themes of applying the elements that characterise science, using creativity and critical thinking, developing technological skills, and being aware of the issues and impacts of science, are all evident in BHSC NST. However,

¹³⁷ Brazil, Ministry of Education. (n.d.). *Curricular References for the Preparation of Formative Itineraries*. p. 11.

there is less emphasis on making connections between and within science subjects and collaboration in BHSC NST than the DP. Moreover, although scientific investigation is present in BHSC NST, there is less detail regarding the specific experiments and experimental skills compared to the DP.

4.10.2 Content

This section compares and contrasts the chemistry content of DP chemistry and BHSC NST. For the content analysis of BHSC NST, several sources are used. For BHSC NST (BGE), the BNCC's specific competencies and specific skills for NST have been used, as well as the Rio de Janeiro Referential Curriculum (RJRC) for chemistry in basic general education. For the analysis of BHSC NST (FI), Rio de Janeiro's specialisation pathways for Natural Sciences and Technology formative itineraries have been used. The chemistry content from the BNCC and RJRC are presented in the following diagrams.

Figure 21: Visualiser of BHSC Natural Sciences and Technology. (Source - BNCC).

Natural Sciences and Technology		
Specific Competencies		
1. Analyse natural phenomena and technological processes, based on the interactions and relationships between matter and energy, to propose individual actions and collective actions that improve production processes, minimize impacts on and improve living conditions at the local, regional and global level.	2. Analyse and use interpretations of the dynamics of Life, the Earth and the Cosmos to elaborate arguments, make predictions about the functioning and the evolution of living beings and the Universe, and to ground and defend ethical and responsible decisions.	3. Investigate problem situations and evaluate applications of scientific knowledge and its implications in the world, using procedures and languages of the Natural Sciences, in order to propose solutions that consider local, regional and/or global demands, and communicate their findings and conclusions to a variety of audiences, in a variety of contexts and through different media and digital information technologies and communication (TDIC).
Specific Skills*		
EM13CNT101 - EM13CNT107	EM13CNT201 - EM13CNT209	EM13CNT301 - EM13CNT310

* See [Appendix D](#) for the Natural Sciences and Technology Specific Skills in full detail.

Figure 22: Visualiser of BHSC Natural Sciences and Technology. (Source - RJRC).

Basic General Education	Formative Itinerary	
Chemistry (based on the BNCC and organised using the Specific Competencies and Skills)	Integrated Core	Specialisation Pathways for Natural Sciences and Technology
	Life Project	Energy Solutions
	Elective 1	Energy and its transformations
	Elective 2	Energy, environmental impacts, and sustainability
	Elective 3 (chosen from Catalogues, such as the Catalogue of Electives for Natural Sciences and Technology)	Energy: Problematisation and awareness raising
		Natural Resources
		Consumption, multiple uses and management
		Diversified sustainable practices
		Natural resources and sustainable development

4.10.2.1 Structure

Science in the DP is structured such that physics, chemistry and biology are separate subjects, each with their own distinct content. In contrast, the BHSC combines physics, chemistry, and biology into Natural Sciences and Technology (NST). Where DP students choose one science subject to study at either SL or HL, high school students in Brazil study all sciences as part of NST in basic general education (BGE), and then can choose to specialise in NST in their formative itinerary (FI). As such, unlike the offering of DP chemistry HL, the BHSC does not offer an option to specialise in chemistry specifically. Moreover, DP science subjects are studied over the two-year programme, whereas science subjects may be taught in any or all years of high school in Brazil.

Within DP chemistry, content is arranged into two conceptual themes – Structure and Reactivity. Three topics are covered within each theme, each with two to five related subtopics.

In contrast, BHSC NST (BGE) content is not organised using chemistry topics. Indeed, the BNCC articulates specific competencies and skills for NST that are an integration of skills and physics, chemistry, and biology content. Each state in Brazil can decide how to organise their curriculum to ensure that the NST specific competencies and skills are taught in basic general education. For example, the Rio de Janeiro's Referential Curriculum (RJRC) organises basic general education into distinct subjects, with chemistry being one of these. The RJRC then organises its chemistry content using the NST specific competencies and specific skills and adds topics that should be linked with these.

Content for BHSC NST (FI) is developed by each Brazilian state and combines physics, chemistry, and biology content. As an example, the RJRC organises NST formative itinerary content into two specialisation pathways, namely 'Natural Resources' and 'Energy Solutions', each of which is made up of three curricular components.¹³⁸

4.10.2.2 Content Alignment

This section will analyse the alignment of chemistry content in DP chemistry and BHSC NST. The following tables present a simplified summary of the extent of content alignment that BHSC NST (BGE) and BHSC NST (FI) have at the topic level with DP chemistry.

¹³⁸ Rio de Janeiro State Government, Department of Education. (2022). *Curricular Organisation of Formative Itineraries*.

Table 38: Summary of the content alignment BHSC NST has with the main topics in DP chemistry.

DP chemistry topics	BHSC NST (BGE)		BHSC NST (FI)*	
	SL presence	AHL presence	SL presence	AHL presence
Structure 1. Models of the particulate nature of matter				
Structure 1.1 – Introduction to the particulate nature of matter		N/A		N/A
Structure 1.2 – The nuclear atom				
Structure 1.3 – Electron configurations				
Structure 1.4 – Counting principles by mass: The mole		N/A	**	N/A
Structure 1.5 – Ideal gases		N/A		N/A
Structure 2. Models of bonding and structure				
Structure 2.1 – The ionic model		N/A		N/A
Structure 2.2 – The covalent model				
Structure 2.3 – The metallic model				
Structure 2.4 – From models to materials				
Structure 3. Classification of matter				
Structure 3.1 – The periodic table: Classification of elements				
Structure 3.2 – Functional groups: Classification of organic compounds				
Reactivity 1. What drives chemical reactions?				
Reactivity 1.1 – Measuring enthalpy changes		N/A	**	N/A
Reactivity 1.2 – Energy cycles in reactions			**	**
Reactivity 1.3 – Energy from fuels		N/A	**	N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A		N/A	
Reactivity 2. How much, how fast and how far?				
Reactivity 2.1 – How much? The amount of chemical change		N/A	**	N/A
Reactivity 2.2 – How fast? The rate of chemical change			**	
Reactivity 2.3 – How far? The extent of chemical change			**	
Reactivity 3. What are the mechanisms of chemical change?				
Reactivity 3.1 – Proton transfer reactions				
Reactivity 3.2 – Electron transfer reactions				
Reactivity 3.3 – Electron sharing reactions		N/A		N/A
Reactivity 3.4 – Electron-pair sharing reactions				
Experimental programme				

Key:

	Strong presence of this topic in BHSC NST		Partial presence of this topic in BHSC NST, or the extent of presence is unclear		Little or no presence of this topic in BHSC NST
* Content alignments found for basic general education (BGE) are carried forwards and combined with, where applicable, new alignments identified in the formative itinerary (FI), to represent the cumulative content covered.					
** The documentation indicates that the formative itinerary includes some similar content from this DP topic.					

BHSC Natural Sciences and Technology (Basic General Education) - BHSC NST (BGE)

BHSC NST (BGE) covers some content from most DP chemistry SL subtopics. The only DP SL subtopics which do not appear to be covered in at least some part by BHSC NST (BGE) are from 'Reactivity 3. What are the mechanisms of chemical change?'. There is generally little to no presence of DP AHL content in BHSC NST (BGE). However, the documentation suggests that some content from Reactivity 1.2 – Energy cycles in reactions is present.

It should be noted that, where partial presence has been concluded, this is often based on an assumption that the broadly-described topics for BHSC NST (BGE) can be expected to contain similar content. Thus, the actual degree of alignment may differ to what a judgement of 'partial presence' suggests. The below discusses the presence of each DP topic in BHSC NST (BGE) in more detail.

Structure 1. Models of the particulate nature of matter

BHSC NST (BGE) includes atomic models and the structure of matter, which suggests that there may be some alignment with the SL content of 'Structure 1.1 Introduction to the particulate nature of matter', 'Structure 1.2 The nuclear atom', and 'Structure 1.3 Electron configurations'. Moreover, concepts such as Dalton's model of the atom, atomic mass, and atomic number, are mentioned, as is the Bohr model in physics, which supports the potential coverage of a number of DP SL subtopics in these areas.¹³⁹ Furthermore, references to stoichiometric calculations suggest similar content to 'Structure 1.4 Counting principles by mass: The mole'.

There is limited evidence that BHSC NST (BGE) includes content relating to gases. However, concepts such as the work of a gas and kinetic energy of gases are included within physics.¹⁴⁰ As such, students may encounter related content from 'Structure 1.5 – Ideal gases' throughout their studies. Therefore, it is concluded that BHSC NST (BGE) has partial alignment with SL content in all topics of 'Structure 1. Models of the particulate nature of matter', though it should be noted that the presence of specific concepts has been largely inferred.

With regards to AHL content, spectroscopy could encompass elements of content from 'Structure 1.2 The nuclear atom' and 'Structure 1.3 Electron configuration'. Without more information, however, it is not reasonable to infer that these DP chemistry HL concepts are covered. Therefore, it is concluded that there is little to no presence of this topic in BHSC NST (BGE).

Structure 2: Models of bonding and structure

BHSC NST (BGE) includes the structure of matter, which is further specified to include chemical bonds and interparticle forces.¹⁴¹ As ionic, covalent, and metallic are fundamental bond types, and are therefore likely to be included within these areas, it can be inferred that some similar content is covered to SL concepts within 'Structure 2.1 The ionic model', '2.2 The covalent model', and '2.3 The metallic model'. Furthermore, coverage of SL content from 'Structure 2.4 From models to materials' is possible as students are expected to analyse the properties of materials.¹⁴² Knowledge of polymers is supported by the study of plastics

¹³⁹ These topics have been drawn from the RJRC.

¹⁴⁰ Ibid.

¹⁴¹ Ibid.

¹⁴² Specific skill EM13CNT307 from the BNCC.

(including polymers).¹⁴³ Notably, some specific DP chemistry concepts, such as bonding as a continuum or the concept of the bonding triangle, are less reasonably inferred from the detail in which content is described. Therefore, it is concluded that BHSC NST (BGE) has partial alignment with SL content in all topics of 'Structure 2. Models of bonding and structure', though it should be noted that the presence of some specific concepts has been inferred.

As is the case in other DP chemistry topics, the AHL content goes beyond what can be reasonably inferred from the detail provided regarding chemical bonds. Thus, it is concluded that there is little to no AHL content from 'Structure 2. Models of bonding and structure' in BHSC NST (BGE).

Structure 3. Classification of matter

The documentation includes the study of the periodic table, which is likely to encompass some of the SL content from 'Structure 3.1 The periodic table: Classification of elements'. However, it is unclear whether some elements of this DP chemistry topic, such as periodicity or trends across the periodic table, are present. BHSC NST (BGE) includes understanding the structure and properties of organic compounds, which indicates that some of the SL content from 'Structure 3.2 Functional groups: Classification of organic compounds' may be covered. Therefore, it is concluded that BHSC NST (BGE) has partial alignment with SL content in all topics of 'Structure 3. Classification of matter', though it should be noted that the presence of some specific concepts has been inferred.

AHL content within 'Structure 3.1 The periodic table: Classification of elements' and 'Structure 3.2 Functional groups: Classification of organic compounds', goes beyond what can be reasonably inferred without further references to specific concepts such as transition elements or electrolysis. Thus, it is concluded that there is little to no AHL content from 'Structure 3. Classification of matter' in BHSC NST (BGE).

Reactivity 1. What drives chemical reactions?

BHSC NST (BGE) includes the study of thermodynamics, as well as thermochemistry and other relevant content such as enthalpy of chemical reactions and related calculations.¹⁴⁴ This indicates that BHSC NST (BGE) may cover some SL content from 'Reactivity 1.1 Measuring enthalpy changes' and 'Reactivity 1.2 Energy cycles in reactions'. Although there are no direct references to bond formation/breaking or to Hess' law, both concepts may constitute prerequisite knowledge for enthalpy calculation, and so are likely to be included.

Though there are limited references to fuel, BHSC NST (BGE) requires students to consider how best to meet demands for electricity and make suggestions for how it can be sustainably generated. A variety of renewable and non-renewable resources are further stated in the documentation such as oil and biofuels.¹⁴⁵ Therefore, while there are no references to the combustion of reactive metals or non-metals, it is likely that the remaining content within 'Reactivity 1.3 Energy from fuels' is included within BHSC NST (BGE). Overall, it can be concluded that BHSC NST (BGE) has partial alignment with SL content in all topics of

¹⁴³ This topic has been drawn from the RJRC.

¹⁴⁴ The latter topics are drawn from the RJRC.

¹⁴⁵ These topics have been drawn from the RJRC.

‘Reactivity 1. What drives chemical reactions?’, though it should be noted that the presence of some specific concepts has been inferred.

Presence of the AHL content from ‘Reactivity 1.2 Energy cycles in reactions’ is indicated in BHSC NST (BGE), as knowledge of the enthalpy of combustion for the purposes of energy efficiency are mentioned.¹⁴⁶ There are no references to AHL content within ‘Reactivity 1.4 Entropy and spontaneity’, such as Gibbs law, and thus the presence of these cannot be reasonably inferred.

Reactivity 2. How much, how fast and how far?

Some SL content from ‘Reactivity 2.1 How much? The amount of chemical change’ is present in BHSC NST (BGE), as students are expected to be aware of the conservation of matter and be able to conduct stoichiometric calculations. This is further specified to include the proportions of reactants and products as well as solutions and concentrations.¹⁴⁷ Elements of SL content from ‘Reactivity 2.2 How fast? The rate of chemical change’ may also be represented in BHSC NST (BGE) within the topic of chemical kinetics. The speed of chemical transformation is also referred to – including variables that influence the speed.¹⁴⁸ Finally, some SL content from ‘Reactivity 2.3 How far? The extent of chemical change’ may be present, as BHSC NST (BGE) includes chemical kinetics and equilibrium. Therefore, it is concluded that BHSC NST (BGE) chemistry has partial alignment with SL content in all topics of ‘Reactivity 2. How much, how fast and how far?’, though it should be noted that the presence of some specific concepts has been inferred.

Much of the AHL content within ‘Reactivity 2.2 How fast? The rate of chemical change’ relates to multistep reactions, the presence of which cannot be reasonably inferred from the detail in BHSC NST (BGE) documentation. Likewise, AHL content relating to ‘Reactivity 2.3 How far? The extent of chemical change’ includes more advanced concepts not expressly referred to as present in BHSC NST (BGE). Thus, it is concluded that there is little to no AHL content from ‘Reactivity 2. How much, how fast and how far?’ in BHSC NST (BGE).

Reactivity 3. What are the mechanisms of chemical change?

There is little to no evidence of DP SL and AHL content relating to the mechanism of chemical change in BHSC NST (BGE).

Experimental programme

BHSC NST (BGE) includes students conducting investigations into real-world problems using scientific procedures. Further general competencies are suggestive of planning skills such as developing hypotheses or reaching conclusions; and mention laboratory skills such as employing tools. There are also references to examining models, simulations, and prototypes. There are, therefore, some similarities to the DP’s experimental programme. However, BHSC NST (BGE) does not detail the specific experiments to be conducted, nor the specific practical skills to be developed. Furthermore, there is no inclusion of anything similar to the DP’s collaborative science project. As such, it is concluded that BHSC NST (BGE) partially aligns with this component of the DP chemistry syllabus.

¹⁴⁶ This topic has been drawn from the RJRC.

¹⁴⁷ Ibid.

¹⁴⁸ Ibid.

Other BHSC NST (BGE) Content

BHSC NST (BGE) covers some chemistry content that is not in DP chemistry and is presented in the following table:

Table 39: BHSC NST (BGE) content which is not covered in the DP

Significant content which is not included in DP chemistry
• Risks associated with exposure to and improper disposal of materials • Water and sewage treatment

DP chemistry does not cover as much content relating to the impact of exposure to chemicals beyond safety considerations with regards to practical work. In contrast, BHSC NST (BGE) includes considerations of the benefits and risks to health of different materials considering different factors such as the level of exposure. Moreover, DP chemistry does not feature content relating to the proper disposal of materials, whereas BHSC NST (BGE) requires students to discuss how to properly dispose of substances and the impact of improper disposal. Notably, DP biology does include the effects of microplastics and biomagnification of pollutants.

Additionally, DP chemistry does not make explicit references to water or sewage treatment. In contrast, BHSC NST (BGE) includes considerations of infrastructure programmes, including sanitation, which is further specified to include water and sewage treatment specifically.

Summary

In summary, some SL content from most DP chemistry topics - with the exception of topics in Reactivity 3: What are the mechanisms of chemical change? – are included in BHSC NST (BGE). This suggests that chemistry in BHSC NST (BGE) has a slightly lower breadth of content than DP chemistry SL. Notably, the extent of depth to which topics are explored in BHSC NST (BGE) is inferred from broad references in the documentation. The absence of references to specific chemistry concepts within BHSC NST (BGE) might suggest that chemistry topics are not studied in the same depth as DP SL. There is little to no presence of chemistry AHL content in BHSC NST (BGE) except for some content from 'Reactivity 1.2 Energy cycles in reactions'. Lastly, DP chemistry HL includes a greater number of complex areas than BHSC NST (BGE), thus the former has greater breadth and depth.

BHSC Natural Sciences and Technology (Formative Itinerary) – BHSC NST (FI)

The primary way high school students can further pursue science is by choosing to specialise in Natural Sciences and Technology (NST) in their formative itinerary (FI). The Rio de Janeiro specialisation pathways for NST formative itineraries were consulted to provide examples of the types of content covered in BHSC NST (FI).

A small amount of DP chemistry content is present within the specialisation pathways for Rio de Janeiro. More specifically, SL content from 'Structure 1.4 Counting principles by mass: The mole', and all topics within 'Reactivity 1. What drives chemical reactions?' and 'Reactivity 2. How much, how fast and how far?', is partially present in the specialisation pathways. With regards to AHL content, similar content to 'Reactivity 1.2 Energy cycles in reactions' may be included. No other SL or AHL content could be identified in the specialisation pathways, nor any other chemistry content. This can be attributed to the focus on a particular real-world issue

or context in NST formative itineraries, and the emphasis on application of knowledge as opposed to introducing additional chemistry content.

*Table 40: Chemistry content in BHSC NST (FI) which is not covered in the DP**

Significant content which is not included in DP chemistry
There is no significant chemistry content in the BHSC NST (FI) that is not included in the DP.

Summary

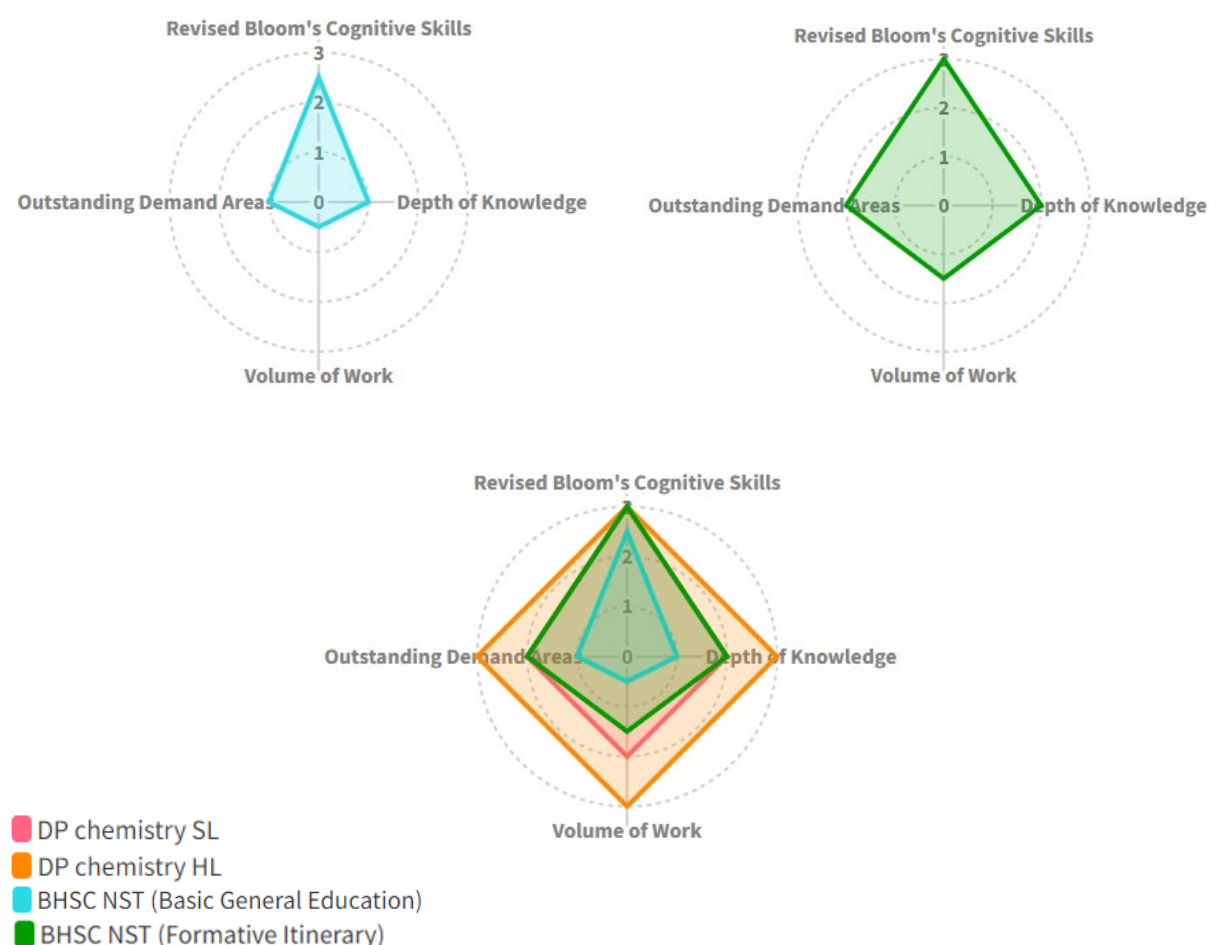
In conclusion, while formative itineraries are developed by each state, the examples from Rio de Janeiro provide useful insights into the content that these may cover and how this aligns with DP chemistry. Overall, the content of BHSC NST (FI) does not present a stronger alignment to DP chemistry content than BHSC NST (BGE), as very few further SL subtopics and AHL subtopics could be identified. Instead, BHSC NST (FI) provides an opportunity for students to extensively apply chemistry (and other science) concepts to a variety of contexts and issues, such as renewable energy sources and sustainable resource consumption. Therefore, the breadth and depth of chemistry content covered in BHSC NST (FI) is less than that of DP chemistry HL. The breadth in comparison to DP SL may be similar and, as mentioned previously, the depth cannot be confidently ascertained due to the lesser amount of detail in the documentation.

4.10.3 Demand

This section considers the alignment between DP chemistry and BHSC NST in terms of demand. Using the same demand tool for the analysis of each subject, a demand profile was created for DP chemistry (SL and HL), BHSC NST (BGE), and BHSC NST (FI).

BHSC NST (BGE) represents the demand of chemistry in basic general education. BHSC NST (FI) represents the cumulative demand of studying chemistry in basic general education and then specialising in an NST formative itinerary. It should be noted that the scores reflect the demand of the whole NST formative itinerary component, rather than its chemistry content specifically. These demand profiles are presented below in the form of radar diagrams, with a superimposed diagram featured to enable the immediate visual comparison of all profiles.

Figure 23: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - Both DP chemistry SL and HL received a score of 3.
 - BHSC NST (BGE) was awarded a score of 2.5, as the learning outcomes have a predominant focus on analysis, with some evidence of evaluation and creation/synthesis focused goals (for instance, creating and/or interpreting equations). However, there is insufficient evidence of a strong presence of evaluation and synthesis to warrant a judgement of 3. For BHSC NST (FI), a score of 3 was awarded due to a predominant focus on synthesis, creation and analysis in the skill for NST formative itineraries. Indeed, the formative itinerary component allows for the synthesis of knowledge across science topics, finding innovative approaches to real world issues and project-based work, all of which suggest higher order thinking, warranting a judgement of 3.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a 3.

- BHSC NST (BGE) was awarded a score of 1 for depth of knowledge. As is the case for other science subjects, the learning outcomes indicate higher order skills (such as making predictions, performing calculations and interpreting results). However, the extent of depth to which chemistry topics are explored is unable to be confirmed from the broad references used in the documentation. As such, whilst there is potential for some topics to be studied in-depth and require complex reasoning, there is insufficient evidence to warrant a judgment of 2. For BHSC NST (FI), depth of knowledge was judged to merit a score of 2. This was the case because the open ended, project-based nature of this course, as well as its contextualisation in the real world, are suggestive of higher order processing. However, as the BHSC NST (FI) does not appear to cover complex science topics, a score of 2, rather than 3, was awarded.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a 3.
 - BHSC NST (BGE) was awarded a score of 0.5. As with other science subjects, the complexity of the concepts being covered can be uncertain due to the limited detail provided. However, the majority of chemistry content can be assumed to be more basic than complex. Indeed, there is very limited evidence for a substantial number of complex subtopics and concepts. Therefore, it was decided that there was a generous time allocation¹⁴⁹ per theme and that this overall represented a light volume of work. For BHSC NST (FI), a score of 1.5 was given. The course has scope for a significant proportion of the time to be spent on issues beyond basic conceptual depth, and the potential for in depth project-based work. Based upon the time allocated to the specialisation component of formative itineraries, the time allocation per theme was judged to be standard. However, the complexity of the content explored is unclear, and may be largely at teacher's discretion. Therefore, the judgement is limited to a 1.5.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a 3.
 - BHSC NST (BGE) was given a score of 1 for outstanding areas of demand as the inclusion of debates, real world applications and the investigative approaches were considered to potentially allow for 1 to 2 stretch areas. For BHSC NST (FI), a score of 2 was awarded. The emphasis on the following provided further stretch areas: real-life application, the project-based work, the cross curricular nature of the course, and the opportunities for discussion and debate.

¹⁴⁹ Time allocations were drawn from the RJRC.

4.11 Mexico

Education in Mexico is overseen by the Secretariat of Public Education and is compulsory from the age of three to 18. The school system is divided into primary school (ages six to 11) and secondary school (ages 11 to 18). Secondary education in Mexico is divided into lower and upper secondary, each lasting three years.

Upper secondary (*Educación Media Superior*) is offered through three main pathways:

- *Bachillerato General*
- *Bachillerato Tecnológico*
- *Educación Profesional Técnica*.

The Mexican *Bachillerato General* (MBG) is a traditional, academic pathway designed to prepare students for higher education, as well as developing the competencies necessary for the world of work.¹⁵⁰ The *Bachillerato Tecnológico*, combines general and vocational education to enable students to pursue higher education or a more professional/technical route.¹⁵¹ Finally, the *Educación Profesional Técnica* is purely vocational and provides access to the labour market and employment.¹⁵² Within the *Educación Media Superior*, the MBG is the focus in this report, as this programme is the most aligned with the DP.

The MBG lasts for three years and is divided into six semesters, with each year consisting of two semesters. During the MBG, students complete five curriculum components, namely the:

- Core component ('*Componente de Formación Fundamental*')
- Mandatory Extended Core component ('*Componente de Formación Fundamental Extendido Obligatorio*')
- Extended Core component ('*Componente de Formación Fundamental Extendido*')
- Work Experience component ('*Componente de Formación Laboral*')
- Expanded Curriculum ('*Currículum Ampliado*').¹⁵³

Students study units from all five of these components. Units in the Core, Mandatory Extended Core, and Extended Core components are organised into Socio-cognitive Resources and Areas of Knowledge, which are outlined below:

Socio-cognitive Resources:

- Language and Communication
- Mathematical Thinking
- Historical Consciousness
- Digital Culture

Areas of Knowledge:

- Natural Sciences, Experimental Sciences and Technology
- Social Sciences
- Humanities

The MBG units used for comparison to DP chemistry are outlined below.

¹⁵⁰ Government of Mexico. (n.d.) *Bachillerato General*. Available from: [Bachillerato General \(sep.gob.mx\)](https://bachillerato.gob.mx)

¹⁵¹ Mexican Secretariat of Education, Science, Technology and Innovation. (2024). *Bachillerato Tecnológico*. Available from: [Bachillerato Tecnológico | Secretaría de Educación, Ciencia, Tecnología e Innovación \(edomex.gob.mx\)](https://bachillerato.tecnologico.gob.mx)

¹⁵² Government of Mexico. (n.d.). *Servicios educativos*. Available from: [Subsecretaría de Educación Media Superior: Servicios educativos \(sep.gob.mx\)](https://servicioseducativos.gob.mx)

¹⁵³ Mexican Secretariat of Public Education. (2024). *Base Document for the Bachillerato General*.

Natural Sciences, Experimental Sciences and Technology¹⁵⁴

Natural Sciences, Experimental Sciences and Technology is one of the four Areas of Knowledge articulated in the Common Curriculum Framework for Higher Secondary Education in Mexico and includes common learning for all high school students. This area is described as referring to human activities and the study of the natural world. In addition to studying these areas, students formulate and verify hypotheses, raise questions and search for answers related to the processes and dynamics of natural phenomena. Some of the units within the Natural Sciences, Experimental Sciences and Technology knowledge area are compulsory for all MBG students and some are optional.

Compulsory Natural Sciences, Experimental Sciences and Technology units in the MBG:

There are six compulsory units in the Core curriculum component. These are designed in a transversal way; therefore each one contains elements of all the science disciplines.

- **Matter and its interactions¹⁵⁵**

This unit is taught in the first semester of the MBG and provides foundational knowledge of scientific concepts. Content includes elements, molecules, microscopic structure, the water cycle and temperature changes within chemical reactions.

- **Conservation of energy and its interactions with matter¹⁵⁶**

This unit is taught in the second semester of the MBG, and whilst it builds on some concepts covered in the Matter and its interactions, it is also aimed at providing a foundational knowledge of scientific concepts. Content includes different types of energy and energy transfers, electromagnetic fields, changes of state, and the energy in chemical reactions.

- **Ecosystems: interactions, energy and dynamics¹⁵⁷**

This unit is taught in the third semester of the MBG and contains fundamental areas of science but has a greater focus on biology than the previous units. Content includes cells, photosynthesis and respiration, the carbon cycle, food webs and ecosystems.

- **Chemical reactions: conservation of matter in the formation of new substances¹⁵⁸**

This unit is taught in the fourth semester of the MBG and is designed to build on the content studied within the 'matter and its interactions' unit by providing more depth and detail. Content includes chemical reactions, exothermic and endothermic reactions, atomic structure, the periodic table and nuclear reactions.

¹⁵⁴ Mexican Secretariat of Public Education. (2024). *Base Document for Bachillerato General*.

¹⁵⁵ Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area Studies in Matter and its Interactions*. Available from: [Undersecretariat of Higher Secondary Education: Proposal for the Common Curricular Framework for Upper Secondary Education \(sep.gob.mx\)](https://sep.gob.mx/)

¹⁵⁶ Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Conservation of energy in its interactions with matter*.

¹⁵⁷ Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Ecosystems: interactions, energy and dynamics*.

¹⁵⁸ Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Chemical reactions: conservation of matter in the formation of new substances*.

- **Energy in the processes of daily life**¹⁵⁹

This unit is taught in the fifth semester of the MBG and builds on the knowledge acquired through previous units. This unit focuses on how energy is linked to the real world and how understanding it helps students to make sense of phenomena in their day-to-day lives. Content includes forces, motion, momentum, Newton's laws, moments, magnetic fields and electricity.

- **Organisms: structures and processes. Inheritance and biological evolution**¹⁶⁰

This unit is taught in semester six of the MBG and builds biology and chemistry content from previous units. Content includes specialised cells, reproduction, variation, inheritance, natural selection, adaptation, evolution and protein synthesis.

There are also three compulsory units within the Mandatory Extended Core component.

- **Science Workshop I**¹⁶¹

This unit is taught in the second semester and weaves together the overarching concepts from other units. However, within Science Workshop I there is more focus on practical work and experimental activities. These include designing models, formulating questions and hypotheses and proposing solutions to problems within the students' environment.

- **Science Workshop II**

- **Space and Society**

At the time of writing this report, there is currently no publicly available documentation for the MBG units Science Workshop II and Space and Society.

Optional Natural Sciences, Experimental Sciences and Technology units in the MBG:¹⁶²

- **Selected Topics in Chemistry I**
- **Selected Topics in Chemistry II**

The optional units listed above are part of the Extended Core component and, if chosen, are studied in the last two semesters of high school. Students of the MBG choose eight optional units, typically four pairs, from a range of Areas of Knowledge and Socio-cognitive Resources, and therefore the optional units studied will vary between students.

The analysis will consider, and distinguish between, Natural Sciences, Experimental Sciences and Technology units which are compulsory in the MBG, and those which are optional.

¹⁵⁹ Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Energy in the processes of daily life*.

¹⁶⁰ Mexican Secretariat of Public Education. (2023). *Programme of Knowledge Area studies in Organisms: structure and processes. Inheritance and biological evolution*.

¹⁶¹ Mexican Secretariat of Public Education. (2024). *Programme of the UAC of the Knowledge Area Science Workshop I*.

¹⁶² Undersecretary of Higher Secondary Education. (2018). *Programs of Study for the Class of 2022 – 2025. Propaedeutic Training Component*. Available from: [Programs of Study for the Generation 2023 - 2026 and Subsequent. \(sep.gob.mx\)](https://sep.gob.mx)

4.11.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of science.

The learning outcome themes for all DP science subjects were extracted from the aims and assessment objectives of the DP sciences subject group, hence the themes are the same for physics, chemistry and biology. Likewise, the MBG articulates learning outcomes that are applicable to all sciences, and these are currently presented as Learning Progressions and Extended Disciplinary Competencies. Where relevant, General Competencies for the MBG have also been considered.

The following table demonstrates the learning outcome themes that were extracted from the DP learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the MBG curricula.

Table 41: Presence of the DP sciences subject group learning outcome themes in the MBG

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the Bachillerato General	
1. Conceptual understanding and making connections		Strongly present in Learning Progressions, General Competences and Extended Disciplinary Competences.
2. Use and application of knowledge, methods, tools, and techniques that characterise science		Strongly present in Learning Progressions, General Competences and Extended Disciplinary Competences.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)		Strongly present in the Learning Progressions, General Competences and Extended Disciplinary Competences.
4. Apply skills necessary to carry out insightful and ethical investigations (planning, collecting data, organising, following ethical guidelines)		Strongly present in the Learning Progressions, General Competences and Extended Disciplinary Competences.
5. Development of technological skills		Present in the Learning Progressions, General Competences and Extended Disciplinary Competences.
6. Effective collaboration and communication		Strongly present in the Learning Progressions, and General Competences.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science		Not particularly evident in the Learning Progressions, however, strongly present in the General Competences and Extended Disciplinary Competences.

Key:

	<i>This theme is well-evidenced in the learning outcomes of the MBG.</i>		<i>This theme is partially evidenced in the learning outcomes of MBG.</i>		<i>This theme is not evident in the learning outcomes of the MBG.</i>
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Presence of the DP's Learning Outcome Themes

As can be seen in the table, there is strong alignment between the DP learning outcome themes and the Mexico curricula. All DP learning outcome themes are found within many

areas of the Mexico curricula, although some are more strongly and widely emphasised than others. Below, the extent to which each theme is present in the MBG is discussed in more detail.

1. Conceptual understanding and making connections

There is strong evidence of the DP's theme of making connections and developing conceptual understanding within the MBG. For compulsory units, the Learning Progressions describe 'Science and Engineering Practices', where students are drawing on different sources of information and then comparing them with what they learn in the classroom. The fundamentals of Science Workshop I also highlight the importance of this theme through the discussion of how students will reflect on the relationship between science, technology and the context in which they are covering different concepts.

For the optional units, the General Competences also include this theme through requiring students to express ideas and concepts, articulate knowledge from various fields, and establish relationships between them and their daily life. Finally, the Extended Disciplinary Competences expect students to carry out interdisciplinary projects, which further strengthens the presence of this theme.

2. Use and application of knowledge, methods, tools, and techniques that characterise science

The DP's theme of knowledge, methods, tools and techniques that characterise science encompasses different aspects, and therefore parts of it can be found in different places; these various parts taken as a whole result in this theme being strongly present in the MBG. For compulsory units, the Science and Engineering Practices state that students will collect evidence and then explain phenomena based on this evidence. It goes further to stipulate that this evidence is consistent with the ideas and theories of science. Science Workshop I aims to promote skills such as observation, experimentation and problem solving.

Regarding optional units, the General Competences cover this theme well, as they require students to follow instructions and procedures reflectively, understanding how each step contributes to achieving an objective. Students are also expected to build hypotheses, design, and then apply models to test the validity of these hypotheses. Furthermore, it is outlined that students will synthesise the evidence they obtain through experiments to produce conclusions and formulate new questions. The Experimental Sciences Extended Disciplinary Competences also illustrate this theme by outlining a requirement for students to use specialised tools and equipment, and handling substances and equipment appropriately and safely.

3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)

The DP's theme of using critical thinking, particularly analysis and synthesis, is strongly reflected within the Mexico curricula. For compulsory units, students are expected to formulate, refine and evaluate problems, evaluate information and its reliability and make evidence-based decisions from a critical standpoint. Skills highlighted in Science Workshop I include observation, experimentation and problem-solving, as well as the aim of encouraging students' capacity for logical thinking. The transversal relationships in the Core curriculum component emphasise the importance of students' critical thinking and their ability to reflect, discuss, contrast and investigate information.

The General Competences require students to choose between sources of information and discriminate between them based on their relevance and reliability; thereby requiring students to analyse and evaluate different texts or data sets. This theme is also present in the General Competences, where students are expected to synthesise evidence, evaluate arguments, critically and responsibly assess benefits and risks and evaluate the implications of the use of science and technology. Problem-solving is also an aspect that is present through the Mexico curricula and mentioned repeatedly in various areas through references to students proposing ways to solve a problem and defining a course of action with specific steps. This also encompasses the creativity aspect of this DP theme through the focus on students designing prototypes or models in order to solve problems.

4. Apply skills necessary to carry out insightful and ethical investigations

There are many references in the Mexico curricula to skills involving investigations, such as the descriptions within the Science and Engineering Practices where students are required to develop skills of planning and conducting research, searching for information to use as evidence for carrying out planned investigations. There is also a statement referring to the analysis and interpretation of data, followed by reference to students building explanations and designing solutions. The introduction to the Science Workshop I unit mentions practical work, and describes the promotion of observation, experimentation and problem-solving skills. Another compulsory unit, Science Workshop II, is likely to contain further evidence of practical work; however, at the time of writing, this unit was not publicly available for review.

For optional units, the General Competences detail scientific investigations more clearly through statements describing how students will build hypotheses and design and apply models to test their validity, as well as the synthesis of evidence obtained through experimentation to produce conclusions and formulate new questions. The Extended Disciplinary Competences of the Experimental Sciences show the presence of this theme through the description of students using specialised tools and equipment and applying the appropriate health and safety techniques to practical work in order to minimise risk. Therefore, overall, there is strong presence of this DP theme in the Mexico curricula.

5. Development of technological skills

Technology skills are mentioned less frequently throughout the MBG than other skills, although there is a strong presence of this theme, nonetheless. In the compulsory units, the Science and Engineering Internship promotes the development of technological skills through expecting students to use mathematical and computational thinking, including for the design of simple computational models. Furthermore, the Learning Progressions outline how the socio-cognitive resource of Digital Culture can be integrated into Natural and Experimental Sciences and Technology through providing access to Socio-cognitive virtual laboratories, databases and simulations, and thus further reinforcing that the development of technological skills is an overarching theme.

For the optional units, the General Competences also demonstrate this theme by expecting students to use information and communication technologies to process and interpret information. Moreover, the development of technological skills can be inferred from some of the Extended Disciplinary Competences for Experimental Sciences, as these include using specialised tools and equipment and designing prototypes and models – all of which will likely involve the application of technology.

6. Effective collaboration and communication

Both communication and collaboration are skills mentioned throughout the Mexico curricula. For example, the compulsory units include repeated reference to highlighting the importance of working collectively and the transversal relationships describe that there are different ways for students to communicate their ideas.

For the optional units, while not explicitly present in the Extended Disciplinary Competencies for Experimental Sciences specifically, the General Competences evidence this theme by outlining expectations for students to cultivate interpersonal relationships, express ideas, share opinions, and consider others' perspectives. Moreover, the 'effective' aspect of this DP theme is really highlighted through the expectation that students will apply different communication strategies depending on the audience, the context and the objectives of the communication.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

References to the impact of science at global and local levels are less explicit than the other DP learning outcome themes. However, it can be inferred from some of the introductions given for the compulsory units that these aspects will be considered during the course. Indeed, the introduction to both 'Conservation of Energy and its Interaction with Matter' and 'Energy in the Processes of Daily Life units' stipulate that students should establish a broader understanding of how the world works and how humanity takes advantage of this knowledge. Furthermore, Science Workshop I expects students to understand how science and technology influence each other and society, as well as how science and technology can offer alternatives to address specific problems in an individual's environment. Also, the MCCEMS expect the Social Sciences Socio-cognitive Resource to be integrated into Natural and Experimental Sciences and Technology through the consideration of social, economic and cultural perspectives.

For the optional units, there is also presence of this theme in the General and Extended Disciplinary Competences. Indeed, the General Competences describe students being able to recognise and understand biological, economic, political and social implications, including environmental damage, in an interdependent global context, and the Extended Disciplinary Competences expect students to apply scientific and technological advances to improve the conditions of their social environment.

Other Themes in the MBG

There are no other themes within MBG science that are not also present in the DP.

Summary

All DP learning outcome themes are present in the MBG's Learning Progressions, which are shared across all science disciplines. Within the Extended Disciplinary Competences (Experimental Sciences), there is also evidence of all DP learning outcome themes. Some themes are heavily emphasised in the MBG (namely conceptual understanding, critical thinking and problem-solving), whilst others are referenced less regularly (insightful investigations and awareness of the impact of science), but nevertheless still have a strong presence.

4.11.2 Content

This section compares and contrasts the content of the DP and MBG curricula falling within the category of chemistry. The MBG chemistry-related units are presented below in diagrams which show the key topics and subtopics included in each.

Figure 24: Visualiser of common science content in the MBG

Core curriculum component	Natural Sciences, Experimental Sciences and Technology	1. Matter and its interactions	2. Conservation of energy and its interactions with matter	3. Ecosystems: interactions, energy and dynamics	4. Chemical reactions: conservation of matter in the formation of new substances	5. Energy in the processes of daily life	6. Organisms: structures and processes. Inheritance and biological evolution
Mandatory Extended Core curriculum component	Natural Sciences, Experimental Sciences and Technology	1. Science Workshop I	2. Science Workshop II*				

*At the time of writing, the programme of study for Science Workshop II was not publicly available

Figure 25: MBG chemistry content visualiser

Optional Extended Core curriculum components	Selected Topics in Chemistry I	Block I	States of aggregation of matter and chemical nomenclature	Explain the characteristics of the states of aggregation of matter, the laws of gases and the rules of the nomenclature of chemical compounds for their application in biogeochemical cycles and industrial processes present in the environment, favouring collaborative and organized work.
		Block II	Stoichiometry	Develop stoichiometric calculations of the limiting reagent, efficiency and purity from a balanced chemical equation to apply it to solve problems in your environment, favouring methodical and organized work.
		Block III	Solutions	Prepare proposals using the preparation of different types of solutions to solve problems in the environment with a critical and responsible attitude.
	Selected Topics in Chemistry II	Block I	Chemical Kinetics	Analyse the factors, speed, abundance and balance of a chemical reaction to provide solutions to problems in the environment, promoting beneficial behaviour in society.
		Block II	Thermochemistry and Electrochemistry	Apply different processes to build an electro-voltaic cell, based on the analysis of the functioning of thermodynamics and electrochemistry, reflecting on human actions and their environmental impact.
		Block III	Organic Biomolecules	Demonstrate the structures of organic biomolecules through functional groups to contextualise their chemical classification, favouring the disposition to critical and informed work.

4.11.2.1 Structure

There are many differences in structure between DP chemistry and the MBG units. Chemistry in the DP is a distinct, two-year subject, offered at either SL or HL. In contrast, the MBG offers the knowledge area of Natural Sciences, Experimental Sciences, and Technology, which encompasses chemistry and other sciences. The compulsory units in this knowledge area integrate the sciences and all content within these units is studied to the same level. Only in the optional units of this knowledge area is chemistry offered as a separate science discipline. The compulsory units altogether span the duration of the MBG, whereas the optional units only span the final year. Therefore, within the MBG, there is more emphasis on breadth of scientific knowledge and less scope to specialise in chemistry specifically.

DP chemistry content is broken down into two overarching areas (Structure and Reactivity), and three themes within each: Structure 1, 2 and 3 and Reactivity 1, 2 and 3, each of which is then organised into subtopics. In contrast, the MBG's compulsory units integrate chemistry (and other science) concepts into six overarching scientific areas such as 'Matter and its interactions'. For the optional units, the MBG offers Selected Topics in Chemistry I and Selected Topics in Chemistry II. These units are each organised into three blocks of learning.

4.11.2.2 Content Alignment

The following table represents a simplified summary of the MBG's content alignment, at topic-level, with DP chemistry (SL and HL). The analysis considers the alignment that the compulsory units alone have with DP chemistry, as well as the alignment of all the units combined (compulsory and optional).

Table 42: Summary of content alignment between the DP chemistry topics and the MBG

DP chemistry topics	Presence of SL content in the MBG		Presence of AHL content in the MBG	
	Compulsory units	Compulsory and optional units	Compulsory units	Compulsory and optional units
Structure 1. Models of the particulate nature of matter				
Structure 1.1 – Introduction to the particulate nature of matter			N/A	N/A
Structure 1.2 – The nuclear atom				
Structure 1.3 – Electron configurations				
Structure 1.4 – Counting principles by mass: The mole			N/A	N/A
Structure 1.5 – Ideal gases			N/A	N/A
Structure 2. Models of bonding and structure				
Structure 2.1 – The ionic model			N/A	N/A
Structure 2.2 – The covalent model				
Structure 2.3 – The metallic model				
Structure 2.4 – From models to materials				
Structure 3. Classification of matter				
Structure 3.1 – The periodic table: Classification of elements				
Structure 3.2 – Functional groups: Classification of organic compounds				

Reactivity 1. What drives chemical reactions?				
Reactivity 1.1 – Measuring enthalpy changes			N/A	N/A
Reactivity 1.2 – Energy cycles in reactions				
Reactivity 1.3 – Energy from fuels			N/A	N/A
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A	N/A		
Reactivity 2. How much, how fast and how far?				
Reactivity 2.1 – How much? The amount of chemical change			N/A	N/A
Reactivity 2.2 – How fast? The rate of chemical change				
Reactivity 2.3 – How far? The extent of chemical change				
Reactivity 3. What are the mechanisms of chemical change?				
Reactivity 3.1 – Proton transfer reactions				
Reactivity 3.2 – Electron transfer reactions				
Reactivity 3.3 – Electron sharing reactions			N/A	N/A
Reactivity 3.4 – Electron-pair sharing reactions				
Experimental programme				

Key:

Strong presence of this topic in the MBG.	Partial presence of this topic in the MBG.	Little or no presence of this topic in the MBG.	N/A	This topic does not exist at the respective level.
Compulsory units: - Matter and its interactions - Conservation of energy and its interactions with matter - Ecosystems: interactions, energy and dynamics - Chemical reactions: conservation of matter in the formation of new substances - Energy in the processes of daily life - Organisms: structures and processes. - Science Workshop I Optional units: Selected Topics in Chemistry I & II <i>Any alignments found in the compulsory units are carried over and combined with those in the optional units, to represent all the chemistry content offered in the Bachillerato General</i>				

As evidenced in table 42, there is at least partial alignment between some of the MBG chemistry topics and the DP, with some topics showing strong alignment. Each DP theme will be taken in turn and discussed in more detail below.

Structure 1: Models of the particulate nature of matter

Regarding SL content within Structure 1, there is strong alignment between the MBG and the DP through all topics within this unit. In particular, topics 1.1 - Introduction to the particulate nature of matter, and 1.4 - Counting principles by mass: the mole, have a strong presence in the MBG. Two topics within the MBG compulsory units align well with the DP Structure 1.1: 'Matter and its Interactions', and 'Chemical Reactions, Conservation of Matter in the Formation of New Particles'. Both these reference the use of the particle model to understand matter, and how substances are made of one type of atom. The compulsory units also partially align

with Structure 1.2, and 1.3, as they include content regarding atomic structure, patterns in the periodic table and properties of the light given off by atoms.

Structure 1.4 shows strong alignment with the optional units in the MBG, particularly 'Selected Topics in Chemistry I' which includes stoichiometric calculations and molar relationships, as well as calculations regarding the purity of chemicals. This supports the conclusion that there is a strong presence of Structure 1.4 content in this unit. In addition, 'Selected Topics in Chemistry I' covers the gas laws and ideal gas equation. However, there is not enough detail to conclude that there is a strong presence of Structure 1.5 content.

Regarding AHL content within Structure 1; there is no alignment between the MBG and topics 1.2 – The nuclear atom or 1.3 – Electron configurations. Indeed, there are no references to mass spectra, emission spectra or ionisation energy data in the MBG, therefore no alignment could be found for these.

Structure 2: Models of bonding and structure

Regarding SL content within Structure 2, topics 2.1 - The ionic model and 2.3 - The metallic model show partial alignment with the MBG. The compulsory units include the attraction and repulsion between electrical charges, and the structure, properties and transformations of matter, which aligns well with DP topic 2.1 content focused on ionic bonds and ionic compounds. However, the MBG documentation is not detailed enough to conclude that there is a strong presence of this content. The compulsory units of the MBG also partially align with the DP Structure 2.3 topics, as they include electrical charges at the atomic scale. However, without specific mention of metallic bonds or radius of metal ions, the units cannot be considered to have strong alignment with this topic's SL content.

Furthermore, the MBG shows no alignment with topics 2.2 - The covalent model and 2.4 - From models to materials as the content within these topics has little to no presence in the MBG. The compulsory and optional units also do not include any of the AHL content from Structure 2.

Structure 3: Classification of matter

Regarding SL content within Structure 3, the MBG shows some alignment with both DP topics. Indeed, the MBG compulsory units contain an overarching, general statement which broadly refers to properties that are predictable from patterns (e.g. the reactivity of metals, the types of bond formed, and the reaction with oxygen). Whilst this is covering periodicity and implicitly suggests that certain DP content within topic 3.1 is present in the MBG, without key terminology such as 'valence electrons' and a specific focus on key Groups (such as the halogens and the Group 1 metals), only a partial, rather than strong, alignment can be concluded.

Topic 3.2 - Functional groups: classification of organic compounds shows full alignment with the MBG optional units. Indeed, Selected Topics in Chemistry II includes coverage of the chemical classification of organic biomolecules and distinguishing between functional groups of organic biomolecules. Furthermore, chemical nomenclature (oxides, hydroxides, hydrides etc.) is present within 'Selected Topics in Chemistry I', thereby further strengthening this alignment.

Regarding AHL content within Structure 3, there is no alignment between the MBG and topics 3.1 - The periodic table: classification of elements and 3.2 - Functional groups: classification of organic compounds. Within the MBG there is no mention of the DP HL content within these topics.

Reactivity 1: What drives chemical reactions?

Regarding SL content within Reactivity 1, the topics show variation in how much alignment there is between the DP and MBG. The compulsory units partially align with Reactivity 1.2, as they include references to the energy required to break bonds. Moreover, aside from a small reference to reactions gaining or releasing energy, the compulsory units contain very little other Reactivity 1 content, thus there are no further alignments with DP topics.

The optional units have partial alignment with Reactivity 1.1 – Measuring enthalpy changes, as Selected Topics in Chemistry II includes endothermic and exothermic reactions. Furthermore, the optional units strengthen the alignment with Reactivity 1.2, as, in addition to bond energies, Hess' Law is covered in Selected Topics in Chemistry II. Finally, none of the units cover combustion or fuels, thus there is no alignment with Reactivity 1.3 – Energy from fuels content.

Regarding AHL content within Reactivity 1, Reactivity 1.2 Energy cycles in reactions shows partial alignment with the MBG optional units due to the presence of entropy calculations in the Selected Topics in Chemistry II topics. However, there is no alignment between Reactivity 1.4 Entropy and spontaneity and the MBG as the detailed calculations requiring Gibbs energy are not present in the MBG.

Reactivity 2: How much, how fast and how far?

Regarding SL content within Reactivity 2, there is no alignment between the MBG and the DP within topic 2.1 How much? Reactivity 2.2 – How fast? The rate of chemical change, and Reactivity 2.3 How far? The extent of chemical change both show strong presence in the MBG in the compulsory units and the optional Selected Topics in Chemistry II taken together. The MBG compulsory unit 'Chemical Reactions, Conservation of Matter in the Formation of New Substances' includes coverage of the energy required or released in chemical reactions, and reversible reactions in the context of dynamic equilibrium. This alignment is further evidenced by the optional unit Selected Topics in Chemistry II, which includes activation energy and Le Châtelier's principle.

Regarding AHL content within Reactivity 2, there is no alignment between the DP reactivity 2.2 How fast? The rate of chemical change and the MBG. There is partial alignment between the DP and Reactivity 2.3 How far? The extent of chemical change. Indeed, one of the compulsory MBG units includes dynamic equilibrium, however as it does not specify 'equilibrium law', and with no mention of Gibbs' energy change, there is not enough detail to conclude that there is a strong presence of this topic's content.

Reactivity 3: What are the mechanisms of chemical change?

Regarding SL content within Reactivity 3, the MBG compulsory units do not contain any content from this DP unit. However, topic 3.1 shows partial alignment and 3.2 has strong presence in the MBG optional units. The overlapping content between the DP reactivity 3.1 is present in the MBG's optional topic 'Selected Topics in Chemistry I', as it includes acids and

bases and the calculation of pH and OH. There is no mention in the MBG units of the logarithmic nature of the pH scale, and the ion product constant of water (K_w) is also not found within the MBG, hence the alignment here is only partial. Reactivity 3.2 content has a strong presence in the MBG optional topic 'Selected Topics in Chemistry II', as it includes the characteristics of oxidation-reduction reactions and the applications of electrolysis. There is no alignment between the DP topics Reactivity 3.3. Electron sharing reactions and Reactivity 3.4 Electron-pair sharing reactions and the MBG.

Regarding AHL content within Reactivity 3, there is no alignment between the topics 3.1 proton transfer reactions, 3.2 electron transfer reactions and 3.4 electron-pair sharing reactions, and the MBG.

Experimental programme

The DP's experimental programme is outlined in a way that emphasises the need for students to enhance and embed their understanding through the use of practical work and the development of scientific skills such as experiments, databases, simulations and modelling. However, the realities of this within each school may differ in terms of the exact practical activities carried out and the context these activities are conducted within. The MBG curricula make references throughout the science subject area to activities that may be described as practical experiments. For example, the common Core unit Matter and its Interactions includes a statement where, throughout the course, students will "carry out practices related to the nature of matter and its properties".¹⁶³ This goes further to then describe how students will develop skills such as using models and obtaining and analysing data. The MBG optional unit Selected Topics in Chemistry I describes students combining different chemical substances in order to prepare solutions. These aspects suggest a strong presence of practical work within the MBG.

Summary

In summary, the MBG compulsory units show at least partial alignment with the DP SL chemistry course. When the MBG compulsory and optional units are taken together, there is a greater level of overlap between the DP SL chemistry and the MBG. For HL content, there is very little alignment between the MBG and the DP. Only one DP topic (Reactivity 2.3 How far? The extent of chemical change) shows partial alignment with the MBG compulsory units. Reactivity 1.2 Energy cycles is the only DP topic that shows presence in the MBG when viewing the compulsory and optional units together. This shows that the DP covers both a greater breadth and depth of chemistry content than the MBG.

Table 43: MBG chemistry content which is not covered in the DP

Significant MBG chemistry content which is not included in the DP*
Chemical Reactions – Conservation of Matter in the Formation of New Substances – The Chemistry of the air, how to improve what we breathe? (<i>presumably focused on pollution/particulates etc.</i>) Matter and its Interactions – Nanotechnology In general – the relation of things to the use in the world/community/environment.

*Notably, 'significant content' does not include topics which are typically studied *prior* to upper secondary.

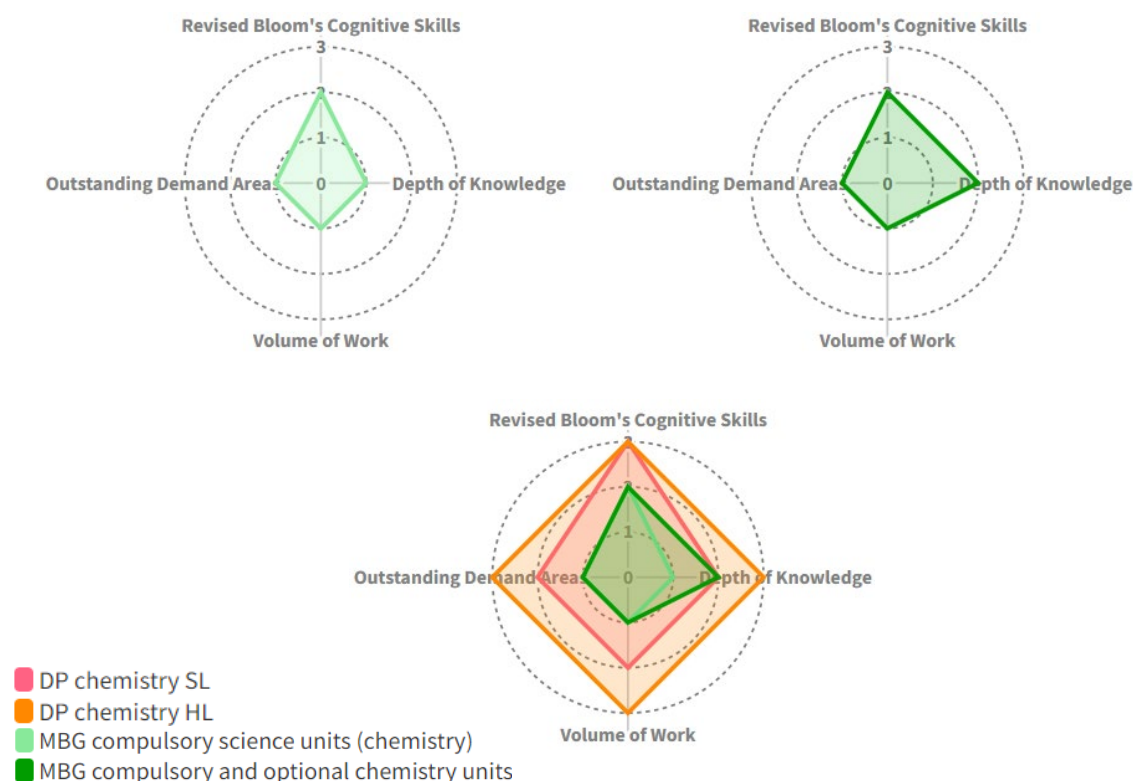
¹⁶³ Mexican Secretariat of Public Education. (2023). *Learning Progressions in the area of Natural Sciences, Experimental Sciences and Technology*. p. 36.

As seen in table 43, there are certain aspects of chemistry content present in the MBG that is not covered in the DP. The first of these being the chemistry of the air and how to improve this, which is likely to be focused on particulates and pollution within the air. Whilst this is something that is generally included at an educational level prior to upper secondary, there is not enough detail in the documentation to determine the level to which this is covered. The same can be said of the other aspects in table 43; nanotechnology and the relation of chemistry content to the use in the world/community/environment. Both these areas may be covered to a fundamental level, or it may be that a great level of detail in these areas is covered, however there is not enough detail within the documentation to determine this.

4.11.3 Demand

The DP and MBG curricula were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, MBG compulsory science units (chemistry), and the MBG compulsory and optional chemistry units (combined). These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 26: Visual representations of subject demand



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - DP physics SL and HL received a score of 3 for this category.
 - For the MBG compulsory units and the MBG compulsory and optional units (combined), a score of 2 was given. Whilst there is strong evidence of skills such

as analysis, problem-solving and showing innovation, this was not tailored to subject content. A score of 2 was given due to statements being too generalised. Whilst the Extended Disciplinary skills are written with a scientific focus, this did not warrant raising the score above a 2 as there was still not enough evidence of the synthesis and creation higher order thinking skills.

- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2, DP HL received a score of 3 for depth of knowledge.
 - The MBG compulsory units received a score of 1 for depth of knowledge, whereas the compulsory and optional MBG units taken together received a score of 2. Some aspects of the MBG compulsory units appear to be below the level of upper secondary, and although there are areas of DP SL chemistry that are present in these MBG units; many of the more challenging topics are not covered in the MBG, hence the score of 1 for these units. The optional units of the MBG go into slightly greater depth and begin to explore some areas of the DP HL course, therefore a higher score of 2 was merited.
- Regarding the scores for **Volume of Work**:
 - The DP chemistry SL received a score of 2, DP HL received a score of 3 for volume of work.
 - A score of 1 was given to both the MBG compulsory units and the compulsory and optional units combined. This is a higher score than what was given to the MBG physics course, due to more chemistry content being covered in the compulsory units. However, the workload was not deemed significant enough to warrant a similar score to the DP, as fewer chemistry topics are covered. These topics are also not studied in extensive depth and therefore the amount of time allocated to them is fairly generous, thus resulting in a score of 1.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2, DP HL received a score of 3 for outstanding areas of subject demand.
 - The MBG compulsory units alone, and the MBG compulsory and optional units combined, received the same score of 1 for this category. The interdisciplinary nature and significant real-world focus of the MBG units results in a strong emphasis on connections. Moreover, there was evidence of project-based learning, which contains scope for students to explore scientific concepts in-depth. Altogether, these aspects were deemed to warrant a score of 1.

4.12 Japan

The Japanese education system includes six years of elementary school followed by six years of secondary school, which is divided into three years of lower secondary (grades 7-9) and three years of upper secondary (grades 10-12).¹⁶⁴ MEXT – the Ministry of Education, Culture, Sports, Science and Technology – regulates the education system from kindergarten to upper secondary school and develops curriculum standards known as the *National Course of Study*.¹⁶⁵ The *Course of Study* is revised approximately once every 10 years; the most recent revision took place in 2018 and was implemented from 2020 to 2022.¹⁶⁶

The courses offered in high schools providing upper-secondary education are classified as general, specialised, or integrated. General courses, and their associated subjects, are suitable for those wishing to progress to higher education or employment, but who do not intend to pursue a specific vocational area. In contrast, specialised courses provide vocational or specialist education for those who intend to pursue a particular vocational area or career. There are two types of subjects offered in specialised courses: industry and non-industry. Integrated courses, introduced in 1994, offer a variety of subjects that draw from both general and specialised courses.¹⁶⁷

A minimum of 74 credits is required to graduate high school¹⁶⁸ and students are required to study compulsory subjects from the following areas:

- Japanese Language
- Geography and History
- Civics
- Mathematics
- Science
- Health and Physical Education
- Arts
- Foreign Language
- Home Economics
- Information
- Comprehensive Inquiry or Inquiry-based Study of Science and Mathematics.

For Science, students are required to choose two subjects from among 'Science and Human Life', 'Basic Physics', 'Basic Chemistry', 'Basic Biology' and 'Basic Earth Science' (one of which will be 'Science and Human Life'), **or** three subjects from among 'Basic Physics', 'Basic Chemistry', 'Basic Biology' and 'Basic Earth Science'.

In addition to compulsory subjects, students study electives in order to reach the minimum credit requirement. Optional subjects are offered in the same areas as listed above. There is

¹⁶⁴ National Information Centre for Academic Recognition Japan (NIC-Japan). (n.d.). *Overview of the Japanese Education System*. Available from: <https://www.nicjp.niad.ac.jp/en/japanese-system/about.html>

¹⁶⁵ MEXT. (2018). *High School Course of Study. Chapter VI Institutions of Higher Learning*. p. 5-6. Available from: <https://www.mext.go.jp/en/policy/education/overview/index.htm>

¹⁶⁶ MEXT. (2018). *High School Course of Study. Supplementary Provisions (Ministry of Education, Culture, Sports, Science and Technology Decree No. 13 on March 30, 2006)*. p. 11.

¹⁶⁷ MEXT. (n.d.). *Principles Guide Japan's Educational System*. Available from: <https://www.mext.go.jp/en/policy/education/overview/index.htm>

¹⁶⁸ MEXT. (2018). *High School Course of Study. Chapter VI Institutions of Higher Learning*. p.5-6.

also a wide range of industry and non-industry specialised subjects to choose from. Industry specialised subjects have the following subject areas: Agriculture, Industry, Business, Fisheries, Home Economics, Nursing, Informatics, and Welfare.¹⁶⁹ Non-industry specialised subjects are organised into the areas of: Science and Mathematics, Physical Education, Music, Art and Design, and English. Students studying vocational courses must have a minimum of 25 credits from specialised subjects and schools are to determine the credits for each subject.

The chemistry subjects from the Japanese High School Curriculum (JHSC) which were used in the analysis are described below.

Advanced Chemistry¹⁷⁰

Regarding general subjects, the JHSC offers Basic Chemistry and Advanced Chemistry. Advanced Chemistry carries four credits and is an optional subject that can be studied after Basic Chemistry. The analysis focused on Advanced Chemistry, as it aligns more closely with the upper secondary level.

Chemistry for the Science and Mathematics Course¹⁷¹

The JHSC also offers specialised science subjects, with one subject available for each science discipline. Chemistry for the Science and Mathematics Course (SMC) combines the content from the general subjects – Basic and Advanced Chemistry – while providing opportunities for further expansion.

4.12.1 Learning Outcomes

This section compares and contrasts the learning outcomes of curricula falling within the category of science. Ecctis extracted learning outcome themes for DP physics, chemistry and biology from the sciences subject group's aims and assessment objectives, hence the themes are the same for all the sciences.

The JHSC defines three overarching objectives for the science subject area, outlining the qualities and abilities students should develop. These concise objectives are further elaborated in the *Commentary on the High School Curriculum Guidelines for Science*. Both the objectives and their explanations were considered in the learning outcome analysis.

The following table displays the presence of the learning outcome themes that were extracted from the DP science learning outcomes and indicates if and where they were judged to have presence within the learning outcomes of the JHSC science subjects.

¹⁶⁹ MEXT. (n.d.). *Principles Guide Japan's Educational System*.

¹⁷⁰ MEXT. (2018). *High School Course of Study. Science*. p. 103-130. Available from: [高等学校学習指導要領（平成30年告示）](#)

¹⁷¹ MEXT. (2018). *High School Course of Study. Science and Mathematics*. p. 437-441.

Table 44: Presence of the DP sciences subject group learning outcome themes in the JHSC science subjects.

Themes extracted from the learning outcomes of the DP sciences subject group	Presence in the JHSC	
1. Conceptual understanding and making connections.		Partially present in the science objectives.
2. Use and application of knowledge, methods, tools, and techniques that characterise science.		Partially present in the science objectives.
3. Creativity and critical thinking (problem-solving, analysis, evaluation, and synthesis).		Partially present in the further explanations of the science objectives.
4. Apply skills necessary to carry out insightful and ethical investigations (planning, collecting data, organising, following ethical guidelines).		Strongly present in the science objectives. Skills in scientific exploration and investigation are greatly emphasised.
5. Development of technological skills.		Not generally evident in the science objectives, but present in Physics (SMC).
6. Effective collaboration and communication.		Not evident in the science objectives.
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science.		Partially present in the further descriptions of the science objectives.

Key:

	This theme is well-evidenced in the learning outcomes of the JHSC.		This theme is partially evidenced in the learning outcomes of JHSC.		This theme is not evident in the learning outcomes of the JHSC.
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Presence of the DP's Learning Outcome Themes

The JHSC learning outcomes for science have some degree of alignment with most of the DP learning outcome themes. However, the DP themes tend to only be partially present, and two themes have little to no presence in the JHSC learning outcomes. The extent to which each theme is present in the JHSC learning outcomes is discussed below.

1. Conceptual understanding and making connections

This DP theme is partially present in the JHSC science learning outcomes. The first science objective describes students deepening their understanding of natural objects and phenomena and its further description states that students will understand scientific concepts, principles and laws. However, conceptual understanding, or making connections within the subject or to other subjects is not explicitly required by the objectives.

2. Use and application of knowledge, methods, tools, and techniques that characterise science

This DP theme is also partially present in the JHSC science learning outcomes. The science objectives somewhat demonstrate this theme through expectations that students think scientifically, make observations, and develop skills for conducting scientific exploration and investigation. These aspects may encompass methods, tools and techniques that characterise science, but it is not explicit enough to determine a strong presence of this theme.

3. Creativity and critical thinking (problem-solving, analysis, evaluation, and synthesis)

This DP theme is partially present in the JHSC science learning outcomes. Critical and creative thinking skills are not explicitly evident in the science objectives themselves, however the further explanation of these describe students independently identifying and considering

problems, analysing natural objects and phenomena in terms of qualitative and quantitative relationships, and making judgements based on scientific evidence. However, analysis, evaluation and synthesis generally receive less emphasis compared to the DP science learning outcomes.

4. Apply skills necessary to carry out insightful and ethical investigations

There are many references in the JHSC learning outcomes to investigations and the skills required to conduct them. Indeed, the science objectives describe how students will develop skills related to experiments, the ability to investigate scientifically and an attitude of “proactively engaging with natural objects and phenomena”¹⁷². The further explanations of the objectives state that students should make predictions or hypotheses and conduct observations and experiments to verify these. They also include that students will conduct experiments on a topic of their choosing and analyse and interpret the results. Hence there is an overall strong presence of this DP theme in the JHSC learning outcomes.

5. Development of technological skills

This DP theme has little to no presence in the JHSC learning outcomes, as the science objectives do not focus on the development of technology skills. Indeed, while students are to find topics for investigation and analyse results, there are no explicit references to the use of technology or how to achieve these objectives. However, the development of technology skills receives more focus in the specialised Physics (SMC) subject, which requires students to deal with analytical techniques using computers.

6. Effective collaboration and communication

Effective collaboration and communication skills are not included in the JHSC learning outcomes. While these skills may be used during scientific inquiry and experiments, there are no specific requirements in JHSC the learning outcomes.

7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science

This DP theme has a partial presence in the JHSC science learning outcomes. The explanation of the science objectives highlights aspects of the current global context, including the conservation of the natural environment and the growing role of science and technology. It emphasises that, to build a sustainable society that takes into account global issues, it is important for students to consider multiple perspectives and make evidence-based judgements. However, there is no explicit requirement for students to be aware of global issues, nor is there clear evidence that they need to consider the cultural, ethical and social impacts of science.

Other Themes in the JHSC

There are no significantly different themes or skills within the JHSC science learning outcomes which are not also present in DP science learning outcomes.

Summary

Among the DP science learning outcome themes, only developing skills for scientific investigation is well-evidenced in the JHSC science learning outcomes. Four other themes—conceptual understanding, methods and techniques that characterise science, critical thinking skills, and awareness of local and global problems—are partially present. However, two DP themes—the development of technological skills and the use of communication and

¹⁷² MEXT. (2018). *High School Course of Study. Science*. p 103.

collaboration—have little to no presence in the JHSC science learning outcomes. While these skills may be incorporated into science teaching and learning, they receive less emphasis in the JHSC science outcomes compared to the DP.

4.12.2 Content

This section compares and contrasts the content of the DP and JHSC falling within the category of chemistry. The content of the JHSC chemistry subjects is presented below in diagrams which show the key topics and subtopics included in each.

Figure 27: JHSC chemistry content visualiser.

General Subjects	Basic Chemistry	(1) Chemistry and human life	(a) Chemistry and matter	A. Chemical characteristics	B. Separation and purification of substances	C. Elements and compounds	D. Thermal motion and the three states of matter
		(2) The structure of matter	(a) The constituent particles of matter	A. Atomic structure	B. Electron configuration and periodic table		
			(b) Substances and chemical bonds	A. Ions and ionic bonds	B. Molecules and covalent bonds	C. Metals and metallic bonds	
		(3) Transformation of matter and its uses	(a) Amount of substance and chemical reaction formula	A. Amount of substance	B. Chemical reaction formula		
			(b) Chemical reactions	A. Acids, bases and neutralization			
			(c) Chemistry in the world	A. Chemistry opens a new world			
	Advanced Chemistry	(1) State of matter and equilibrium	(a) State of matter and its changes	A. State change	B. Properties of gas		
			(b) Solutions and equilibrium	A. Dissolution equilibrium	B. Solutions and their properties		
		(2) Change and equilibrium of substances	(a) Chemical reactions and energy	A. Chemical reactions and heat/light	B. Batteries	C. Electrolysis	
			(b) Chemical reactions and chemical equilibrium	A. Reaction rate	B. Chemical equilibrium and its shift	C. Ionization equilibrium	
		(3) Properties of inorganic substances	(a) Inorganic substances	A. Main group elements	B. Transition elements		
		(4) Properties of organic compounds	(a) Organic compounds	A. Hydrocarbons			
			(b) Polymer compounds	A. Synthetic polymer compounds	B. Natural polymer compounds		
		(5) The role of chemistry	(a) Chemistry in human life	A. Various substances and human life	B. Chemistry building the future		

Specialised Subjects	Chemistry for the Science and Mathematics Course	(1) Chemistry and human life	Refer to content in Basic Chemistry (Chemistry and human life). Contents will be expanded as necessary, e.g. green sustainable chemistry.
		(2) Material composition	Refer to content in Basic Chemistry (Structure of matter). These contents will be developed and expanded, for example, on electron orbitals and molecular shapes.
		(3) Changes in materials and their uses	Refer to content in Basic Chemistry (Transformation of matter and its uses) and Advanced Chemistry (Chemical reactions and energy). Content will be expanded as necessary, e.g. neutralization titration of a mixed solution may be considered.
		(4) State of matter and chemical equilibrium	Refer to content in Advanced Chemistry (State of matter and equilibrium and Chemical reactions and chemical equilibrium). Content will be expanded as necessary, e.g. consideration of the direction of reaction, considering enthalpy, entropy, and Gibbs energy, etc.
		(5) Properties of inorganic substances	Refer to content in Advanced Chemistry (Properties of inorganic substances). Content will be expanded as necessary, e.g. the electron configuration of transition metal ions.
		(6) Properties of organic compounds	Refer to content in Advanced Chemistry (Properties of organic substances). Content will be expanded as necessary, e.g. the study of substitution reactions and addition reactions focusing on electron transfer.
		(7) The role of chemistry	Refer to content in Advanced Chemistry (The role of chemistry). Content will be expanded as necessary, e.g. by researching new materials
	In addition, in the course of dealing with these topics, instrumental analysis and its principles and theories will also be covered.		

Structure

Like DP chemistry, the JHSC general subjects offer two levels of study, Basic Chemistry and Advanced Chemistry. Similar to how AHL content builds upon SL content, the Advanced Chemistry content builds on that of Basic Chemistry. However, Basic Chemistry has significantly lesser breadth and depth than SL. This reflects that Japan's upper secondary begins a year earlier and also requires students to study a wider range of science disciplines.

The JHSC specialised subjects do not offer different levels of study for chemistry. Instead, a single subject, Chemistry (SMC), is offered, which covers the content from both Basic Chemistry and Advanced Chemistry, with opportunities for further expansion.

The DP chemistry content is divided into two main areas: *Structure* and *Reactivity*. These are further split into three sections, each organised into several subtopics. In contrast, JHSC chemistry subjects are divided into between three and seven topics.

Content Alignment

The following table presents a simplified summary of the content alignment that JHSC chemistry has, at the topic-level, with DP chemistry (SL and AHL content). The analysis of JHSC Advanced Chemistry also considers the content that will have been studied in the pre-requisite subject, Basic Chemistry. Chemistry (SMC) encompasses the content from Advanced Chemistry (and Basic Chemistry) and expands it. An asterisk (*) indicates alignment exclusive to Chemistry (SMC).

Table 45: Summary of content alignment between the DP chemistry topics and the JHSC chemistry subjects.

DP chemistry topics	Presence of SL content in Advanced Chemistry/ Chemistry (SMC)	Presence of AHL content in Advanced Chemistry/ Chemistry (SMC)
Structure 1. Models of the particulate nature of matter		
Structure 1.1 – Introduction to the particulate nature of matter		N/A
Structure 1.2 – The nuclear atom		
Structure 1.3 – Electron configurations		
Structure 1.4 – Counting particles by mass: The mole		N/A
Structure 1.5 – Ideal gases		N/A
Structure 2. Models of bonding and structure		
Structure 2.1 – The ionic model		N/A
Structure 2.2 – The covalent model		
Structure 2.3 – The metallic model		
Structure 2.4 – From models to materials		
Structure 3. Classification of matter		
Structure 3.1 – The periodic table: Classification of elements		
Structure 3.2 – Functional groups: Classification of organic compounds		*
Reactivity 1. What drives chemical reactions?		
Reactivity 1.1 – Measuring enthalpy changes		N/A
Reactivity 1.2 – Energy cycles in reactions		
Reactivity 1.3 – Energy from fuels		N/A

DP chemistry topics	Presence of SL content in Advanced Chemistry/ Chemistry (SMC)	Presence of AHL content in Advanced Chemistry/ Chemistry (SMC)
Reactivity 1.4 – Entropy and spontaneity (AHL only)	N/A	*
Reactivity 2. How much, how fast and how far?		
Reactivity 2.1 – How much? The amount of chemical change		N/A
Reactivity 2.2 – How fast? The rate of chemical change		
Reactivity 2.3 – How far? The extent of chemical change		
Reactivity 3. What are the mechanisms of chemical change?		
Reactivity 3.1 – Proton transfer reactions		
Reactivity 3.2 – Electron transfer reactions		
Reactivity 3.3 – Electron sharing reactions		N/A
Reactivity 3.4 – Electron-pair sharing reactions		
Experimental programme		

Key:

<i>Strong presence of this topic in the JHSC.</i>	<i>Partial presence of this topic in the JHSC.</i>	<i>Little or no presence of this topic in the JHSC.</i>	N/A	<i>This topic does not exist at the respective level.</i>
*Content is only in the specialised subject, Chemistry (SMC).				

Overall, the JHSC chemistry content has reasonable alignment with the SL content in DP chemistry. Indeed, JHSC chemistry has strong or partial alignment with the SL content of most topics across *Structure* and *Reactivity*. Thus, the breadth of study of DP chemistry at SL and JHSC Advanced Chemistry is similar. JHSC chemistry content has the strongest alignment with the topic *Structure 1. Models of the particulate nature of matter*, followed by *Structure 2. Models of bonding and structure*. In addition, the emphasis in the JHSC on scientific investigation results in a strong alignment with the DP's experimental programme at SL. Practical work, inquiry, and consideration of problems are all present in JHSC chemistry, though it can be noted that there is no evidence of a collaborative project.

The JHSC chemistry content has the least alignment with *Reactivity 3. What are the mechanisms of chemical change?* Moreover, most alignments that JHSC chemistry has with SL content are partial, rather than strong. This is due to JHSC chemistry not necessarily covering all the SL concepts in these topics and subtopics. For example, with regards to *Structure 2.3 – The metallic model*, JHSC chemistry covers a topic on metallic bonds, though does not include understandings about their strength. JHSC chemistry generally has little to no alignment with AHL content in DP chemistry.

However, content can be developed and expanded in the specialised subject, JHSC Chemistry (SMC). Only a few examples of this extended content are given, such as entropy and Gibbs' energy, substitution and addition reactions, and instrumental analysis. Therefore, JHSC Chemistry (SMC) has the potential to offer greater breadth and depth than JHSC Advanced Chemistry and align more closely with DP chemistry content. However, the extent of this cannot be confirmed and may vary depending on the students taking the subject.

As shown in table 27 below, there is some content covered in JHSC chemistry which is not present in DP chemistry. This includes some different content covered such as dissolution equilibrium, colloidal solutions, electrolysis, polymer compounds, as well a topic dedicated to exploring real-world applications of chemistry. Although DP chemistry encourages links to real-world contexts in chemistry, it is not an isolated topic.

Table 46: JHSC chemistry content which is not covered in the DP.

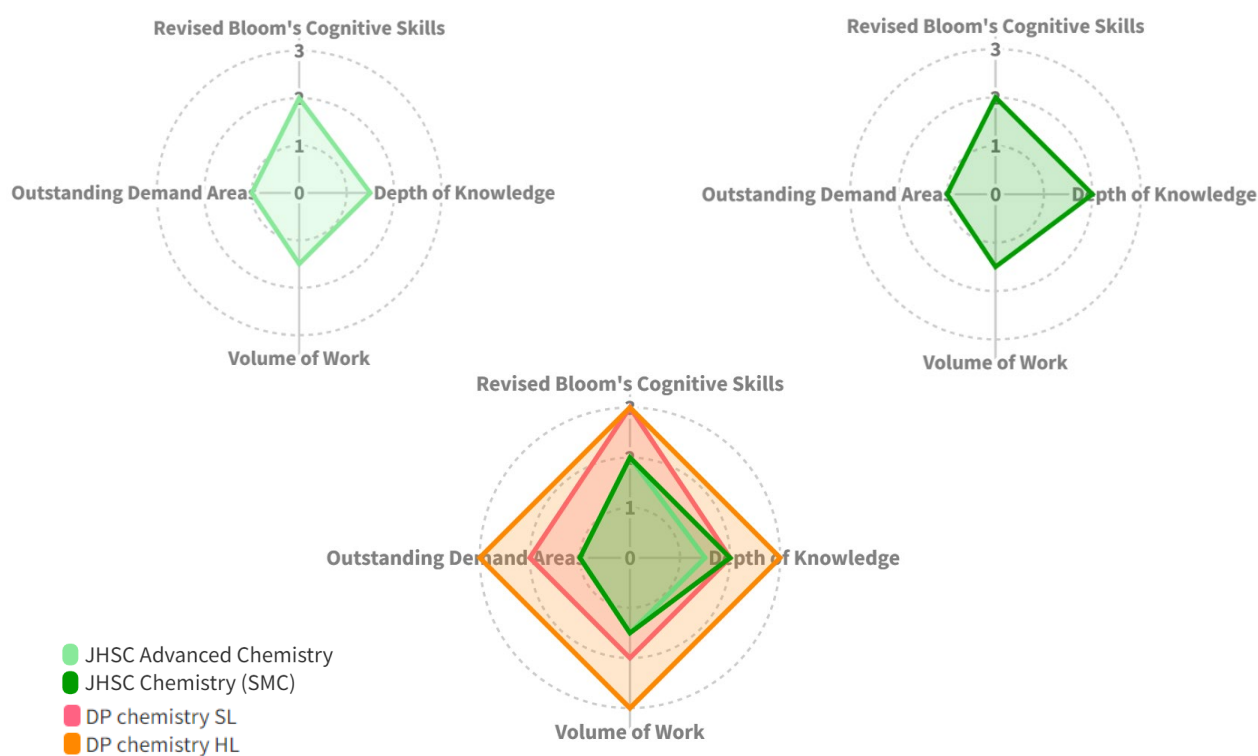
Significant JHSC chemistry content which is not included in the DP
- Dissolution equilibrium, solubility of gases and Henry's law - Colloidal solutions – Tyndall effect, Brownian motion, dialysis and electrophoresis - Faraday's law (Electrolysis) - Resins and monosaccharides (Polymer compounds) - The role of chemistry topic

Overall, students studying Advanced Chemistry will cover a similar breadth of content to DP chemistry at SL, though likely with somewhat less depth. Chemistry (SMC) covers the same content as the general subjects while allowing opportunity for expansion. Hence, it may offer greater breadth and depth and align more closely with DP chemistry content. However, the volume of content and extent of alignment cannot be confirmed and are likely to vary.

4.12.3 Demand

The DP and JHSC chemistry subjects were analysed using the same demand tool in order to create a demand profile for DP chemistry SL, DP chemistry HL, JHSC Advanced Chemistry, and JHSC Chemistry (SMC). These demand profiles are presented below in the form of radar diagrams, with the last diagram showing all profiles superimposed in one place, enabling immediate visual comparison.

Figure 28: Visual representations of subject demand.



The panel of experts carried out a detailed analysis of each course and reached a consensus on the scores shown in the profiles above. The following points were particularly important within the panel discussion:

- Regarding the scores for **Bloom's Cognitive Skills**:
 - DP chemistry SL and HL received a score of 3.
 - Advanced Chemistry and Chemistry (SMC) both received a score of 2. While there was evidence of higher-order thinking skills, particularly in the context of conducting scientific experiments, the emphasis was on analysis, rather than evaluation and synthesis. As a result, a score of 2, rather than 3, was deemed appropriate.
- Regarding the score for **Depth of Knowledge**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a score of 3.
 - Advanced Chemistry received a score of 1.5. While some of the activities outlined for the subject demonstrated strategic thinking, the depth of the content covered was not sufficient to merit a score of 2, thus Advanced Chemistry was assigned a score of 1.5. Chemistry (SMC) received a score of 2, based on the assumption that the content of Advanced Chemistry would be extended.
- Regarding the scores for **Volume of Work**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a score of 3.
 - Both Advanced Chemistry and Chemistry (SMC) received a score of 1.5. Advanced Chemistry covers a breadth of content, with the majority of time spent on topics of basic depth. However, it was judged that there were more instances of depth in its content compared to the other sciences, resulting in a score of 1.5. Chemistry (SMC) also received a score of 1.5, as there was not enough evidence to indicate that the volume of work would be moderate-heavy. However, the score is an estimate, as the extent of additional content in specialised subjects is not defined, and schools have the flexibility to determine the number of credits for the subject.
- Regarding the scores for **Outstanding Areas of Subject Demand**:
 - DP chemistry SL received a score of 2 and DP chemistry HL received a score of 3.
 - Both Advanced Chemistry and Chemistry (SMC) received a score of 1. The emphasis on project-based learning and exploration of real-world applications of chemistry were considered sufficient to justify a score of 1.

5. Key Findings

This section summarises the alignment and main similarities and differences found between the DP and the comparison subjects of each of the eleven comparison programmes in this study.

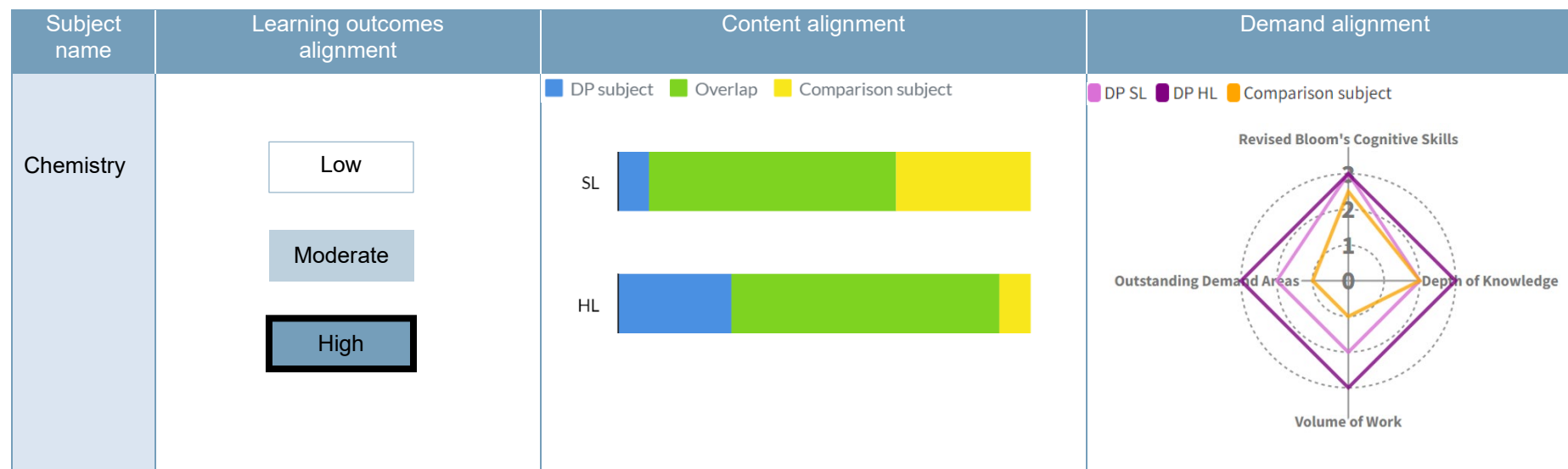
Key:

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
Displays the name of the comparison subject	Low Moderate High This represents the learning outcome alignment between the DP subject and the comparison subject. A black border is placed around the selected judgement – 'Moderate' in this example.	■ DP subject ■ Overlap ■ Comparison subject SL HL These bars represent the content alignment between the DP subject and the comparison. There is one bar showing alignment with SL content and another for HL content (inclusive of SL content). The green section of the bar represents the overlap of content between the subjects. The blue section represents content which was in the DP subject only. The yellow section represents content which was in the comparison subject only. Therefore, if, say, the blue section was longer than the yellow, this can be interpreted as DP subject having more content unique to itself than the comparison did. A large green bar would indicate that a substantial proportion of content overlaps between the DP and the comparison subject.	■ SL ■ HL ■ Comparison This radar diagram displays the demand judgement scores for the comparison subject(s) and the DP subject – both SL and HL.

5.1 Australia (Victoria)

The subject level alignment between the DP and VCE chemistry subjects is represented below:

Figure 29: Visual representations of subject-level alignment (chemistry subjects)



- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP and VCE chemistry is high, with most themes extracted from the DP learning outcomes being present in the VCE's learning outcomes. Indeed, the learning outcomes of VCE chemistry similarly focus on developing skills of scientific inquiry, technological skills, application, creative and critical thinking, awareness of global issues, environmental and societal implications. However, development of conceptual understanding is only an implicit theme in the learning outcomes of VCE chemistry, rather than explicit.
- **Content alignment:** there is significant content overlap between VCE and DP chemistry, for both SL and HL. Compared to SL, VCE chemistry covers a higher number of sub-topics, as it includes some content found in the DP chemistry HL but not in the SL, as well as additional sub-topics unique to VCE chemistry (i.e. not found in either the DP HL or SL). Conversely, the DP chemistry HL as a whole features more content than the VCE, as it includes a high proportion of HL-only content that is not present in the latter.
- **Demand alignment:** the VCE chemistry course is closer to the DP SL in demand level, though the latter scores higher for volume of work and number of stretch areas. The DP HL course scores significantly higher than VCE chemistry, scoring higher for depth of knowledge, volume of work, and stretch areas

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** the learning outcome themes extracted from DP chemistry are strongly present in VCE chemistry, with exception of conceptual understanding and making connections which is implicitly present, rather than explicitly. There is also a high degree of alignment regarding the emphasis given to each of these themes – VCE similarly emphasises application of skills and knowledge, scientific inquiry, creative and critical thinking, development of technological skills, awareness of global issues and environmental and societal implications, and communication and collaboration skills.
- **Similarities in content:** the majority of DP SL chemistry topic areas are covered in VCE chemistry, with shared coverage being especially evident in relation to the topics within 'Structure' content. Such topics include all those in 'Structure 2. Models of bonding and structure', 'Structure 3. Classification of matter', 'Reactivity 2. How much, how fast, how far?', 'Reactivity 3.1 – Proton transfer reactions', 'Reactivity 3.2 – Electron transfer reactions' and nearly all in 'Reactivity 1. What drives chemical reaction?' and 'Structure 1. Models of the particulate nature of matter'. Therefore, VCE chemistry shares a large proportion of content with DP SL, but somewhat exceeds the latter's depth in certain topics. Moreover, VCE chemistry also covers a few areas of AHL content, mostly within 'Structure', including similar coverage of classification of elements and classification of organic compounds. Practical activities, individual investigation and project work are also covered in both the DP and VCE content throughout the course of study.

- **Similarities in demand:** from a demand perspective, the VCE chemistry curriculum is closer to the DP chemistry SL course than the DP chemistry HL course, with the demand level of the HL being significantly higher. In particular, the VCE chemistry's scores for the Bloom's and depth of knowledge demand categories broadly align with DP SL.

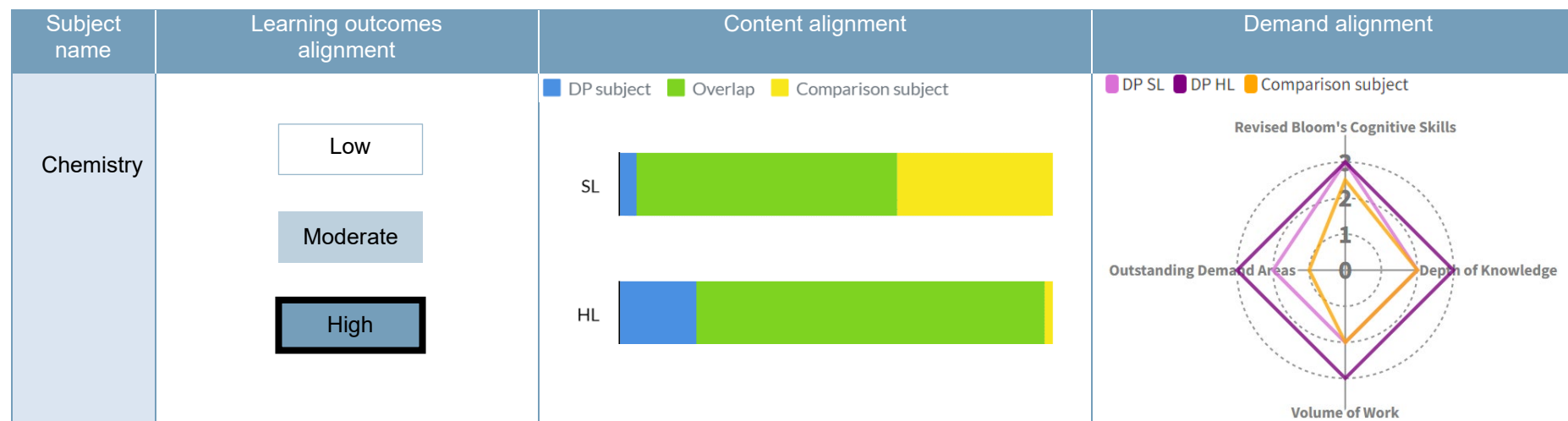
The **key differences** identified were the following:

- **Differences in learning outcomes:** there are only a few differences of note. Firstly, VCE chemistry has less focus than the DP on conceptual understanding, as this is implied through other expectations rather than explicitly stated. Also, VCE chemistry includes statements about the types of attitudes and values it aims to develop within students during their studies of chemistry, which are reflected in the IB learner profile rather than the DP's specific aims for the sciences subject group.
- **Differences in content:** despite VCE chemistry covering most SL content, there is considerably less coverage of AHL content. Indeed, there is mostly no alignment with AHL content in 'Reactivity' topics, such as proton transfer reactions, entropy and spontaneity, energy cycles in reactions, rate of chemical change, and the extent of chemical change. Therefore, VCE chemistry has less depth in certain topics than DP HL. Furthermore, some topics can also be found in the VCE chemistry course which are not present in DP chemistry, including Faraday's law calculations, Carbon 13 nuclear magnetic resonance (NMR), properties and analysis of water, key food molecules, and metabolism in the human body. There are also structural dissimilarities, as where AHL content in the DP HL typically builds on SL content, in the VCE there is less progression in terms of content between units, with no prerequisite content from Unit 1 being required to take Units 2 and 3.
- **Differences in demand:** from a demand perspective, the VCE chemistry curriculum is closer to the DP chemistry SL course than the DP chemistry HL course, with the demand level of the HL being significantly higher. This is mainly due to the volume of work and outstanding demand areas scores – the DP chemistry HL has a significantly higher workload and number of stretch areas when compared to VCE chemistry.

5.2 Canada (Ontario)

The subject level alignment between the DP chemistry and OSSD chemistry is represented below:¹⁷³

Figure 30: Visual representations of subject-level alignment (chemistry)



DP SL

DP HL

Comparison subject

Revised Bloom's Cognitive Skills

Outstanding Demand Areas

Depth of Knowledge

Volume of Work

¹⁷³ For the purposes of simplicity, the summary visual includes the results from the comparison between the DP (SL and HL) and OSSD chemistry grades 11 and 12 combined. For specific information on the grade 11 course, refer back to section 5.

- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP and OSSD chemistry is judged to be high, as all themes extracted from the DP learning outcomes are present in the OSSD's learning outcomes. While there are some small differences in focus – for example, the OSSD emphasising knowledge of Canadian contributions to science and making less explicit reference to scientific communication than the DP – the level of overlap is, nevertheless, substantial.
- **Content alignment:** there is a large amount of topic and sub-topic overlap between DP and OSSD chemistry, for both SL and HL. DP SL has a small amount of content unique to itself, though the majority is shared with the OSSD. Compared to SL, OSSD chemistry contains more content unique to itself – these being sub-topics which are found in HL. Therefore, there is considerable alignment with DP HL chemistry overall, as a large proportion of AHL content is covered, as well as almost all SL content. However, the DP HL contains some additional content which is not in the OSSD.
- **Demand alignment:** OSSD chemistry has stronger alignment with the DP chemistry SL course, although it features fewer stretch areas than the latter. The DP HL significantly surpasses OSSD in demand level, featuring more stretch areas, greater depth of knowledge, and a higher volume of work.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** all seven general learning outcome themes extracted from DP chemistry are present to some extent in all Ontario chemistry courses. In terms of emphasis on those themes, the OSSD is especially similar in its focus on developing technology skills, developing understanding and making connections, awareness of issues and the impact of science on the environment and society, creativity and critical thinking, and skills of scientific inquiry.
- **Similarities in content:** OSSD chemistry, as a whole, encompasses nearly all DP SL content and covers a significant amount of AHL content, therefore there is large overlap with HL overall. Topics which are covered in a similar level of detail as DP HL include electron configurations, classification of elements, energy cycles in reactions, the extent of chemical change, proton transfer reactions, and electron transfer reactions. Generally, the OSSD covers chemistry topics in similar detail to that of DP HL, thus there is a high level of alignment between the two.
- **Similarities in demand:** the demand of OSSD courses varies significantly by grade (see key difference section below). Taken as a whole, the OSSD chemistry curriculum is closer to the DP chemistry SL course than the DP chemistry HL course, with the demand level of the HL being higher. In particular, the OSSD grade 12 chemistry scores for Bloom's, depth of knowledge and volume of work demand categories mostly align with DP chemistry SL.

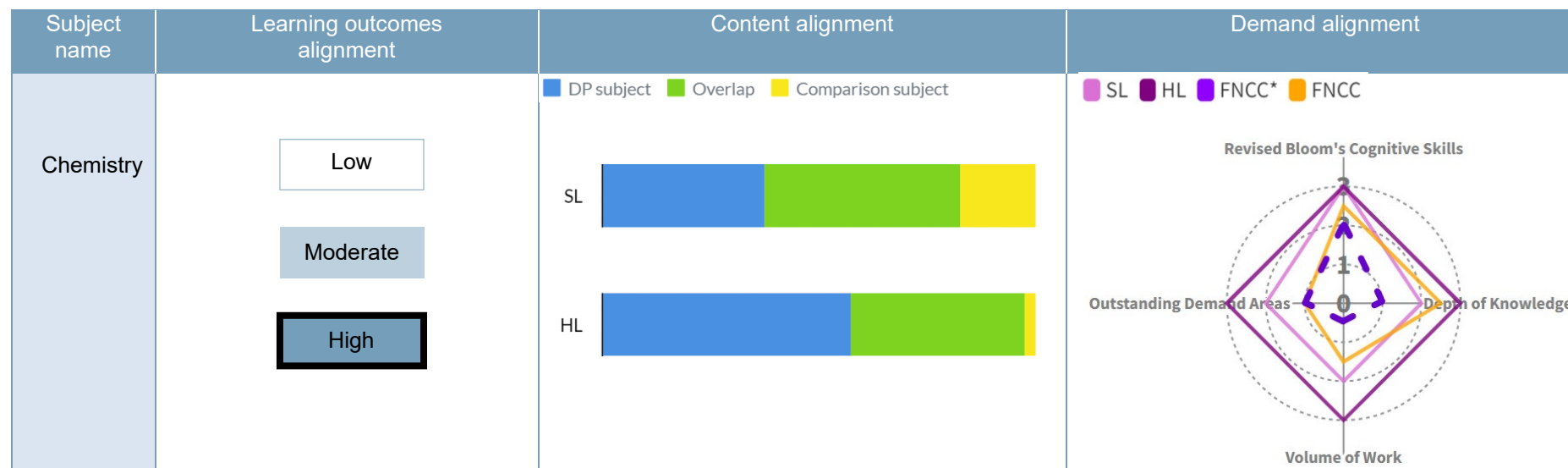
The **key differences** identified were the following:

- **Differences in learning outcomes:** whilst Ontario similarly sets general outcomes for all sciences through its key science skills and goals, the curricula also have specific 'overall expectations' for each individual course between grade 9 and 12. When these are used to add context to the goals, it consistently emerges that courses tend to have some learning outcome themes which are not present in the DP, including a focus on Canadians' contributions to science, the recognition of indigenous peoples' knowledge and customs, and an explicit expectation that students understand the careers that study of science can relate/lead to. Furthermore, the emphasis on each theme varies per grade – OSSD science grades 9 and 10 have a more substantial focus on knowledge and understanding, while grades 11 and 12 chemistry observe a similar level of emphasis on higher order thinking skills as the DP chemistry course.
- **Differences in content:** as with other science courses, one of the key differences between the OSSD and DP in relation to chemistry is that the OSSD programme includes two years of de-streamed general science before specialising in the third and fourth years. As a result, the grades 9-10 science curricula in Ontario have little in common with DP chemistry in terms of subject content, as only 25% of those courses are dedicated to chemistry. Taken as a whole, while there is generally a high level of alignment between DP chemistry HL and the OSSD chemistry curriculum, there are a few HL sub-topics included within the DP curriculum which are not in the OSSD. These include the covalent model, classification of organic compounds, entropy and spontaneity, and the rate of chemical change.
- **Differences in demand:** the demand of OSSD courses varies significantly by grade, with science grades 9 and 10 observing, expectedly, low scores for demand across all categories, and grades 11 and 12 chemistry observing more similar scores to those of the DP chemistry SL and HL courses. Taken as a whole, the OSSD chemistry curriculum is closer to the DP chemistry SL course than the DP chemistry HL course, with the demand level of the HL being higher. This is mainly due to the outstanding demand areas score – the DP chemistry HL has a significantly higher number of stretch areas when compared to the OSSD courses.

5.3 Finland

The subject-level alignment between the DP chemistry and FNCC chemistry is represented below:

Figure 31: Visual representations of subject-level alignment (chemistry)



NB: For demand, the FNCC* refers to compulsory modules only, while FNCC represents the full FNCC chemistry curriculum, including both compulsory modules and the additional optional modules combined.

- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP and FNCC chemistry is significant, with all themes extracted from the DP learning outcomes being present in the FNCC's learning outcomes.
- **Content alignment:** there is a reasonable amount of content overlap between the DP and FNCC chemistry, with the latter containing a mixture of SL and HL sub-topics. However, the FNCC describes the content coverage of these topics in far lesser detail than the DP, resulting in some 'partial' rather than 'full' sub-topic alignments, especially for HL sub-topics. This is true also for alignment with the DP's experimental programme, with the FNCC only including limited detail on practical experiments and scientific inquiry. Though the FNCC has some level of alignment with several DP sub-topics, a significant amount of SL and HL content is absent from the FNCC, especially within the sub-topics from Reactivity 3. What are the mechanisms of chemical change?. The fact that only some SL and HL sub-topics are clearly included in the FNCC subjects results in relatively limited content alignment between the DP and the FNCC. Overall, the documented volume of FNCC content is exceeded by DP HL, which has greater breadth and depth than the former. However, FNCC chemistry content appears to be of a similar size to that of DP SL, provided that both compulsory and optional modules are studied.
- **Demand alignment:** the demand of FNCC chemistry varies depending on how many modules within this subject are taken. When considering only the compulsory modules, the demand of FNCC chemistry is surpassed in all categories by both SL and HL. When taking into account all modules (both compulsory and national optional modules), FNCC chemistry scores comparably to DP SL, scoring the same or similar in all categories.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** FNCC chemistry covers all learning outcome themes extracted from the DP, though some are more emphasised than others. Many are found within the 'task of the subject' and the 'transversal competences' sections of the curriculum. The FNCC chemistry places particular importance on the awareness of local and global problems, and creativity and critical thinking.
- **Similarities in content:** for both SL and AHL, there are some overlaps in subject content with the FNCC chemistry curriculum. A reasonable number of SL topics are covered in the FNCC chemistry, particularly Structure 1. Models of the particulate nature of matter and Structure 2. Models of bonding and structure, whereas the FNCC only partially covers the content in the SL topic of Structure 3. Classification of matter. The FNCC also has some alignment with AHL content, having strong alignment for Structure 2.4. - From models to materials, and partial alignment in several other topics.
- **Similarities in demand:** when all modules (both compulsory and optional) of the FNCC chemistry syllabus are considered, there is reasonable alignment with the demand of the DP SL. Indeed, the overall FNCC chemistry syllabus scores similarly to DP SL for Bloom's cognitive skills, depth of knowledge, and volume of work.

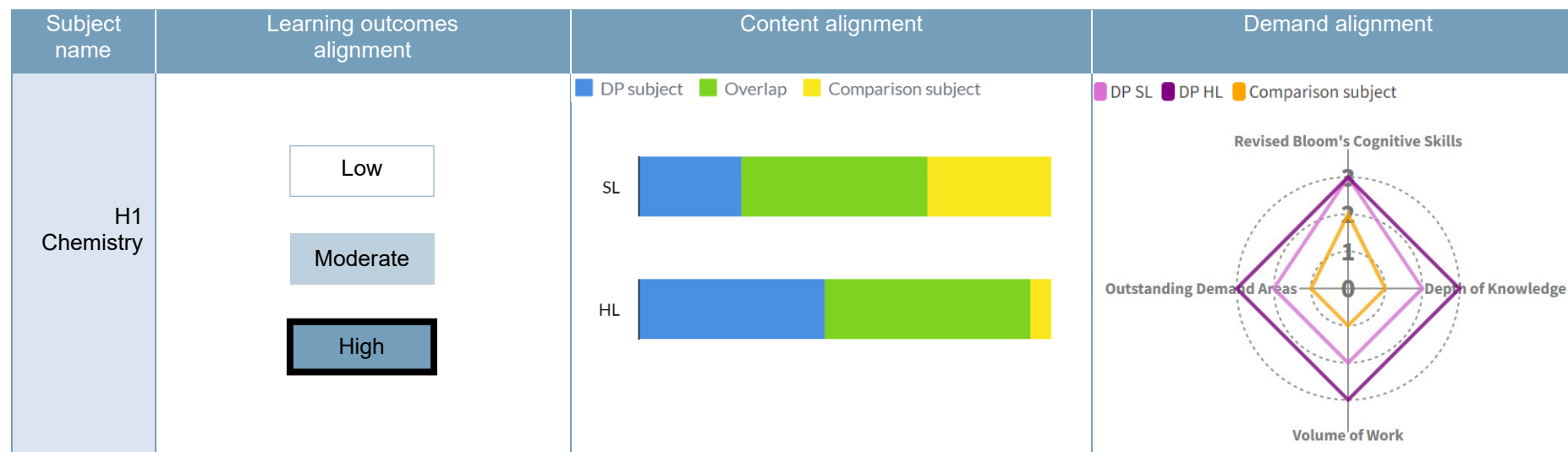
The **key differences** identified were the following:

- **Differences in learning outcomes:** the themes of applying necessary skills to carry out investigations and demonstrating knowledge that categorises science are not emphasised within the FNCC learning outcomes as extensively as in the DP. Instead, the FNCC learning outcomes are more centred around students developing skills that help them appreciate the impact of their every-day choices and take responsibility for their own actions.
- **Differences in content:** with the exception of Structure 3. Classification of matter, there are a number of sub-topics within all other SL topics which are not covered in the FNCC. Additionally, the FNCC also does not cover a number of AHL sub-topics, showing particularly low alignment with those within Structure 2. Models of bonding and structure and Reactivity 3. What are the mechanisms of chemical change?. Overall, based on the information available in the FNCC documentation, the FNCC chemistry curriculum is not as broad or as deep as the DP (though schools may go beyond this in practice).
- **Differences in demand:** the FNCC compulsory chemistry course scores lower in all categories than the DP SL and HL chemistry. The FNCC compulsory and optional chemistry combined scored less than HL in all categories, reflecting limited alignment with the demand of DP HL overall. The most significant difference in scores came from the outstanding areas of subject demand category, with the FNCC scoring notably less than both SL and HL.

5.4 Singapore

The subject level alignment between the DP chemistry and SGA chemistry is represented below:

Figure 32: Visual representations of subject-level alignment (chemistry)



Subject name	Learning outcomes alignment	Content alignment	Demand alignment
H2 Chemistry	Low Moderate High	DP subjectOverlapComparison subject SL HL	DP SLDP HLComparison subject Revised Bloom's Cognitive Skills Outstanding Demand Areas Depth of Knowledge Volume of Work
H3 Chemistry	Low Moderate High	DP subjectOverlapComparison subject SL HL	DP SLDP HLComparison subject Revised Bloom's Cognitive Skills Outstanding Demand Areas Depth of Knowledge Volume of Work

DP SL

DP HL

Comparison subject

Revised Bloom's Cognitive Skills

2

1

0

Outstanding Demand Areas

Depth of Knowledge

Volume of Work

- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP and SGA chemistry is significant, with nearly all themes extracted from the DP learning outcomes being present in the SGA's learning outcomes.
- **Content alignment:** there is a large amount of overlapping chemistry content between the DP and SGA curricula. H1 includes a significant amount of SL content and is comparable in breadth and depth. H2 covers nearly all SL and HL sub-topics; therefore, there is a high level of alignment and comparability in breadth and depth of study when H2 is studied. Though H3 chemistry covers a few more details from DP HL, alignment overall slightly decreases as H3 covers some topics that are not present in the DP. Finally, the SGA subjects have alignment with the DP's experimental programme, as practical work and scientific inquiry are featured in all of them.
- **Demand alignment:** H1 is surpassed in all demand categories by both SL and HL, whereas H2 and H3 score similarly to DP SL and DP HL, respectively.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** each SGA chemistry subject available in Singapore covers most of the DP themes. Conceptual understanding, techniques that characterise science and an awareness of local and global problems are strongly emphasised within chemistry in both programmes. Like the DP, the SGA also places importance on creativity and critical thinking and skills for scientific inquiry within its learning outcomes.
- **Similarities in content:** there is significant content overlap between the SGA and the DP chemistry curriculum. H1 includes many of the same topics as SL, as well as a small amount of HL content. Though H1 does not cover all SL areas, and covers some areas in lesser detail, the inclusion of some HL content and sub-topics not found in the DP means that overall it has comparable breadth and depth to DP SL. H2 has very strong alignment with DP HL, sharing most of its content with the latter; thus, the subjects have comparable breadth and depth. H3 includes one or two further HL sub-topics from the DP, plus some sub-topics which are not in the DP. Notably, every Structure and Reactivity sub-topic, both SL and HL, is covered to some extent in the SGA chemistry curriculum, resulting in a high level of content alignment overall.
- **Similarities in demand:** the scores for the presence of higher-order cognitive skills (taken from Bloom's Revised Taxonomy) are the same for the DP and H3 chemistry, as the subjects place similar emphasis on analysis, evaluation, and creation in their learning outcomes. H2 chemistry also has the same scores as the DP SL content for depth knowledge of knowledge and volume of work, thus is of a similar demand level to the DP SL overall. As well as Bloom's, H3 has the same scores as HL in two additional categories: depth of knowledge and volume of work, thus aligning well with DP HL.

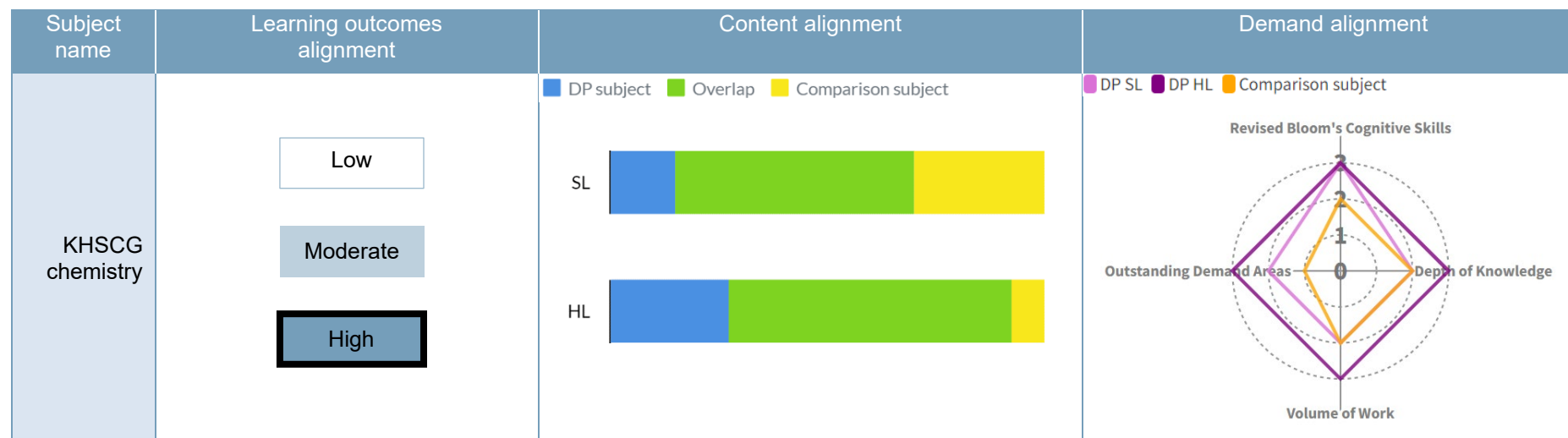
The **key differences** identified were the following:

- **Differences in learning outcomes:** there is a distinct absence of the development of technology skills; this DP theme is not found within any area of the SGA chemistry outcomes. Furthermore, collaboration has less emphasis in the SGA than the DP.
- **Differences in content:** though H1 has similar breadth and depth to the DP SL, it does not share content with the SL topics of Structure 1.5 – Ideal gases, Structure 1.3 – Energy from fuels, Reactivity 3.2 – Electron transfer reactions and 3.3 – Electron sharing reactions. A few sub-topics are also absent from H2 and H3; however, the amount of absent DP content is small. Furthermore, all SGA subjects contain some sub-topics which are not in the DP, such as nanomaterials (H1), elimination (all), and molecular stereochemistry (H3).
- **Differences in demand:** H1 is surpassed by DP SL and HL for all demand categories, hence has low alignment in terms of demand. H2 chemistry has a slightly lower score for the presence of higher order thinking skills and does not match the DP HL in any other categories. All three SGA chemistry subjects have fewer outstanding demand areas than the DP and therefore score consistently less in this category.

5.5 South Korea

The subject level alignment between the DP chemistry and KHSCG chemistry is represented below: ¹⁷⁴

Figure 33: Visual representations of subject-level alignment (chemistry)



¹⁷⁴ The summary visual shows the results from the comparison between the DP (SL and HL) and KHSCG Chemistry I and Chemistry II combined.

- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP and KHSCG chemistry is significant, with all themes extracted from the DP learning outcomes being present in the KHSCG's learning outcomes.
- **Content alignment:** there is a significant amount of content overlap between DP and KHSCG chemistry. Aside from a few sub-topics, most of the DP SL and HL content, including features of the experimental programme, can be found in the KHSCG curricula. That said, it can be noted that some of these alignments are only 'partial' due to KHSCG not covering the sub-topics in the same level of detail as the DP. Overall, there is considerable alignment between the topic coverage of KHSCG and the DP SL and HL, though HL covers a number of topics in greater depth.
- **Demand alignment:** the demand level of KHSCG chemistry is more closely aligned with that of DP SL, with the former scoring the same for depth of knowledge and volume of work, though slightly less for Bloom's cognitive skills and outstanding areas of demand. The level of alignment of the KHSCG with DP HL is lower, as DP HL chemistry scores higher in all demand categories.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** there is a high level of alignment between the learning outcomes of DP chemistry and those of KHSCG chemistry, with all themes extracted from the DP being strongly evidenced in the KHSCG. The KHSCG curriculum similarly aims to create well-rounded, curious students who have an appreciation for science and its place in the world. Specifically, the KHSCG also aims to develop conceptual understanding, application, skills for scientific inquiry, technological skills, communication and collaboration, creativity and critical thinking, and awareness of global and local problems and the impact of science.
- **Similarities in content:** there is a large amount of overlapping content between the DP and KHSCG chemistry. Most of the DP SL and HL topics, as well as features of the experimental programmes, can be identified in the KHSCG, and conversely the majority of KHSCG topics are covered by the DP. Notably, alignment levels between the KHSCG and DP are higher when comparing KHSCG against SL, and more limited when comparing against HL.
- **Similarities in demand:** KHSCG scores the same as DP SL for depth of knowledge and volume of work and is generally more aligned with SL than HL for demand.

The **key differences** identified were the following:

- **Differences in learning outcomes:** no significant differences in learning outcomes were found.
- **Differences in content:** there are two sub-topics (Structure 3.2 – Functional groups: Organic compounds, and Reactivity 3.4 – Electron-pair reactions) with which the KHSCG curriculum shows no alignment at either SL or HL. Additionally, the KHSCG

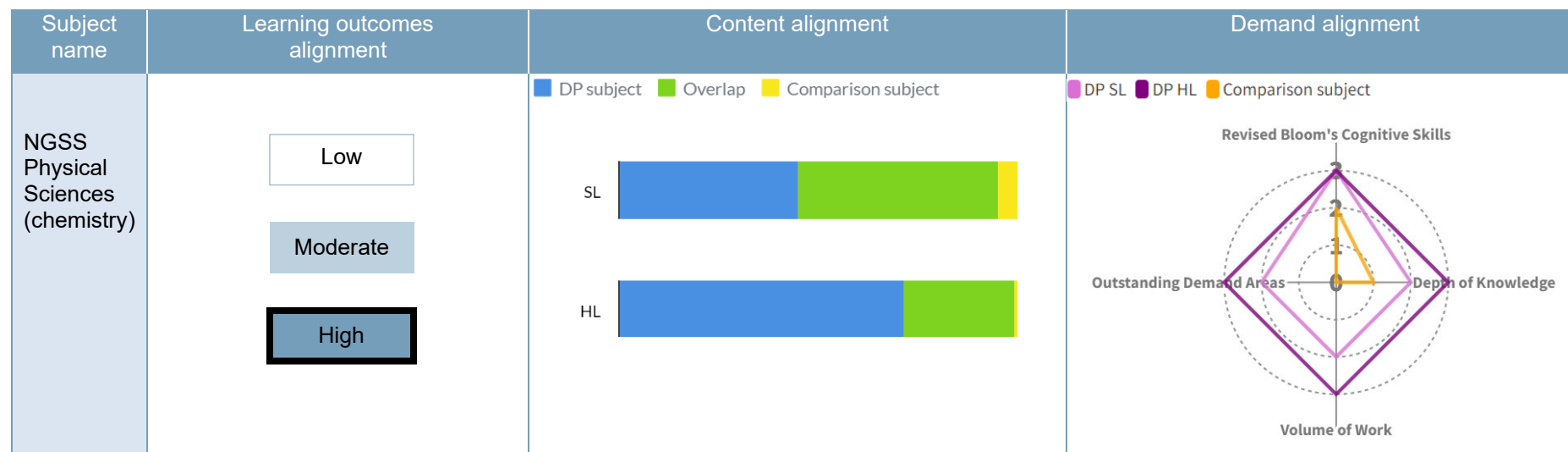
also shows no alignment at HL with the DP sub-topic structure 2.3 – The metallic model, despite being highly aligned at SL. Moreover, the general theme of highlighting the ‘real-life’ importance of chemical concepts and applications is more explicitly stated in the KHSCG syllabus with relation to the use of buffers in vitro, fermentation and catalysts in industry. Furthermore, whilst the content of KHSCG surpasses SL in breadth, it covers less content overall than DP HL chemistry.

- **Differences in demand:** KHSCG chemistry scores lower than DP HL for all demand categories and scores less than DP SL for Bloom's cognitive skills and outstanding demand areas.

5.6 United States (NGSS)

The subject level alignment between the DP chemistry and the NGSS is represented below:

Figure 34: Visual representations of subject-level alignment (chemistry subjects)



- **Learning outcomes alignment:** the level of alignment between the learning outcomes of the DP chemistry course and those of the NGSS physical sciences is high, with most themes extracted from the DP learning outcomes being present in the NGSS's learning outcomes. Indeed, the NGSS also demonstrate a focus on scientific inquiry, critical thinking skills, and communication. However, there are slight differences with regards to the emphasis of certain themes, with the NGSS having a lesser focus on scientific implications and conceptual understanding and a greater focus on use of models and computational thinking.
- **Content alignment:** while there is some topic and sub-topic overlap between the NGSS and the DP chemistry SL, very limited alignment exists between the NGSS and the topics and sub-topics covered uniquely at HL. As to content depth and level of detail covered, this is considerably higher in both DP chemistry SL and HL than in the NGSS, with both having a considerable amount of additional content which is not present in the NGSS.
- **Demand alignment:** both the DP chemistry SL and HL considerably surpass the NGSS in demand level. The NGSS score lower in all categories, with particularly strong differences in outstanding areas of demand and volume of work. The NGSS do, however, score more closely with the DP on cognitive skills, as there is evidence of some higher-order thinking such as analysis.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** the majority of learning outcome themes extracted from DP chemistry are present to some extent in the NGSS, with similar coverage of acquisition and application of knowledge of ideas, theories and concepts in chemistry, creative and critical thinking skills, investigation skills, use of technology, and effective communication and collaboration.
- **Similarities in content:** the depth and breadth of content for chemistry in the DP, both at SL and HL, significantly exceed that of the chemistry topics in NGSS physical sciences. However, there is some coverage of key fundamental topic areas featured in the DP SL course, including periodicity, the mole concept, bonding, rates of reaction and the nuclear atom. Moreover, both the NGSS and the DP have somewhat flexible structures, in that neither specifies a specific order for topics to be studied in, and both allow for practical demonstrations, modelling, and links to real world scenarios.
- **Similarities in demand:** both the DP and the NGSS show some evidence of higher-order thinking skills in their learning outcomes. However, while conceptual thought and critical thinking are predominant in the majority of the DP's course aims, reference to higher order thinking skills in the NGSS is limited.

The **key differences** identified were the following:

- **Differences in learning outcomes:** there are some evident differences in the extent of the coverage of the DP themes in comparison with the NGSS physical sciences.

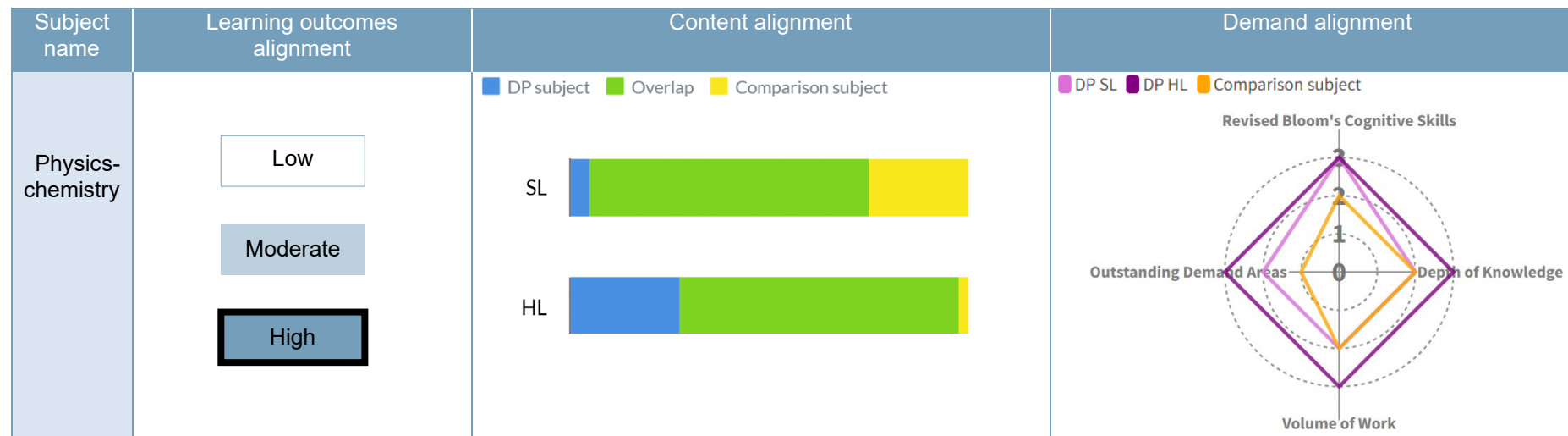
Development of conceptual understanding is not referenced in the NGSS and consideration of ethical, social, environmental, and cultural implications of science is only present in a limited number of performance expectations. Additionally, a couple of outcome themes receive greater emphasis in the NGSS when compared to the DP, namely the larger emphasis on the ability to use computational thinking and on understanding and applying scientific models.

- **Differences in content:** the depth and breadth of content for chemistry in the DP, both at SL and HL, considerably exceed that of the chemistry topics in the NGSS physical sciences. The NGSS coverage of chemistry is significantly narrower and there is no reference to the majority of HL content in the NGSS content areas, while many SL sub-topics, such as electron configurations, ideal gases, classification of organic compounds, proton transfer, electron sharing, and transfer reactions, are also absent.
- **Differences in demand:** from a demand perspective, it is hard to gauge the real demand of the NGSS in practice, as each state is free to independently decide how to implement them. Working purely from the documentation, the NGSS have been judged to be of much lower demand than both the DP chemistry SL and HL courses across all demand categories considered (Bloom's cognitive skills, depth of knowledge, volume of work and outstanding demand areas).

5.7 France

The subject level alignment between the DP chemistry and FB chemistry is represented below:

Figure 35: Visual representations of subject-level alignment (chemistry)



*The yellow bar for FB physics-chemistry represents chemistry-only additional content, it does not represent the physics content.

- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP chemistry and FB physics-chemistry is significant, with all themes extracted from the DP learning outcomes being present, to some extent, in the FB's 'skills developed' or 'preamble'. While there are some small differences in focus – e.g. the FB making a more subtle reference to the development of technology skills – the level of overlap is, nevertheless, substantial.
- **Content alignment:** there is a large amount of topic and subtopic overlap between FB physics-chemistry and DP chemistry, both at SL and, to a lesser extent, HL. DP SL covers some topics that are not covered by the FB, though the majority of content is shared with FB physics-chemistry. Compared to SL, the DP HL features additional content that is not present in FB, though there is still a substantial amount of content overlap with FB physics-chemistry. Notably, there are no significant content areas covered by FB physics-chemistry which cannot be found in DP chemistry.
- **Demand alignment:** FB physics-chemistry has stronger alignment with the DP chemistry SL course, although it features fewer stretch areas than the latter. The DP SL and HL both surpass the FB physics-chemistry in demand level, with DP HL also featuring more stretch areas, greater depth of knowledge, and a higher volume of work than the latter.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** all the seven general learning outcome themes extracted from DP chemistry are present to some extent in all FB physics-chemistry documentation. In terms of emphasis on those themes, the FB is particularly well aligned with the DP on four of them: the use of knowledge, tools and techniques that categorise science, creativity and critical thinking, the skills to carry out investigations and collaboration and communication.
- **Similarities in content:** FB physics-chemistry contains some subtopics from each of the overarching topics covered by DP chemistry at SL. At topic level, the greatest level of alignment was seen in the DP's Structure 1, Structure 3 and Reactivity 2 topics, with the FB observing strong alignment with all subtopics within these. In regard to DP HL content, the FB showed at least partial alignment with all subtopics of the DP's Structure 2, Reactivity 2 and Reactivity 3 topics. FB physics-chemistry also shows a similar breadth of content as the DP SL chemistry.
- **Similarities in demand:** FB physics-chemistry curriculum received the same score as DP chemistry SL for depth of knowledge and volume of work, as both go into similar levels of depth and the amount of content students are expected to cover over the course of each subject amounting to a similar volume of work.

The **key differences** identified were the following:

- **Differences in learning outcomes:** FB physics-chemistry, whilst not highlighting this as a 'skill' per se, does emphasise the importance of students understanding and using

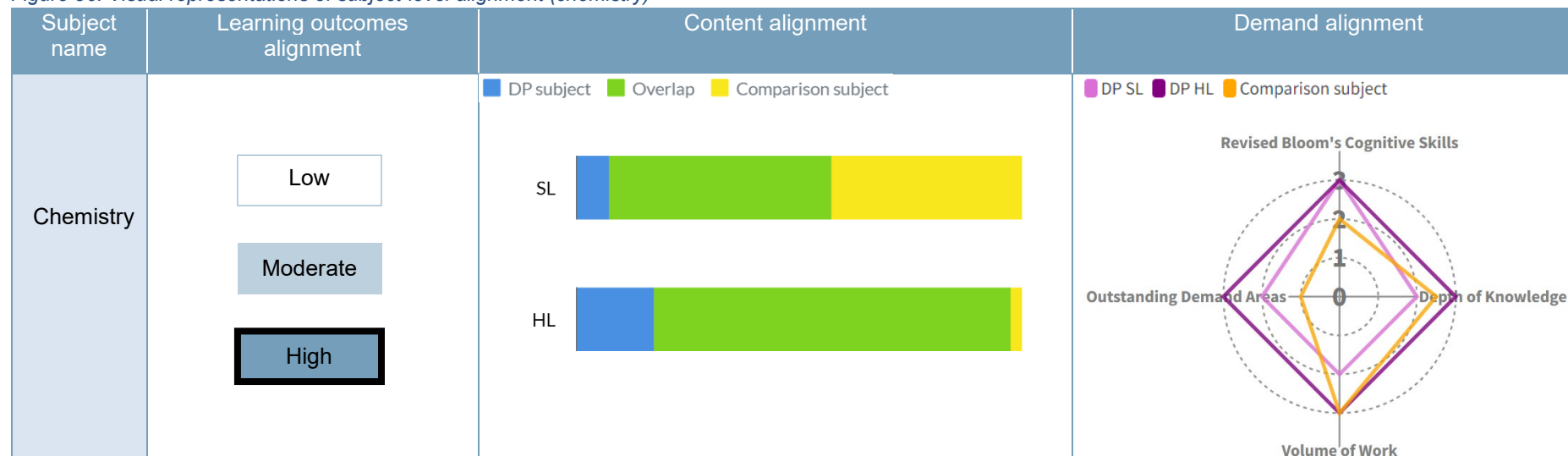
models. Modelling plays a pivotal role in students' education through the FB, with students being expected to be able to link models and theories with observations, facts, data and explanations. Whilst modelling is referenced in the DP chemistry course, it is not as prominent a feature as in FB physics-chemistry.

- **Differences in content:** the most notable difference between the DP and FB regarding their coverage of chemistry content is that chemistry in the FB is taught as part of the FB physics-chemistry combined course, whereas chemistry and physics are taught as separate subjects in the DP. The FB's combination of chemistry and physics results in the DP chemistry covering more chemistry content than FB physics-chemistry, with the latter failing to cover, for instance, alloys, Hess's law and free radical substitution. Additionally, DP AHL content not found in the FB includes: Structure 1.3, Reactivity 1.2 and Reactivity 1.4.
- **Differences in demand:** the demand of FB physics-chemistry is lower in most categories than that of DP chemistry, both at SL and HL. DP SL exceeds the FB in Bloom's cognitive skills and the areas of outstanding demand, while the DP HL exceeds the FB in all demand categories.

5.8 Spain

The subject level alignment between the DP chemistry and SB chemistry is represented below:

Figure 36: Visual representations of subject-level alignment (chemistry)



DP SL

DP HL

Comparison subject

Revised Bloom's Cognitive Skills

Outstanding Demand Areas

Depth of Knowledge

Volume of Work

- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP and SB chemistry is high, as all themes extracted from the DP learning outcomes are present to some extent in the SB's specific competences. There are some small differences in approach; for example, the SB places greater emphasis on the inter-connectedness of chemistry and physics, reflected in the combined teaching of these subjects in the first-year SB physics and chemistry course. The SB also places less focus than the DP on developing technological skills. Nevertheless, the level of overlap between the DP and SB is substantial.
- **Content alignment:** there is a large amount of topic and subtopic overlap between DP and SB chemistry. While alignment with the DP is more limited for the first-year SB physics and chemistry course – which is unsurprising given that the latter covers both physics and chemistry – there is a substantial degree of content alignment between the second-year SB chemistry and the DP, both at SL and HL.
- **Demand alignment:** SB chemistry aligns with DP HL with regards to depth of knowledge and volume of work, however, it is surpassed by both DP SL and HL for Bloom's cognitive skills and outstanding demand areas.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** all learning outcome themes from the DP are present in the SB specific competences. There is strong alignment between the DP and the SB regarding the themes of conceptual understanding and making connections, techniques that categorise science, and creativity and critical thinking. The 'collaboration' aspect of the DP learning outcome theme on collaboration and communication is very prevalent in the SB, as is the awareness of global problems in the context of the environment and sustainability.
- **Similarities in content:** there is some level of content alignment between the first-year SB physics and chemistry subject and DP chemistry, with the former covering eleven DP chemistry subtopics at SL, ten of which are covered to a similar breadth and level of detail. As to the SB chemistry subject, the latter covers the vast majority of DP subtopics at both SL and HL, many of which to a similar depth and level of detail.
- **Similarities in demand:** SB physics and chemistry received the same score as the DP SL chemistry in only one area: volume of work. The SB chemistry subject, in turn, scored the same or similarly to DP HL for depth of knowledge and volume of work.

The **key differences** identified were the following:

- **Differences in learning outcomes:** from the DP learning outcome themes, some are more emphasised in the SB than others. The SB features less focus than the DP on investigative skills and the development of technological skills. These are briefly mentioned or can be inferred from the SB's specific competences, but are less clearly defined than they are in the DP. Although 'collaboration' is heavily emphasised in the SB, the mention of the 'communication' component of this theme is much more subtle

than in the DP. Within the DP theme of awareness of global and local problems, although the global problems are strongly emphasised in the SB, there is less reference than in the DP to the ethical and cultural elements of this theme.

- **Differences in content:** although SB physics and chemistry has some alignment with the DP chemistry SL subject, ten DP SL subtopics were found to have little or no presence in SB physics and chemistry. SB chemistry also differs slightly from the DP in terms of depth of content covered. For example, unlike DP SL, SB does not cover the advantages and disadvantages of fossil fuels and biofuels, and free radical substitutions are also not referenced. The SB chemistry does not cover any large content that is not also found in the DP, though it does cover polymers in greater depth than the DP, by including their applications, properties and associated environmental risks.
- **Differences in demand:** SB physics and chemistry received lower scores than the DP SL, and therefore DP HL, for Bloom's cognitive skills, depth of knowledge and outstanding demand areas. SB chemistry exceeds the DP SL's scores in two categories (volume of work and depth of knowledge) but scored lower than both DP SL and HL for Bloom's cognitive skills and outstanding demand areas. This indicates that the DP, at both SL and HL, gives students the opportunity to develop a wider range of cognitive skills than the SB, and provides more opportunities to stretch and challenge students.

5.9 Brazil

The subject level alignment between DP chemistry (SL and HL) and BHSC Natural Sciences and Technology (NST) is represented below:

Figure 37: Visual representations of subject-level alignment (chemistry)



* Chemistry content was broadly described in the documentation for BHSC NST. As such, specific concepts mentioned in DP chemistry topics were often not identifiable. Where there was limited reference to specific concepts, but broader evidence of coverage, it was concluded that the DP topic/subtopic was 'partially present' in BHSC NST. Therefore, the actual level of alignment may be slightly stronger, or weaker, than what is presented in these key findings.

** BHSC NST (FI) here represents the pathway of studying chemistry in basic general education and then specialising in a NST formative itinerary. The learning outcomes and demand conclusions for this pathway consider the NST formative itinerary component as a whole, whereas the content judgements only consider its chemistry content specifically (physics and biology content is not included).

- **Learning outcomes alignment:** the level of alignment between the learning outcomes of DP sciences and BHSC NST is high. Indeed, all DP sciences learning outcome themes are represented either completely or partially in the BHSC NST. Specifically, the themes of applying the elements that characterise science, using creativity and critical thinking, developing technological skills, and being aware of the issues and impacts of science, are all evident in the learning outcomes for BHSC NST. The DP themes of developing conceptual understanding and making connections; and of collaboration and communication, are also partially evident.
- **Content alignment:** the significantly more limited detail in BHSC NST documentation regarding the chemistry content to be covered poses a challenge when ascertaining the level of content alignment with DP chemistry. Generally, the documentation reviewed indicates there is low-moderate content alignment between DP chemistry and BHSC NST, with the level of content alignment with DP chemistry being very similar for both BHSC NST (BGE) and BHSC NST (FI). DP SL content from most DP chemistry topics is partially present in BHSC NST, though there is little evidence of coverage of AHL chemistry content. Where found, DP topics tend to have a 'partial', rather than 'strong', presence in BHSC NST – partially due to the BHSC describing the content in far less detail than the DP chemistry guide. As less chemistry content appears to be present, BHSC NST (BGE) and BHSC NST (FI) are concluded to have less breadth and depth than DP chemistry SL and HL.
- **Demand alignment:** it can be noted that the demand scores for BHSC subjects are based on documentation which has somewhat limited detail regarding subject content. Generally, the documentation reviewed indicates that there is low-moderate alignment between the demand scores of DP chemistry and BHSC NST. Indeed, BHSC NST (BGE) scores lower than DP chemistry SL, whereas BHSC NST (FI) scores the same in most demand categories and is closely aligned with DP physics SL. The BHSC NST subjects do not align strongly with DP chemistry HL, as both BHSC NST (BGE) and BHSC NST (FI) have lower scores in most categories.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** the learning outcomes of BHSC NST have many similarities to those of DP sciences. BHSC NST similarly aims for students to use and apply knowledge and procedures typical of natural sciences (including scientific inquiry), use creativity and critical thinking, develop technological skills, and be aware of global and local problems and the impacts of science. Likewise, students are expected to develop conceptual understanding and communication skills which partially reflects the DP learning outcome themes of developing conceptual understanding and making connections, and of collaboration and communication.
- **Similarities in content:** SL content from most DP chemistry topics is partially present in BHSC NST (namely, from Structure 1. Models of the particulate nature of matter, Structure 2. Models of bonding and structure, Structure 3. Classification of matter, Reactivity 1. What drives chemical reactions?, and Reactivity 2. How much, how fast and how far?). Significantly, the documentation indicates that BHSC NST includes

some SL content from each of the sub-topics within these topics. Moreover, it can be noted that DP AHL content from sub-topic Reactivity 1.2 – Energy cycles in reactions is also partially present in BHSC NST. Lastly, it can be noted that BHSC NST includes practical work, thus partially aligning with the experimental programme in DP physics.

- **Similarities in demand:** BHSC NST (BGE) has the same demand score as DP chemistry SL for depth of knowledge. Generally, however, BHSC NST (FI) has stronger alignment with DP chemistry SL, as it receives the same scores for Bloom's cognitive skills, depth of knowledge, and outstanding demand areas. BHSC NST (FI) also shares the same score as DP chemistry HL for Bloom's cognitive skills.

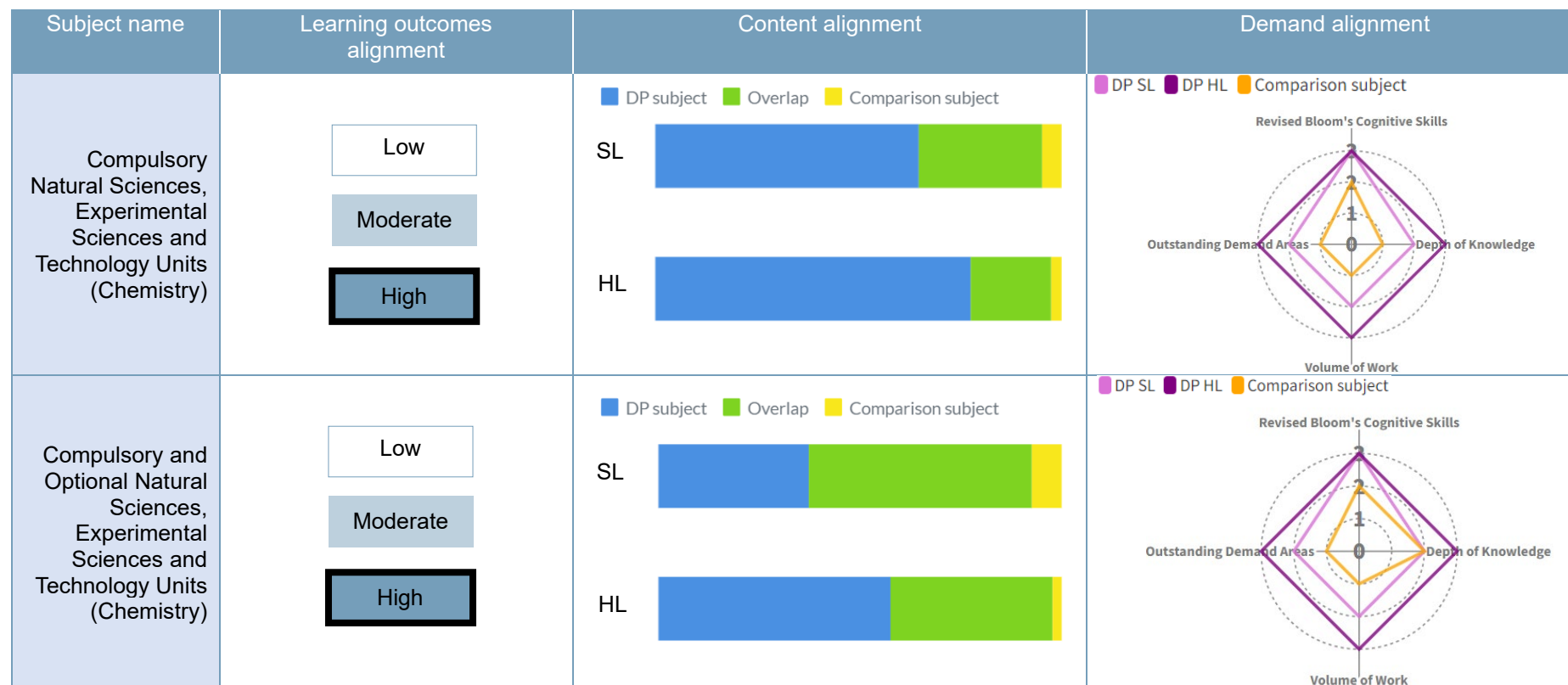
The **key differences** identified were the following:

- **Differences in learning outcomes:** The learning outcomes for BHSC NST place less emphasis on making connections between science subjects than the learning outcomes for DP sciences. Likewise, although BHSC NST learning outcomes require students to demonstrate respect and take part in group work, they make less explicit reference than the DP to the development of collaborative skills. Finally, DP sciences outline the specific experiments that students should conduct, whereas – although scientific investigation is present – there is limited mention of specific experiments within BHSC NST.
- **Differences in content:** Where alignments are found with DP chemistry topics, these tend to be partial, as opposed to strong – though this is sometimes due to the limited detail available in the BHSC NST documentation. Moreover, little DP SL content from Reactivity 3: What are the mechanisms of chemical change? is present in BHSC NST. Likewise, there is limited DP AHL chemistry content in BHSC NST. BHSC NST (FI) does not present a stronger alignment with DP chemistry content than BHSC NST (BGE), as it covers few additional SL sub-topics and AHL sub-topics than the latter. BHSC NST (FI) offers specialisation in science generally, as opposed to chemistry specially, and provides an opportunity for students to extensively apply scientific concepts to a variety of contexts and issues. Finally, BHSC NST contains fewer mentions of specific experimental activities compared to DP chemistry's experimental programme.
- **Differences in demand:** There is an overall low-moderate alignment between the demand scores of DP chemistry and BHSC NST subjects. BHSC NST (BGE) scores lower than DP chemistry SL for Bloom's cognitive skills, volume of work, and depth of knowledge. Moreover, BHSC NST (BGE) scores lower than DP chemistry HL for all demand categories. BHSC NST (FI) scores lower for volume of work in comparison to DP chemistry SL and has lower scores than DP chemistry HL for depth of knowledge, volume of work, and outstanding areas of demand.

5.10 Mexico

The subject level alignment between DP chemistry (SL and HL) and the MBG Natural Sciences, Experimental Sciences and Technology units (chemistry-focus) is represented below:

Figure 38: Visual representations of subject-level alignment (chemistry)



MBG Compulsory units: Matter and its interactions, Conservation of energy and its interactions with matter, Ecosystems: interactions, energy and dynamics, Chemical reactions: conservation of matter in the formation of new substances, Energy in the processes of daily life, Organisms: structures and processes, Science workshop I.

MBG Optional units: Selected Topics in Chemistry I & II

- **Learning outcomes alignment:** the level of alignment between the science learning outcomes of the DP and MBG is significant. Indeed, all themes extracted from the DP sciences learning outcomes are present in the Natural Sciences, Experimental Sciences and Technology units of the MBG.
- **Content alignment:** the level of content alignment between MBG compulsory units and DP chemistry is low. The MBG compulsory units align with only some of the DP SL content, and very little AHL content. The MBG compulsory and optional units combined show greater alignment with DP chemistry, reflecting a more moderate level of alignment. Indeed, the MBG compulsory and optional units combined align with the SL content from most DP chemistry topics. Comparatively, however, there is greater alignment with DP SL than HL, as the MBG compulsory and optional units cover very little DP AHL content. MBG students who study the optional units will experience a similar breadth of content to that of DP chemistry SL, but a lower breadth than DP HL, with the latter featuring a high number of topics showing little to no presence in the MBG. In terms of depth, the DP shows a greater depth of content than the MBG units overall, both at SL and at HL.
- **Demand alignment:** there is an overall low level of alignment between the demand scores of DP chemistry and MBG Natural Sciences, Experimental Sciences and Technology units. DP chemistry receives higher scores in all categories than the MBG compulsory units. The MBG compulsory and optional units did receive the same score for one category (Depth of Knowledge) as DP SL, but scored lower than the DP in all other categories.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** there is a high level of alignment between the learning outcomes of DP sciences and the Natural Sciences, Experimental Sciences and Technology units of the MBG. All themes extracted from the DP are strongly evidenced in the MBG compulsory units and optional units. There is particular emphasis in the MBG of the DP themes of conceptual understanding and techniques that characterise science and critical thinking, with the Extended Disciplinary Competences also highlighting the importance of conducting insightful investigations and having an awareness of the impact of science.

Similarities in content: there is a small amount of content overlap between DP chemistry and the MBG compulsory units. The compulsory units cover some SL content and have, to some degree, alignment with at least one topic from each of the Structure and Reactivity units – except Reactivity 3. What are the mechanisms of chemical change? Particularly, the MBG compulsory units have strong alignment with SL content from Structure 1.1 Introduction to the particulate nature of matter and Reactivity 2.3 How far? The extent of chemical change. It can also be noted that the compulsory units have partial alignment with AHL content from Reactivity 2.3 How far? The extent of chemical change. Regarding the MBG compulsory and optional units combined, there is a greater level of content alignment with DP chemistry. Indeed, the optional units include SL content from several more DP topics, particularly increasing

alignment with topics from Structure 1. Models of the particulate nature of matter and Reactivity 3. What are the mechanisms of chemical change?. Furthermore, the optional MBG units also include slightly more AHL content, namely from Reactivity 1.2 – Energy cycles in reactions. Moreover, it can be noted that the MBG units (both compulsory and optional) have a strong presence of practical work and are thus judged to have strong alignment with the experimental programme component of DP chemistry. Overall, the MBG units (compulsory and optional) combined have moderate content alignment with DP chemistry SL and cover a similar breadth of content.

- **Similarities in demand:** whilst there are no significant similarities between the demand scores of the DP and the MBG compulsory units, the MBG received a score of only one point below the DP SL for all categories. Additionally, DP chemistry SL and the MBG compulsory and optional units score the same (two) for depth of knowledge.

The **key differences** identified were the following:

- **Differences in learning outcomes:** there are no significant differences in the learning outcomes of DP sciences and MBG Natural Sciences, Experimental Sciences and Technology units.
- **Differences in content:** there is limited content overlap between DP chemistry and the MBG compulsory units. Indeed, the compulsory units do not cover any content from Reactivity 3. What are the mechanisms of chemical change?, and have particularly limited alignment with Reactivity 1. What drives chemical reactions? and Structure 3. Classification of matter. In addition, the compulsory units generally do not cover DP AHL chemistry content. There is no significant chemistry content that is unique to the MBG and not found in the DP. Although relatively small concepts such as nanotechnology and the quality of the air are present in the compulsory units, there are no significantly large or complex areas of chemistry that are found in the MBG and not the DP. As such, the compulsory units have a significantly lesser breadth and depth of chemistry content than DP chemistry SL and HL. Regarding the MBG compulsory and optional units combined, there is moderate, rather than high, content alignment with DP chemistry. Indeed, six DP chemistry topics are not covered in either the compulsory or optional units and several others are only partially present. Moreover, the majority of DP AHL chemistry content is not covered by the compulsory and optional units. Therefore, while having greater alignment with DP chemistry than the compulsory units alone, the MBG units combined still have lesser breadth and depth than DP chemistry SL and, particularly, HL.
- **Differences in demand:** DP chemistry SL and HL score higher in all demand categories than the MBG Natural Sciences, Experimental Science and Technology units (chemistry-focus). Compared to MBG compulsory and optional units combined, both DP SL and HL chemistry score higher in all categories except for Depth of Knowledge, where DP SL has the same score. Overall, these scores reflect that DP features greater depth and breadth of chemistry knowledge than the MBG, with more opportunities for students to be stretched and challenged with regards to chemistry.

5.11 Japan

The subject level alignment between DP chemistry (SL and HL) and JHSC chemistry subjects is represented below:

Figure 39: Visual representations of subject-level alignment (chemistry).

Subject name	Learning outcomes alignment	Content alignment	Demand alignment
JHSC Advanced Chemistry	Low Moderate High	DP subject Overlap Comparison subject SL DP subject Overlap Comparison subject HL DP subject Overlap Comparison subject	DP SL DP HL Comparison subject Revised Bloom's Cognitive Skills 2 1 0 Outstanding Demand Areas 2 1 0 Depth of Knowledge 2 1 0 Volume of Work 2 1 0
JHSC Chemistry for the Science and Mathematics Course (SMC)*	Low Moderate High	DP subject Overlap Comparison subject SL DP subject Overlap Comparison subject HL DP subject Overlap Comparison subject	DP SL DP HL Comparison subject Revised Bloom's Cognitive Skills 2 1 0 Outstanding Demand Areas 2 1 0 Depth of Knowledge 2 1 0 Volume of Work 2 1 0

*The JHSC states that content may be expanded as appropriate in specialised science subjects, such as Chemistry (SMC). Therefore, in practice, the subject content and demand may differ slightly to what is represented here.

- **Learning outcomes alignment:** There is a moderate level of alignment between the DP and JHSC science learning outcomes. The DP learning outcome themes tend to only be partially present in the JHSC objectives and two themes have little to no presence.
- **Content alignment:** Both Advanced Chemistry and Chemistry (SMC) have moderate content alignment with SL chemistry content and limited alignment with AHL chemistry content. Advanced Chemistry covers a similar breadth of content to DP chemistry at SL, though with less depth in certain topics. Chemistry (SMC) covers the same content as Advanced Chemistry, while allowing opportunity for expansion. Hence, there is scope for the specialised subject to offer greater breadth and depth in practice.
- **Demand alignment:** The JHSC chemistry subjects have moderate alignment with the demand scores of DP chemistry at SL and limited alignment with the demand scores of DP chemistry at HL. However, the specialised subject Chemistry (SMC) allows for expansion, hence there is scope for the demand to be greater in practice.

The **key similarities** identified were the following:

- **Similarities in learning outcomes:** The most significant similarity between DP and JHSC science learning outcomes is the emphasis on developing skills for scientific investigation. Indeed, the JHSC objectives expect students to verify their predictions and hypotheses using observations and experiments throughout the subjects. The JHSC objectives also partially align with the DP themes of conceptual understanding, use and application of methods, tools, and techniques, and awareness of global and local issues and the impact of science.
- **Similarities in content:** The SL content from all DP chemistry topics is at least partially present in JHSC chemistry, with the strongest alignment being with the topics of *Structure 1. Models of the particulate nature of matter* and *Structure 2. Models of bonding and structure*. Furthermore, the examples of expanded content given for Chemistry (SMC) show some partial alignment with the AHL content of a few subtopics such as *Reactivity 1.4 – Entropy and spontaneity*. In addition, the emphasis in the JHSC on scientific investigation results in a strong alignment with the DP's experimental programme.
- **Similarities in demand:** JHSC subjects score similarly to DP chemistry at SL for all demand categories, particularly for depth of knowledge. Chemistry (SMC) has slightly greater alignment with DP chemistry at SL, scoring the same or very similarly for volume of work and depth of knowledge.

The **key differences** identified were the following:

- **Differences in learning outcomes:** The DP themes of communication and collaboration and developing technological skills are not present in the JHSC objectives. Furthermore, the objectives place less emphasis on conceptual understanding, use and application of methods, techniques and tools, critical thinking skills, and awareness of issues and the impact of science.

- **Differences in content:** JHSC chemistry content has varying degrees of alignment with the SL content across topics, with the weakest alignment being with *Reactivity 3. What are the mechanisms of chemical change?*. Moreover, most alignments that JHSC chemistry has with SL content are partial, rather than strong. This is due to JHSC chemistry not necessarily covering all the SL concepts in these topics and subtopics. Moreover, JHSC chemistry subjects generally have little to no alignment with AHL content in DP chemistry. However, content can be developed and expanded in the specialised subject, Chemistry (SMC). Therefore, there is scope for Chemistry (SMC) to offer greater breadth and depth than Advanced Chemistry and align more closely with DP chemistry content. Lastly, the JHSC subjects cover a few different areas to DP chemistry, such as some content regarding colloidal solutions and a distinct topic on the role of chemistry in the world.

Differences in demand: JHSC subjects, particularly Advanced Chemistry, tend to score lower than DP chemistry subjects. Both JHSC chemistry subjects overall score considerably less than DP chemistry at HL.

6. Cross-cutting Findings

This section summarises the main cross-cutting trends, similarities and differences found when comparing the DP subjects against the comparison subjects in the eleven comparison programmes. In particular, the section focuses on the cross-cutting findings uncovered from the learning outcomes, content and demand analyses.

6.1 Learning Outcomes

Table 47: Presence of the DP's science learning outcomes in the comparison chemistry curricula.

Themes extracted from learning outcomes of the DP sciences subject group	Presence in the comparison curricula										
	VCE (Victoria)	OSSD (Ontario)	FNCC/ GUSE (Finland)	SGA (Singapore)	KHSCG (South Korea)	NGSS (US)	FB (France)	SB (Spain)	BHSC (Brazil)	MBG (Mexico)	JHSC (Japan)
1. Conceptual understanding and making connections											
2. Use and application of knowledge, methods, tools, and techniques that characterize science											
3. Creativity and critical thinking (problem-solving, analysis, evaluation, synthesis)											
4. Skills for scientific inquiry											
5. Development of technological skills											
6. Effective collaboration and communication											
7. Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science											

Key:

	<i>This theme is well-evidenced in the learning outcomes of the comparison curriculum.</i>		<i>This theme is partially evidenced in the learning outcomes of the comparison curriculum.</i>		<i>This theme is not evidenced in the learning outcomes of the comparison curriculum.</i>
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The table above displays the themes extracted from the DP sciences subject group learning outcomes (which apply to chemistry) and summarises their presence in the chemistry curricula of the eleven comparison programmes/standards. Additionally, to complement the above, the table below lists the main learning outcome themes found in the chemistry curricula of the comparison programmes/standards which were different to those of the DP, including any notable differences in emphasis or approach.

Table 48: Summary of different themes/emphases featured in the learning outcomes of the comparison curricula.

Comparison	Different themes/emphases to the DP
Australia (Victoria)	No other significant themes present.
Canada (Ontario)	Canadian contributions to the field of chemistry and recognition of indigenous people's knowledge and customs. Greater emphasis on careers.
Finland (FNCC)	The importance of collaboration with outside agencies such as local or international workplaces.
Singapore	No other significant themes present.
South Korea	No other significant themes present.
US (NGSS)	More emphasis on being able to develop and use models and computational thinking.
France (FB)	More emphasis on modelling and using models to connect theoretical knowledge to the real world.
Spain (SB)	The portrayal of chemistry/chemicals in the media and how to overcome the negative influences of journalism.
Brazil (BHSC)	A greater focus on the historic contextualisation of scientific information and on the misuse of knowledge from natural sciences.
Mexico (MBG)	No other significant themes present.
Japan (JHSC)	No other significant themes present.

Regarding structure and presentation of learning outcomes, the DP, NGSS, and FB describe one set of outcomes which are applicable to all science courses in the programme/standards – i.e. they do not outline specific outcomes for each course available in science. In contrast, other programmes have course-specific outcomes, with some featuring both overarching outcomes for the sciences subject area and course-specific outcomes. That said, the VCE, FNCC, KHSCG, and JHSC course-specific outcomes only slightly differ where they are contextualised for the content of the subject. Similarly, the OSSD course-specific expectations are primarily content-focused. However, for SGA, SB, BHSC, and MBG, the course-specific outcomes describe somewhat different skills for each course, as well as content. For instance, the aims for SGA H2 and H3 are slightly different, as the H3 builds on the knowledge and skills acquired in H2. Similarly, the outcomes for the SB are slightly different between the first and second year courses, as students move from a combined science course to a stand-alone chemistry course. Furthermore, the BHSC includes additional skills for formative itineraries and the MBG presents a different set of competencies for its optional units.

Generally, the comparison curricula feature similar learning outcome themes to those in the DP. In particular, the themes of *Using and applying knowledge, methods, tools, and techniques that characterise science*, *Creativity and critical thinking*, and *Skills for scientific inquiry* are strongly present in nearly all curricula. Furthermore, *Effective collaboration and communication* and *Awareness of global and local problems and the environmental, ethical, cultural, and social impact of science*, are generally present, though these have partial or limited presence in three curricula. The DP themes which are the least evidenced across the curricula are *Conceptual understanding and making connections* and *Development of technological skills*.

In general, there are only a few themes featured in the comparison curricula that are less emphasised or not present in DP science learning outcomes. However, one notable difference is the OSSD's greater national focus, placing significant emphasis on Canadian contributions to science and recognition of indigenous people's knowledge and customs. In addition, the latter also pays greater attention to careers, while the NGSS and FB place stronger emphasis than the DP on modelling. The FNCC puts particular emphasis on understanding how collaboration with outside agencies is important in gaining skills and knowledge in chemistry – a unique feature that does not receive the same level of attention in any of the comparison curricula. The BHSC places an emphasis on recognising the historic contextualisation of scientific information. For example, BHSC NST includes an expectation for students to discuss models, theories, and laws proposed in different times. Likewise, there is a greater emphasis in the BHSC on deliberate misuse of scientific knowledge, including where scientific knowledge has been used for the purposes of segregation, discrimination and the deprivation of rights.

Overall, there is generally a high degree of alignment between the DP and comparison curricula learning outcomes for chemistry. The DP and JHSC have the least alignment for learning outcomes, as the latter focuses on a narrower range of outcomes. While certain themes may be less present, the other curricula have strong alignment with the DP with regards to learning outcomes, in particular the VCE, OSSD, FNCC, KHSCG, and MBG.

6.2 Content

6.2.1 Structure

The DP offers two levels of chemistry study, SL and HL. Similarly, the option to study chemistry at different levels is offered across all comparison programmes (excluding the NGSS, which are not a full curriculum). This is done by offering subjects at different levels (as in the SGA) or by allowing students to choose how many chemistry/science courses they study.

While offering different levels of chemistry study, it is important to note that some of the curricula combine chemistry with other sciences in some of the courses they offer, in contrast to the DP which offers chemistry on its own. The combining of sciences is a particularly significant feature in the FB, SB, BHSC, and MBG. The FB offers Physics-chemistry for either one or two years and the SB offers Physics and Chemistry in the first year and a stand-alone chemistry course in the second year. The MBG core units integrate the sciences, whilst optional stand-alone chemistry units are offered in final year. In the BHSC, the formative itinerary component combines all sciences.

In terms of how the content is structured within the subjects/courses, one feature that the DP shares with most of the comparison chemistry curricula is that all content within a specific course is compulsory. This feature is shared by most curricula, except the FNCC and VCE, which feature optional topics and areas.

Like most comparison chemistry subjects, the DP breaks its chemistry content down into a small number of overarching topic areas, with each being further divided into a number of sub-topics. The exact number of topics and sub-topics varies considerably across the curricula,

some, like the KHSCG, divide their chemistry content into only two topics, while others, such as the OSSD or FNCC, divide it into five or six topics, respectively. The MBG's compulsory units integrate chemistry (and other science) concepts into six overarching scientific areas. DP chemistry is unique in its division of content into *Structure* and *Reactivity*.

Somewhat uniquely, the DP chemistry course organises its content into topics which are the same for SL and HL. This feature is generally not replicated across the comparison curricula, where usually chemistry courses within the same programme have different overarching topics and thematic focuses. Only in the KHSCG and the SGA does the structure stay the same in different electives/subjects.

As to how the topics and sub-topics are presented, the DP and other curricula all similarly state these as succinct titles which describe the subject content. In contrast, the VCE uniquely describes its large topic areas (Areas of Study) using mostly guiding questions, such as 'How can the diversity of materials be explained?'. The OSSD, in turn, presents more descriptive sub-topics than other curricula, detailing the concepts to be understood, links to technology, environment, and society, and the skills required for scientific inquiry. Furthermore, the BHSC content is not organised using chemistry topics but rather by specific competencies and skills for Natural Sciences and Technology; which are an integration of skills and physics, chemistry, and biology content.

Overall, the structure of the science/chemistry subject area and chemistry courses within the comparison curricula varies significantly – with differences found in the number of chemistry subjects offered per programme; the offering of combined science courses; the overarching topic and sub-topic areas and whether these differ by course/level of study; the number of topics and sub-topics covered, as well as their optionality; and the level of detail used to describe each topic/sub-topic. Nevertheless, all (except the NGSS) offer students the option to study chemistry in greater or lesser depth – some by allowing study at different levels, others by allowing students to study additional chemistry (or combined science) courses.

6.2.2 Content Alignment

The following tables summarise the presence of DP chemistry SL and AHL content in the chemistry curricula of the eleven comparison programmes/standards. Here, all chemistry content within each comparison curriculum is considered. To view the chemistry content within specific subjects, and how it aligns with DP chemistry, refer to the relevant country in Section 4. Subject-Level Alignment.

Table 49: Presence of DP chemistry SL content in the chemistry curricula of the eleven comparison programmes/standards.¹⁷⁵

DP chemistry – SL content		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
Structure 1. Models of the particulate nature of matter	1.1 Introduction to the particulate nature of matter											
	1.2 The nuclear atom											
	1.3 Electron configurations											
	1.4 Counting particles by mass: The mole											
	1.5 Ideal gases											
Structure 2. Models of bonding and structure	2.1 The ionic model											
	2.2 The covalent model											
	2.3 The metallic model											
	2.4 From models to materials											
Structure 3. Classification of matter	3.1 The periodic table: Classification of elements											
	3.2 Functional groups: Classification of organic compounds											
Reactivity 1. What drives chemical reactions?	1.1 Measuring enthalpy changes											
	1.2 Energy cycles in reactions											
	1.3 Energy from fuels											
Reactivity 2. How much, how far and how fast?	2.1 How much? The amount of chemical change											
	2.2 How fast? The rate of chemical change											
	2.3 How far? The extent of chemical change											
Reactivity 3. What are the mechanisms of chemical change?	3.1 Proton transfer reactions											
	3.2 Electron transfer reactions											
	3.3 Electron sharing reactions											
	3.4 Electron-pair sharing reactions											
Experimental programme												

¹⁷⁵ NB: only topics covered featured at the respective level (i.e. SL) have been included in the table.

Table 50: Presence of DP chemistry AHL content in the chemistry curricula of the eleven comparison programmes/standards.¹⁷⁶

DP chemistry – AHL content		Presence in comparison curricula										
		VCE	OSSD	FNCC	SGA	KHSCG	NGSS	FB	SB	BHSC	MBG	JHSC
Structure 1. Models of the particulate nature of matter	1.2 The nuclear atom											
	1.3 Electron configurations											
Structure 2. Models of bonding and structure	2.2 The covalent model											
	2.3 The metallic model											
	2.4 From models to materials											
Structure 3. Classification of matter	3.1 The periodic table: Classification of elements											
	3.2 Functional groups: Classification of organic compounds											
Reactivity 1. What drives chemical reactions?	1.2 Energy cycles in reactions											
	1.4 Entropy and spontaneity											
Reactivity 2. How much, how far and how fast?	2.2 How fast? The rate of chemical change											
	2.3 How far? The extent of chemical change											
Reactivity 3. What are the mechanisms of chemical change?	3.1 Proton transfer reactions											
	3.2 Electron transfer reactions											
	3.4 Electron-pair sharing reactions											
Experimental programme												

Key:

	Strong presence of this topic in the comparison curriculum.		Partial presence of this topic in the comparison curriculum.		Little or no presence of this topic in the comparison curriculum.
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¹⁷⁶ NB: only topics covered featured at the respective level (i.e. AHL) have been included in the table.

The table below lists any significant content found in the comparison chemistry curricula which was not present in DP chemistry or covered differently.

Table 51: Topics which are not in the DP's content or follow a significantly different approach.

Comparison	Topics
VCE	The properties of water. Carbon 13 nuclear magnetic resonance. Metabolism of food in the human body.
OSSD	No significantly different topics are present.
FNCC	How chemistry can be used to solve health or environmental problems.
SGA	Trends and variations of oxides and chlorides. Half-life and first order reactions. Elimination.
KHSCG	The properties of water and its importance in life. Strong theme of 'real life' importance: e.g. the use of buffers in vivo, fermentation, examples of catalysts in industry, altering freezing/boiling points.
NGSS	No significantly different topics are present.
FB	No significantly different topics are present.
SB	Polymer; their applications, properties and associated environmental risks.
BHSC	Risks associated with exposure to and improper disposal of materials Water and sewage treatment
MBG	The chemistry of the air, how to improve what we breathe? (presumably focused on pollution/particulates etc.) Nanotechnology
JHSC	Dissolution equilibrium, solubility of gases and Henry's law Colloidal solutions – Tyndall effect, Brownian motion, dialysis and electrophoresis Faraday's law (Electrolysis) Resins and monosaccharides (Polymer compounds) The role of chemistry topic

Nearly all curricula contain at least some similar content to that of DP chemistry's main *Structure* and *Reactivity* topics. Only the BHSC had very little to no content from one of these main topics, namely *Reactivity 3. What are the mechanisms of chemical change?*

Coverage of DP chemistry SL content is generally strong across all curricula, with the VCE, OSSD, SGA, FB, and SB showing especially strong alignment with most topics. Generally, a considerable amount of SL content from most of the main *Structure* and *Reactivity* topics is present across the curricula. The SL content of three of sub-topics have strong presence in nearly all comparison curricula, namely *Structure 1.1 Introduction to the particulate nature of matter*, *Structure 1.2 The nuclear atom*, and *Reactivity 2.3 How far? The extent of chemical change*. The topic with the least presence in the comparison curricula is *Reactivity 3. What are the mechanisms of chemical change?*. Within this topic, the content from sub-topics 3.3 and 3.4 have little to presence in over half the comparison curricula.

Coverage of DP chemistry AHL content varies more across the comparison curricula. The OSSD, KHSCG, SGA, FB, and SB cover some AHL content from each of the main *Structure* and *Reactivity* topics in the DP. In particular, the SGA covers most of the AHL content in all sub-topics. The OSSD, KHSCG, FB, and SB also cover AHL content from most sub-topics, albeit with a higher number of sub-topics being only partially covered. In contrast, the NGSS, BHSC, MBG, and JHSC have very little presence of AHL content.

The AHL content of certain sub-topics are more commonly covered across the comparison curricula. The most commonly covered AHL content is from *Structure 2.4 From models to materials*, *Structure 1.2 The nuclear atom and structure*, *Structure 3.1 The periodic table: Classification of elements*, *Reactivity 1.2 Energy cycles in reactions*, and *Reactivity 2.3 How far? The extent of chemical change*. In contrast, the AHL content from some sub-topics is absent from the majority of the curricula; most notably, *Structure 2.2 The covalent model*, *Structure 3.2 Functional groups: Classification of organic compounds*, and *2.2 How fast? The rate of chemical change*.

Regarding the experimental programme, nearly all comparison curricula at least partially align with this DP component, as they include practical work. Alignment with the DP is particularly strong for the SGA, KHSCG, MBG, and JHSC. It should be noted that several of the comparison curricula are less specific about the practical work and investigation to be carried out.

When considering large topics or content areas present in the comparison curricula but not in the DP, one notable difference is the coverage of the properties of water. Both the VCE and the KHSCG cover this content area in their chemistry curricula, while the DP covers this aspect in biology instead. The same is true for the coverage of the human metabolism in the VCE – which is covered chemistry, while the DP also places it in its biology curriculum. Another difference relates to the theme of making connections to ‘real life’ – both the FNCC and KHSCG place significant emphasis on this throughout their curricula, covering examples such as the use of catalysts in industry or learning how to use buffers in vivo. Similarly, the JHSC has a distinct topic focusing on the role of chemistry in the world. While the DP does relate science to the wider world and to real world scenarios, this is less prevalent in the chemistry-specific content, instead being outlined at a higher level in the nature of science section. In addition, the SGA’s coverage of oxides and chlorides is also more significant than that of the DP’s, with the former devoting a significant proportion of its curriculum to studying examples of these chemical compounds and trends/patterns running through these. While both the DP and the SB include coverage of polymers, the SB covers this aspect in greater depth than the DP, by including their applications, properties and associated environmental risks.

Overall, the comparison curricula feature a considerable amount of SL content. However, the SGA, OSSD, KHSCG, FB, and SB have the strongest content alignment with the DP, as they also cover a significant proportion of AHL content.

6.3 Demand

The following table provides a visual representation of the demand scores the expert panel awarded to DP chemistry and the comparison subjects in each of the eleven programmes/standards.

Table 52: The demand scores of chemistry subjects from the DP and eleven comparison programmes.

Demand category	Scores																			
	DP (IB)		VCE	OSSD		FNCC		SGA			KHSCG	NGSS	FB	SB	BHSC		MBG		JHSC	
	SL	HL	Chem.	G 11	G 12	C	All	H1	H2	H3	Chem.	PS	PC	Chem.	BG	FI	C	All	AC	S
Revised Bloom's Cognitive Skills	3	3	2.5	2	2.5	2	2.5	2	2.5	3	2	2	2	2	2.5	3	2	2	2	2
Depth of Knowledge	2	3	2	1.5	2	1	2.5	1	2	3	2	1	2	2.5	1	2	1	2	1.5	2
Volume of Work	2	3	1	2	2	0.5	1.5	1	2	3	2	0	2	3	0.5	1.5	1	1	1.5	1.5
Outstanding Demand Areas	2	3	1	0	1	1	1	1	1	1	1	0	1	1	1	2	1	1	1	1

Key:

VCE (Australia): Chem: Chemistry	OSSD (Canada): G11: Grade 11 Chemistry G12: Grade 12 Chemistry	FNCC/GUSE (Finland): C: Compulsory Chemistry modules All: Compulsory and optional Chemistry modules	SGA (Singapore): H1: Higher 1 Chemistry H2: Higher 2 Chemistry H3: Higher 3 Chemistry	KHSCG (South Korea): Chem: Chemistry I, Chemistry II, Integrated Science, and Scientific Investigation (pathway)	NGSS (US): PS: Standards for Physical Sciences
FB (France): PC: Physics-chemistry	SB (Spain): Chem: Chemistry	BHSC (Brazil): BG: Basic general education FI: Formative itinerary	MBG (Mexico): C: Compulsory science units (chemistry) All: Compulsory and optional science units (chemistry)	JHSC (Japan): AC: Advanced Chemistry S: Chemistry for the Science and Mathematics Course	

With the exception of one subject in the SGA and BHSC, all subjects in the comparison curricula score less than DP chemistry for Bloom's cognitive skills. Scores tend to be 2 or 2.5, demonstrating that, across the curricula, learning outcomes tend to have slightly less evidence of evaluation and creative thinking than the DP, though do demonstrate some critical thinking, including analysis. The only subjects scoring the same as DP chemistry (score of 3) are SGA H3 and BHSC FI.

Except for the NGSS, all the comparison curricula have at least one course or pathway which scores the same as, or very similarly to, DP chemistry at SL for depth of knowledge. In contrast, only the SGA offers a course which scores the same as the DP chemistry at HL for depth of knowledge (i.e. the maximum score for this category), though it's worth noting that the FNCC and SB offer courses which score very similarly. The OSSD, SGA, FNCC, BHSC, MBG, and JHSC include at least one subject or course which scores less than DP chemistry at SL in this category. This would also be true for KHSCG and VCE, depending on the electives/units chosen.

Regarding the volume of work category, a number of comparison curricula have courses that score the same as DP chemistry at SL for this category, namely the OSSD, KHSCG, SGA, and FB. In contrast, only the SGA and SB have a course which matches the volume of work score of DP chemistry at HL and therefore were judged to also comprise a heavy workload. Notably, all the subjects within a number of the comparison programmes/standards have a lower volume of work than DP chemistry at both SL and HL, namely the VCE, FNCC, NGSS, BHSC, MBG, and JHSC. It can be noted that the NGSS and SGA do not describe teaching hours, meaning that particular caution is necessary when interpreting the judgements for these.

Except for one subject in the BHSC, all comparison subjects score less than DP chemistry at both SL and HL for outstanding demand areas. BHSC FI scores the same as DP chemistry at SL for this category.

In summary, while most comparison programmes/standards offer a chemistry course or pathway that has similar demand to that of DP chemistry SL, only the SGA offers a subject that has reasonable alignment with DP chemistry HL. Furthermore, outstanding areas of demand is the primary category in which comparison subjects score lower than DP chemistry.

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Appendix A

This Appendix provides further detail on the criteria utilised by Ecctis' experts and external panel members with subject expertise to measure demand for each of the subjects analysed in this study.

Demand Profile – Subject-level Judgement

- **Revised Bloom's cognitive** skills score (0-3): this is an overall score of course demand, based entirely on a review of learning outcomes. Levels have been defined based on increasing emphasis on Bloom's Higher Order Thinking Skills.
 - Level 0 – remembering and understanding: learning outcomes (as well as assessment and content) are primarily focused on recall and understanding, with limited or no evidence of higher order thinking skills.
 - Level 1 – applying: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding- and application-focused objectives, with only limited presence of higher order thinking skills.
 - Level 2 – analysing: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding and application-focused goals but also feature a substantial focus on analysis. Learning outcomes can also potentially feature some (though limited) evidence of evaluation and creation-focused goals.
 - Level 3 – evaluating and creating (or synthesising): learning outcomes (as well as assessment and content) feature a predominant focus on analysis-, evaluation- and creation/synthesis.
- **Depth of knowledge** (adapted from Webb's) score (0-3): this is an overall score evaluating the depth of knowledge or complexity of knowledge required by curriculum standards and expectations. The score is focused on subject content and learning outcomes, complemented by assessment where relevant/possible. Levels have been defined based on the level of detail studied per topic, as well as the levels of thinking described in Webb's Depth of Knowledge framework.
 - Level 0 – All or most topics are studied in limited detail (pre-upper secondary level). Only basic pre-requisite knowledge is required in order to grasp ideas. The level of cognitive complexity of the information students are expected to know is low (e.g. many tasks may require recall and reproduction of information such as facts, definitions, terms, or simpler procedures – acquired knowledge).
 - Level 1 – Some topics are studied in considerable detail. Moderate levels of pre-requisite knowledge are required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is low to moderate (e.g. many tasks may require engagement of some mental processing beyond habitual responses, including comparison and basic reasoning – knowledge application).

- Level 2 – Most topics are studied in considerable detail. Considerable pre-requisite knowledge is required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is average to high (e.g. some tasks require complex reasoning, planning, using evidence, and a higher level of thinking than the previous two levels. The cognitive demands are often complex and abstract – analysis).
 - Level 3 – All or most topics are studied in very high detail. Considerable pre-requisite knowledge is required in order to grasp ideas in most topics. The level of cognitive complexity of information students are expected to know is mostly high (e.g. many tasks may require complex reasoning, planning, developing, information synthesis, interpretation of data for problem solving, and thinking most likely over an extended period – extended thinking).
- **Volume of work** score (0-3): this is a trifactor score, considering breadth of content and depth of content, evaluated against the programme's specified timeframe. The three factors – breadth, depth, and time – were all considered in defining the levels.
 - Level 0 – light: small number of themes and sub-themes covered; a significant majority of time is spent on straightforward or basic themes; generous time allocation per theme.
 - Level 1 – moderate: typical number of themes and sub-themes covered; more time spent on conceptually complex themes compared to Level 1 (though majority of time still spent on themes of basic depth); standard time allocation per theme.
 - Level 2 – moderate heavy: typical to high number of themes and sub-themes covered; a significant proportion of time spent on issues beyond basic conceptual depth; standard to short time allocation per theme.
 - Level 3 – heavy: high number of themes and sub-themes covered; a large proportion of time spent on issues beyond basic conceptual depth; short time allocation per theme.
- **Outstanding areas of subject demand** score (0-3): this score reflects the number of content areas typically viewed as more challenging and/or conducive to intellectual stretching of learners. Levels have been defined on a scale of increasing presence of 'stretch areas'.
 - Level 0 – no stretch areas (0)
 - Level 1 – few stretch areas (1-2)
 - Level 2 – a significant number of stretch areas (3-4)
 - Level 3 – a high number of stretch areas (>4)

Appendix B

Learner profile	Approaches to learning	Approaches to teaching	International-mindedness
Inquirers: We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life. Knowledgeable: We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance. Thinkers: We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions. Communicators: We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups. Principled: We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences. Open Minded: We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience. Caring: We show empathy, compassion, and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.	In all IB programmes, there are five categories of skills including: Thinking skills: including areas such as critical thinking, creative thinking, and ethical thinking Research skills: including skills such as comparing, contrasting, validating, and prioritizing information Communication skills: including skills such as written and oral communication, effective listening, and formulating arguments Social skills: including areas such as forming and maintaining positive relationships, listening skills, and conflict resolution	In all IB programmes, teaching is: Based on inquiry: A strong emphasis is placed on students finding their own information and constructing their own understandings. Focused on conceptual understanding: Concepts are explored in order to both deepen disciplinary understanding and to help students make connections and transfer learning to new contexts. Developed in local and global contexts: Teaching uses real-life contexts and examples, and students are encouraged to process new information by connecting it to their own experiences and to the world around them. Focused on effective teamwork and collaboration: This includes promoting teamwork and collaboration between students, but also refers to the collaborative relationship between teachers and students.	The aim of all IB programmes is to develop internationally minded people who recognize their common humanity and shared guardianship of the planet. Central to this aim is international-mindedness. International-mindedness is a multifaceted concept that captures a way of thinking, being and acting characterised by an openness to the world and a recognition of our deep interconnectedness to others. To be open to the world, we need to understand it. IB programmes therefore provide students with opportunities for sustained inquiry into a range of local and global issues and ideas. This willingness to see beyond immediate situations and boundaries is essential as globalization and emerging technologies continue to blur traditional distinctions between the local, national and international. An IB education fosters international-mindedness by helping students reflect on their own perspective, culture and identities, as well as those of others. By engaging with diverse beliefs, values and experiences, and by learning to think and collaborate across cultures and disciplines, IB learners gain the understanding necessary to make progress towards a more peaceful world.

Risk-Takers: We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change. Balanced: We understand the importance of balancing different aspects of our lives – intellectual, physical, and emotional – to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live. Reflective: We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.	Self-management skills: including both organizational skills, such as managing time and tasks, and affective skills, such as managing state of mind and motivation.	Designed to remove barriers to learning: Teaching is inclusive and values diversity. It affirms students' identities, and aims to create learning opportunities that enable every student to develop and pursue appropriate personal goals. Informed by assessment: Assessment plays a crucial role in supporting, as well as measuring, learning. This approach also recognizes the crucial role of providing students with effective feedback.	An IB education further enhances the development of international-mindedness through multilingualism. All IB programmes require students to study, or study in, more than one language. This is because we believe that communicating in more than one language helps students to appreciate that his or her own language, culture and world view are just one of many. In this way, it provides excellent opportunities to develop intercultural understanding and respect. International-mindedness is also encouraged through a focus on global engagement and meaningful service with the community. These elements challenge students to critically consider power and privilege, and to recognize that they hold this planet and its resources in trust for future generations. They also highlight the focus on action in all IB programmes: a focus on moving beyond awareness and understanding to engagement, action and bringing about meaningful change to make a more peaceful and sustainable world for everyone.
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Appendix C

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Task brief – Expert Demand Panel – [Subject]

For each subject, highlight in yellow the descriptor(s) deemed to best fit each demand category, using the following criteria (please refer to the demand tables for descriptors of the levels):

- **Revised Bloom's cognitive skills** score (0-3): this is an overall score of course demand, based entirely on a review of learning outcomes. Levels have been defined based on increasing emphasis on Bloom's Higher Order Thinking Skills.
- **Depth of knowledge** (adapted from Webb's) score (0-3): this is an overall score evaluating the depth of knowledge or complexity of knowledge required by curriculum standards and expectations. The score is focused on subject content and learning outcomes, complemented by assessment where relevant/possible. Levels have been defined based on the level of detail studied per topic, as well as the levels of thinking described in Webb's Depth of Knowledge framework.
- **Volume of work** score (0-3): this is a trifactor score, considering breadth of content and depth of content, evaluated against the programme's specified timeframe. The three factors – breadth, depth and time – were all taken into account in defining the levels.
- **Outstanding areas of subject demand** score (0-3): this score reflects the number of content areas typically viewed as more challenging and/or conducive to intellectual stretching of learners. Levels have been defined on a scale of increasing presence of 'stretch areas'.

Demand Judgements – [Subject]

Table 53: [Subject]

Demand Judgement	Score Descriptors (highlight the best-fit descriptor)	Judgement and Key Evidence
Revised Bloom's Cognitive Skills ¹⁷⁷	Level 0 – remembering and understanding: learning outcomes are primarily focused on recall and understanding, with limited or no evidence of higher order thinking skills.	
	Level 1 – applying: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding- and application-focused objectives, with only limited presence of higher order thinking skills.	
	Level 2 – analysing: learning outcomes (as well as assessment and content) comprise a mix of recall-, understanding and application-focused goals but also feature a substantial focus on analysis. Learning outcomes can also potentially feature some (though limited) evidence of evaluation and creation-focused goals.	
	Level 3 – evaluating and creating (or synthesising): learning outcomes feature a predominant focus on analysis-, evaluation- and creation/synthesis.	
Depth of Knowledge ¹⁷⁸	Level 0 – All or most topics are studied in limited detail (pre-upper secondary level). Only basic pre-requisite knowledge is required in order to grasp ideas. The level of cognitive complexity of the information students are expected to know is low (e.g. many tasks may require recall and reproduction of information such as facts, definitions, terms, or simpler procedures – acquired knowledge).	
	Level 1 – Some topics are studied in considerable detail. Moderate levels of pre-requisite knowledge are required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is low to moderate (e.g. many tasks may require engagement of some mental processing beyond habitual responses, including comparison and basic reasoning – knowledge application).	
	Level 2 – Most topics are studied in considerable detail. Considerable pre-requisite knowledge is required in order to grasp ideas in some topics. The level of cognitive complexity of the information students are expected to know is average to high (e.g. some tasks require complex reasoning, planning, using evidence, and a higher level of thinking than the previous two levels. The cognitive	

¹⁷⁷ Evidence pool: Learning outcomes¹⁷⁸ Evidence pool: Learning outcomes, subject content, assessment types

Demand Judgement	Score Descriptors (highlight the best-fit descriptor)	Judgement and Key Evidence
	demands are often complex and abstract – analysis).	
	Level 3 – All or most topics are studied in very high detail. Considerable pre-requisite knowledge is required in order to grasp ideas in most topics. The level of cognitive complexity of information students are expected to know is mostly high (e.g. many tasks may require complex reasoning, planning, developing, information synthesis, interpretation of data for problem solving, and thinking most likely over an extended period of time – extended thinking).	
Volume of work ¹⁷⁹	Level 0 – light: small number of themes and sub-themes covered; a significant majority of time is spent on straightforward or basic themes; generous time allocation per theme. Level 1 – moderate: typical number of themes and sub-themes covered; more time spent on conceptually complex themes compared to Level 1 (though majority of time still spent on themes of basic depth); standard time allocation per theme. Level 2 – moderate heavy: typical to high number of themes and sub-themes covered; a significant proportion of time spent on issues beyond basic conceptual depth; standard to short time allocation per theme. Level 3 – heavy: high number of themes and sub-themes covered; a large proportion of time spent on issues beyond basic conceptual depth; short time allocation per theme.	
Outstanding areas of subject demand ¹⁸⁰	Level 0 – no stretch areas (0) Level 1 – few stretch areas (1-2) Level 2 – a significant number of stretch areas (3-4) Level 3 – a high number of stretch areas (>4)	

¹⁷⁹ Evidence pool: Subject content; assessment types and number; course duration; time allocated per topic/sub-topic (where available).

¹⁸⁰ Evidence pool: Subject content.

Appendix D

This appendix displays the BNCC's specific competencies and specific skills for Natural Sciences and Technology in high school.

Figure 40: Specific competencies and specific skills for Natural Sciences and Technology

1. Analyze natural phenomena and technological processes, based on the interactions and relations between matter and energy, to propose individual and collective actions that improve the production processes, minimize social and environmental impacts and improve local, regional and global living conditions.
(EM13CNT101) Analyze and represent, with or without the use of devices and applications transformations and conservations in systems that involve amount of matter, energy, and motion to make predictions about their behaviors in everyday situations and in production processes that prioritize the sustainable development, the conscientious use of natural resources and the preservation of the life in all its forms.
(EM13CNT102) Perform forecasts, evaluate interventions, and/or build prototypes of thermal systems aimed at sustainability, considering their composition and effects of thermodynamic variables on their functioning, also considering the use of digital technologies to assist in the calculation of estimates and to support the construction of prototypes.
(EM13CNT103) Use knowledge about radiation and its origins to assess the potentialities and risks of its application in equipment of daily use, in the health, the environment, industry, agriculture and electricity generation.
(EM13CNT104) Assess the benefits and risks to health and the environment, considering the composition, toxicity and reactivity of different materials and products, such as also the level of exposure to them, positioning oneself critically and proposing solutions individual and/or collective for their responsible use and disposal.
(EM13CNT105) Analyze biogeochemical cycles and interpret the effects of phenomena and human interference in these cycles, to promote individual actions and/or or collective ones that minimize harmful consequences to life.
EM13CNT106) Evaluate, with or without the use of digital devices and applications, technologies and possible solutions to the demands that involve the generation, the transportation, distribution and consumption of electricity, considering the availability of resources, energy efficiency, cost-effectiveness, geographical and environmental characteristics, waste generation and impacts socio-environmental and cultural aspects.
(EM13CNT107) Perform qualitative and quantitative forecasts on functioning generators, electric motors and their components, coils, transformers, batteries, batteries and electronic devices, based on the analysis of transformation processes and power conduction involved – with or without the use of devices and apps – to propose actions aimed at sustainability.
2. Analyze and use interpretations about the dynamics of Life, the Earth and the Cosmos to develop arguments, make predictions about the functioning and evolution of living beings and the Universe, and to support and defend ethical and responsible decisions.
(EM13CNT201) Analyze and discuss models, theories and laws proposed at different times and cultures to compare different explanations of the emergence and evolution of Life, of the Earth and the Universe with the currently accepted scientific theories.
(EM13CNT202) Analyze the various forms of manifestation of life in its different levels of organization, as well as the favorable environmental conditions and the with or without the use of digital devices and applications (such as simulation and virtual reality software, among others).
(EM13CNT203) Evaluate and predict the effects of interventions on ecosystems, and their impacts on living beings and the human body, based on maintenance mechanisms of life, in the cycles of matter and in the transformations and transfers of energy, using representations and simulations about such factors, with or without the use of digital devices and applications (such as simulation and virtual reality software, among others).

EM13CNT204) Elaborate: explanations, predictions and calculations regarding movements of objects on Earth, in the Solar System, and in the Universe based on the analysis of interactions with or without the use of digital devices and applications (such as simulation and virtual reality software, among others).
(EM13CNT205) Interpret results and make predictions about experimental activities, natural phenomena and technological processes, based on the notions of probability and uncertainty, recognizing the explanatory limits of the sciences.
(EM13CNT206) Discuss the importance of preserving and conserving biodiversity, considering qualitative and quantitative parameters, and evaluate the effects of the action and environmental policies to ensure the sustainability of the planet.
(EM13CNT207) Identify, analyze and discuss vulnerabilities linked to experiences and to the contemporary challenges to which young people are exposed, considering the physical, psycho-emotional and social aspects, in order to develop and disseminate prevention and promotion of health and well-being.
(EM13CNT208) Apply the principles of biological evolution to analyze history human origin, considering its origin, diversification, dispersion across the planet and different ways of interacting with nature, valuing and respecting ethnic diversity and human culture.
(EM13CNT209) Analyze stellar evolution by associating it with the models of origin and distribution of chemical elements in the Universe, understanding their relationships with the conditions necessary for the emergence of solar and planetary systems, their and compositions and the possibilities of the existence of life, using representations and simulations, with or without the use of digital devices and applications (such as software simulation and virtual reality, among others).
3. Investigate problem situations and evaluate applications of scientific knowledge and its implications in the world, using procedures and languages of the Natural Sciences, in order to propose solutions that consider local, regional, and/or global demands, and communicate their findings and conclusions to varied audiences, in different contexts and through different media and digital information and communication technologies (DICT).
(EM13CNT301) Construct questions, develop hypotheses, predictions and estimates, employ measuring instruments and represent and interpret explanatory models, data and/or experimental results to construct, evaluate and justify conclusions in coping of problem situations from a scientific perspective.
EM13CNT302) Communicate, to varied audiences, in different contexts, the results of analyses, research and/or experiments, elaborating and/or interpreting texts, graphs, tables, symbols, codes, classification systems and equations, by means of different languages, media, digital information and communication technologies (ICTs), in order to participate in and/or promote debates on scientific and/or technological topics of socio-cultural and environmental relevance.
(EM13CNT303) Interpret texts of scientific dissemination that deal with themes of the Natural Sciences, available in different media, considering the presentation of the data, both in the form of texts and in equations, graphs and/or tables, consistency of the arguments and the coherence of the conclusions, in order to construct selection strategies from reliable sources of information.
(EM13CNT304) Analyse and discuss controversial situations on the application of knowledge in the field of Natural Sciences (such as DNA technologies, stem cell treatments, neurotechnologies, production of defense technologies, pest control strategies, among others), based on consistent arguments, legal, ethical and responsible, distinguishing different points of view.
(EM13CNT305) Investigate and discuss the misuse of knowledge from the sciences of Nature in the justification of processes of discrimination, segregation and deprivation of individual and collective rights, in different social and historical contexts, to promote equity and respect for diversity.
EM13CNT306) Assess the risks involved in everyday activities, applying knowledge of the Natural Sciences, to justify the use of equipment and resources, as well as safety behaviors, aimed at physical integrity, individual and collective, and socio-environmental, being able to make use of devices and applications that enable the structuring of simulations of such risks.
(EM13CNT307) Analyze the properties of materials to assess the suitability of their use in different applications (industrial, everyday, architectural, or technological) and/or or propose safe and sustainable solutions considering their local and everyday context.

(EM13CNT308) Investigate and analyze the operation of electrical equipment and/or electronics and automation systems to understand contemporary technologies and assess their social, cultural, and environmental impacts.
(EM13CNT309) Analyze related socio-environmental, political and economic issues the dependence of today's world on non-renewable resources and discuss the need to introduce alternatives and new energy technologies and materials, comparing different types of engines and new production processes materials.
(EM13CNT310) Investigate and analyze the effects of infrastructure programs and other basic services (sanitation, electricity, transportation, telecommunications, vaccination coverage, primary health care, and food production, among others) and identify local and/or regional needs in relation to these services in order to evaluate and/or promote actions that contribute to the improvement of quality of life and health conditions of the population.