The International Baccalaureate Diploma Programme (DP): Alignment with Norwegian Upper Secondary Education

Submitted to the International Baccalaureate by UK NARIC

The National Recognition Information Centre for the United Kingdom

The national agency responsible for providing information and expert opinion on qualifications and skills worldwide

September 2018

Contents

List of Tables

List of Figures

List of Acronyms

ATL	Approaches to Teaching and Learning - *IB*
CAS	Creativity, activity, service - *IB*
CP	Career-related Programme - *IB*
DP	Diploma Programme - *IB*
GSU	Higher Education Entrance Qualification for foreign applicants list (*Generell studiekompetanse for utenlandske søkere*)
IB	International Baccalaureate - *IB*
ICT	Information Communication Technology
IUPAC	International Union of Pure and Applied Chemistry
MYP	Middle Years Programme - *IB*
PYP	Primary Years Programme - *IB*
TOK	Theory of Knowledge - *IB*
UK NARIC	The National Recognition Information Centre for the United Kingdom - *IB*

Executive Summary

The International Baccalaureate (IB) Diploma Programme (DP) is an international upper secondary qualification that is offered across the world, including Norway. To support wider understanding of the IB DP in the context of the Norwegian education system, this study sought to identify and evaluate the similarities and differences between the structure, content, assessment and cognitive demand of the IB DP and the Norwegian secondary education system. This involved comparing the overarching aims and goals of the two systems, as well as a more detailed review of the IB DP and the Norwegian Vitnem å l for Videreg å ende Opplæring in key subjects.

To this end, the study aimed to address the following research questions:

1) To what extent does the Diploma Programme align with Norwegian principles and general objectives for education including student personal development, the development of values in Christian and humanist heritage and traditions (e.g. equality and respect for human dignity and nature) and values that also appear in different religions and beliefs, active participation in society and the fostering of a lifelong desire to learn?
2) How do the principles, practices and standards of the DP compare with the overarching pedagogical and learning approaches, as well as the intended learning outcomes, for the Norwegian upper secondary qualification (Vitnem å l for Videreg å ende Opplæring)?
3) In what ways does the content and structure of DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL compare with similarly-focussed upper secondary subjects in Norway?
4) In what ways do the DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL approaches to assessment align or differ with similarly-focussed upper secondary subjects in Norway?
5) Are there differences in the cognitive demand between DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL; and similarly-focussed upper secondary subjects in Norway?

Key findings

Overall, on a policy-level, the IB and Norwegian upper secondary education share objectives focussed on student personal development alongside their academic development. Moreover, both aim to provide students with a holistic education focussed on:

- Preparation for further study or work
- Developing critical thinkers and lifelong learners who are open-minded and understanding of the beliefs and cultures of others
- Developing students who are principled (honest and respectful), ethical and caring (empathetic and compassionate).

On a qualification-level, many similarities were found in the standards for teaching and learning for the IB DP and Vitnem å l for Videreg å ende Opplæring and in the overarching learning outcomes. In particular, schools are encouraged to:

- Provide holistic teaching using a range of methods to assist students in becoming self-motivated and regulated learners
- Provide differentiated teaching that meets all students needs within a democratic and constructivist classroom environment
- Support teachers in curriculum development and delivery while ensuring curricula content is accurate, relevant to the subject area and connections are made across subject areas
- Record and report on students' progression through assessment and feedback and ensure students are aware of their own progress
- Allow students the opportunity to develop: key subject knowledge, communication and presentation skills, critical and ethical thinking skills, and the ability to apply mathematical skills across the programme.

Across the IB DP and Norwegian science subjects reviewed, the comparative analysis found that:

- Similar skills are developed by the two qualifications, including practical, investigative and deduction skills allowing a student to conduct research, extract information from sources and to evaluate and present results
- Students of both systems are expected to be able to apply mathematical knowledge in a scientific context and to use digital tools during investigations or to create graphs
- Differences in the skills, where noted, were minor
- The IB DP courses broadly cover the key topics and content included in the Norwegian courses, and overall, provide a wider coverage of science topics
- Similar externally assessed written examinations are used across all the sciences; these test key subject knowledge. However, overall the assessment methods differ: the Norwegian courses include school-based internal assessment with external assessments conducted for selected students while the IB DP includes mandatory internal and external assessment.

For the mathematics subjects, it was found that:

- The courses aim to develop similar skills including numeracy, technological and mathematical inquiry skills, the ability to communicate mathematically and to formulate logical arguments
- Broadly similar content and associated aims are covered in both qualifications, in particular:
    - IB DP Mathematics HL and SL and Norwegian Mathematics R1 and R2 cover a similar range of mathematics topics related to geometry, algebra and functions
    - Mathematics R1 and the IB DP Mathematics HL and SL similarly cover combinatorics and probability
    - Mathematics R2 and the IB DP Mathematics HL and SL similarly cover differential equations
    - Overall, Mathematics HL was found to cover a wider range of topics
    - IB DP Mathematical Studies SL and the Norwegian Mathematics R1 cover similar topics, but fewer than those covered by IB DP Mathematics HL and SL;

significantly fewer sub-topics are shared between the IB DP Mathematical Studies SL and Norwegian Mathematics R2 courses
    - The content of the IB DP Mathematical Studies SL and Norwegian Mathematics S1 and S2 are closely aligned, albeit with a few differences. The Norwegian Mathematics S1 course includes content on linear optimisation whereas the IB DP Mathematical Studies SL course covers additional mathematics content on *Descriptive Statistics*, *Geometry and Trigonometry*.
- Similar assessment methods are used between the IB DP and Norwegian mathematics courses; both employ internal assessment, although external assessment is not mandatory for all students of the Norwegian course
- When comparing the external written examinations, it is clear that broadly similar questions types are used and that the exams assess similar content and skills including: knowledge and understanding of concepts and content; problem solving skills; use of technology; mathematical reasoning skills; and communication skills in mathematics
- Overall, the IB DP examinations were found to be more demanding; in some courses this was due to the number of questions to complete in the timeframe available, in other courses, this is due to the complexity of procedures the students were required to perform and the amount of guidance provided to students within the questions.

Published by:
UK NARIC
Suffolk House, 68-70 Suffolk Road
Cheltenham, Gloucestershire
United Kingdom
GL50 2ED

Email: projects@naric.org.uk

1. Introduction

1.1 Context and Scope

UK NARIC[1] was commissioned by the International Baccalaureate (IB)[2] to provide a holistic comparison of the IB Diploma Programme (DP) in the context of the Norwegian education system. The DP is one of four programmes[3] offered by the IB across the world, including Norway. As of July 2018, 38 schools in Norway offer IB programmes, out of which 25 deliver the IB DP.

This study examines the ways in and extent to which the IB Diploma Programme aligns with the overall Norwegian upper secondary school system, focussing on the philosophical underpinnings of education at upper secondary level (including objectives and policies) and the resulting qualification design (including content, structure, assessment methods and cognitive demand). Specifically, the study is designed around the following research questions:

- To what extent does the Diploma Programme align with Norwegian principles and general objectives for education including student personal development, the development of values in Christian and humanist heritage and traditions (e.g. equality and respect for human dignity and nature) and values that also appear in different religions and beliefs, active participation in society and the fostering of a lifelong desire to learn?
- How do the principles, practices and standards of the DP compare with the overarching pedagogical and learning approaches, as well as the intended learning outcomes, for the Norwegian upper secondary qualification (Vitnem å l for Videreg å ende Opplæring)?

At a subject-level, the study will also investigate the following:

- In what ways does the content and structure of DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL compare with similarly-focussed upper secondary subjects in Norway?[4]

[1] UK NARIC is the UK's national recognition agency for providing information and guidance on academic, vocational and professional skills and qualifications from all over the world. It has over 20 years' experience in researching, evaluating and comparing international qualifications and education systems to support and inform stakeholder understanding and recognition. More information on UK NARIC can be found in Appendix 1.

[2] The International Baccalaureate (IB) is a non-profit educational foundation founded in 1968. The IB is run internationally by four Global Centres in The Hague, Washington DC, Cardiff and Singapore. A Foundation Office is located in Geneva, and assessment is managed by the IB Global Centre in Cardiff.

[3] The others are the Primary Years Programme (PYP) – delivered to students between the ages of 3-12 and consisting of a written curriculum (what students should learn), a taught curriculum (how students should learn), and how to determine what students have learned (assessed curriculum); the Middle Years Programme (MYP) – offered to students aged 11-16 and including eight subject groups from which students choose their courses and an interdisciplinary unit; and the Career-related Programme (CP) – a two-year programme offered to students between the ages of 16-19 that intends to provide students with transferable and lifelong skills and competences in preparation for further or higher education, apprenticeships or employment.

[4] The reference points for this analysis include: Matematikk R1 and R2; Matematikk S1 and S2; Biologi 1; Kjemi 1; and Fysikk 1.

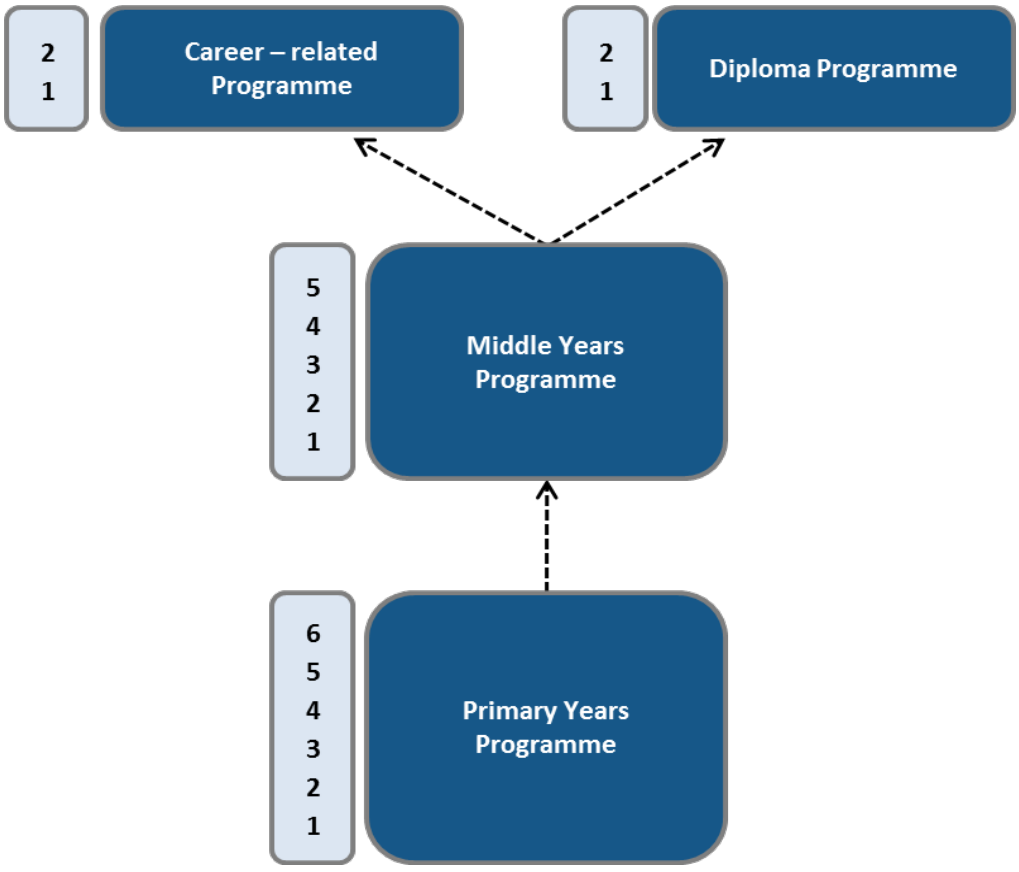
- In what ways do the DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL approaches to assessment align or differ with similarly-focussed upper secondary subjects in Norway?
- Are there differences in the cognitive demand between DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL; and similarly-focussed upper secondary subjects in Norway?

Brief overviews of both systems are provided below to help contextualise the subsequent comparative analysis and findings.

1.1.1 The IB Diploma Programme

The IB DP is a two-year programme offered to students between the ages of 16-19 in authorised schools, referred to as IB World Schools. The IB World Schools can deliver any of the four individual IB programmes or offer them as a continuum. When taken as a continuum, the progression of the IB programmes can be seen in the figure below. Equally, students can enter any of the below IB programmes without previous experience in an IB programme.

Figure 1: Progression of the IB programmes



Schools offering the IB programmes are expected to assist students to become IB Learners. The IB Learner Profile sets out the academic and non-academic attributes which all IB programmes are designed to develop, namely that the IB Learners are[5]:

- Inquirers
- Knowledgeable
- Thinkers
- Communicators
- Principled
- Open-minded
- Caring
- Risk-takers
- Balanced
- Reflective.

No entry requirements are set for the IB DP, as students can come from the IB MYP and/or other qualifications or prior study. For some, but not all, students, the DP may be their first exit qualification for secondary school.

Students of the full DP study six courses chosen from the following subject groups:

Table 1: IB DP Programme subject groups

IB DP Subject Groups[6]
• Studies in Language and Literature • Language Acquisition • Individuals and Societies • Sciences • Mathematics • The Arts.

Most subjects are offered at both higher level (HL) and standard level (SL), and students must take a combination of subjects from both levels, with three or four at HL. The HL subjects are studied in greater depth and breadth than those at SL and with more teaching hours (240 hours for HL and 150 for SL).

Their subject studies are complemented by the DP core, which incorporates:

- A theory of knowledge course (TOK) that allows for reflection on learning in all subjects
- An extended essay of 4,000 words on a topic of interest researched independently
- 'Creativity, activity, service' (CAS) – a student project on the CAS concepts.

[5] For the full IB Learner Profile, please visit: http://www.ibo.org/contentassets/fd82f70643ef4086b7d3f292cc214962/learner-profile-en.pdf

[6] Students may opt to study an additional Science, Individuals and Societies, or languages course, instead of a course in the Arts.

There is an option for students who are not enrolled in a full DP to take individual DP courses and assessment in order to receive a Diploma Programme Course result (DPCR). A DPCR can also be awarded to full DP students who do not meet the minimum requirements for a full DP.

All IB DP courses are assessed through a combination of external and internal assessment. Internal assessment is nonetheless to be based on guidance from the IB which typically covers: the purpose of internal assessment; general expectations on the role and responsibilities of the student and teacher in conducting the assessment; guidelines on acceptable uses of group work, where applicable; recommended time allocation; and assessment criteria with accompanying marks and achievement level descriptors.

Students receive marks for each assessment that are combined for a final grade in each DP course. These grades range from 7 to 1 (7 is the highest score). The results of each course are combined for a total score in the DP. To receive the full DP students must achieve a minimum of 24 points in addition to successful completion of the DP core.

1.1.2 The Norwegian upper secondary education system

Entry requirements

Students have the statutory right to upper secondary education; subject to completion of ten years of compulsory primary and lower secondary education with no specified grades. However students with higher grades in the national examinations taken in the final year of lower secondary education (Grade 10) are more likely to be accepted into their preferred choice of upper secondary school and programme (European Commission, 2018a).

Duration

The Norwegian upper secondary qualification (henceforth referred to as the Vitnemål for Videregående Opplæring or Norwegian programme) is a three year upper secondary qualification designed to prepare students, typically aged 16-19, for higher education study. The first, second and third year of study are called Vg1, Vg2 and Vg3 respectively.

Programme structure and content

Students can choose between general study programmes and vocational study programmes. There are currently five general study programmes designed to prepare students for a different area of higher education study. Alternatively, students who want apprenticeship training can opt for one of the eight vocational study programmes offered; this is generally a four year programme.

The table overleaf outlines the national programmes offered:

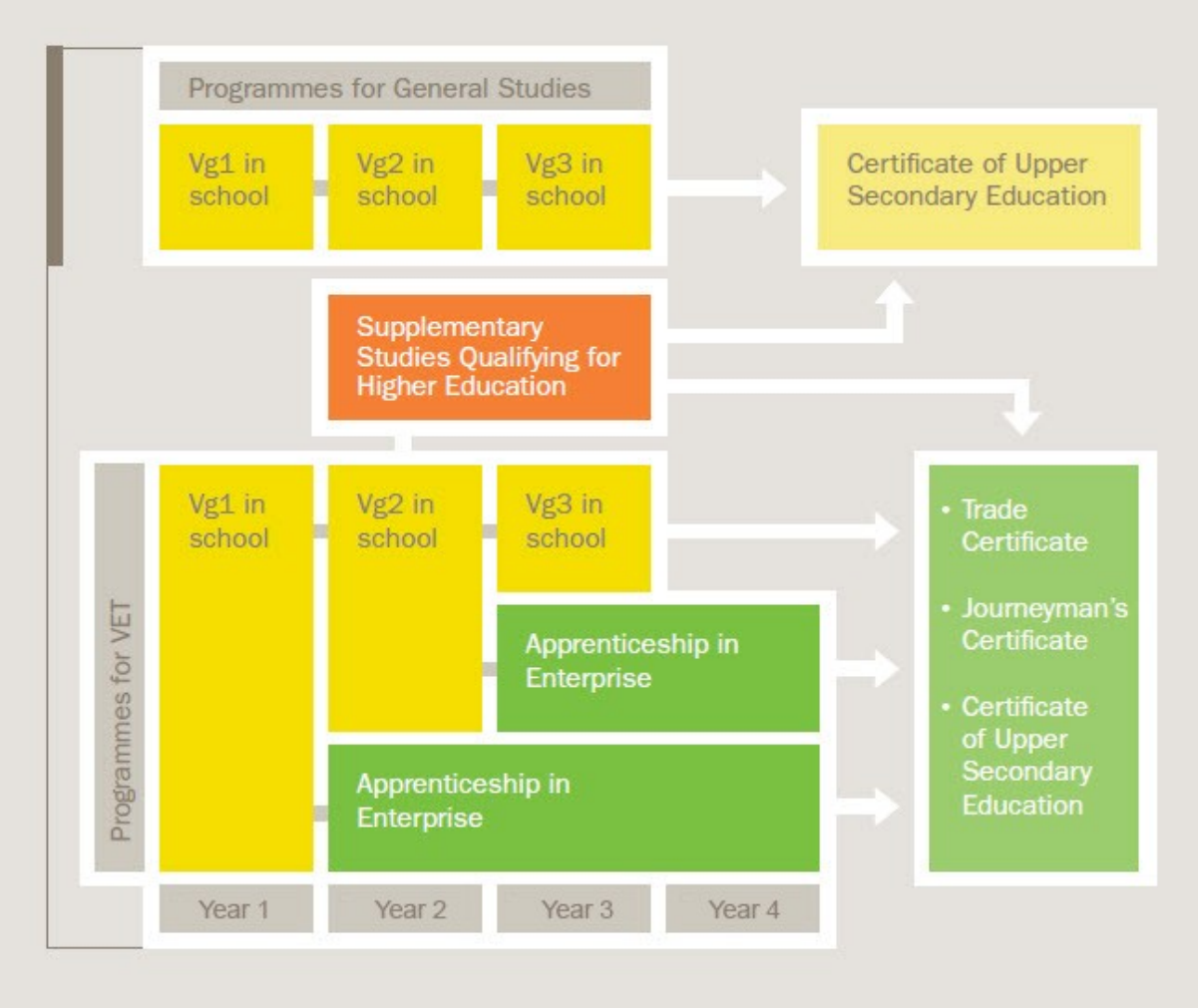
Table 2: Norwegian national programmes in upper secondary education (Utdanningsdirektoratet, 2016e)

General Study Programmes	Vocational Study Programmes

• Art, design and architecture
• General studies with a subject area specialisation
  o Arts, crafts and design
  o Languages, social sciences and economics
  o Natural science and mathematics
• Media and communication
• Music, dance and drama
• Sports and physical education.
	• Agriculture
	• Building and construction
	• Catering and food processing
	• Design and handicraft
	• Electrical engineering
	• Healthcare, childhood and youth development
	• Service and transport
	• Technical and industrial production.

Structurally the upper secondary education programmes can be presented as follows:

Figure 2: Structure of the Norwegian upper secondary programmes



Source: Upper Secondary School (Utdanningsdirektoratet, 2016c)

For the general study programmes, in addition to core subjects in each programme, students select additional subjects from an approved list in relation to their chosen subject area

specialism. Further training is provided for students in the music, dance and drama or sports and physical education programmes while students in the general studies programme can select additional subjects from either arts, crafts and design; languages, social sciences and economics or natural science and mathematics.

During the three-year programme students must complete eleven subjects common to all streams: English, another foreign language, geography, history, physical education, mathematics 1 and 2, natural sciences, Norwegian, religion and ethics, and civics, in addition to subjects specific to a student's chosen stream. Typically in their final year of study, students take a total of seven subjects (UK NARIC, 2017).

Students in the vocational programmes are also given the opportunity to gain access to higher education by completing a supplementary one year Vg3 course in their third year to achieve a general university admission qualification (Utdanningsdirektoratet, 2016d).

Governance

Education goals and budgetary frameworks are centrally established by the Norwegian parliament (*the Storting*) and government. The Ministry of Education and Research, with the assistance of the Norwegian Directorate of Education and Training (*Utdanningsdirektoratet*), is the main government body responsible for all levels of education, in particular, implementing national education policies, developing the national curriculum and ensuring quality of education.

The National Curriculum for Knowledge Promotion defines goals in terms of competencies and five basic areas of skills to be developed across all subjects and also provides regional authorities (municipals and counties), schools and teachers considerable freedom within the national curriculum framework to make decisions on the learning content, teaching materials and instruction methods. The municipal authorities are responsible for running primary and lower secondary schools while the county authorities are responsible for running upper secondary schools (Ministry of Education and Research, 2018).

Assessment

The Norwegian Directorate for Education and Training is responsible for developing, implementing and organising the external written exams. External written exams are organised in accordance with the "*rammeverk for sentralt gitt skriftlig eksamen"* (framework for centrally set written exams). Exam questions are written by the Directorate for each general studies subject[7] based on the notion of competence, which in Norway is defined as "the ability to solve tasks and handle complex challenges". All written exams are assessed by two external assessors in line with the central framework and guidelines from the Directorate. The oral exams are designed by school teachers, in accordance to the national curriculum and implemented with the approval of an external assessor (Utdanningsdirektoratet, 2018b).

[7] Exams for vocational subjects are designed by professional councils (*fagnemnd*) under supervision of the regional county councils.

Regional councils appoint assessors and organise the work of the external assessment of exams. Individual schools are responsible for facilitating internal and external exams, as well as selecting which students are to be externally examined in certain subjects based on guidelines from the Directorate (Utdanningsdirektoratet, 2017).

The certificate for the Vitnemål for Videregående Opplæring qualification is composed of the overall achievement mark for each subject, and an examination grade, where relevant, typically for five or six selected subjects. The overall achievement marks are based on internally conducted classroom assessments performed throughout the school year while the externally conducted end of year examinations can be written, oral or practical as stipulated in the subject curricula.

Students are selected for external examinations at various points during the three-year upper secondary stream. Approximately 20% of students will be chosen to sit one exam; either a written, practical or oral exam in the first year. In the second year, all students are required to sit an exam (written, oral or practical) in one subject. In the third year, all students must sit a written exam in Norwegian language and two other subjects as well as one oral or practical exam. The school choses the subjects the students will be externally examined in, but the regional county council make sure the subjects are chosen evenly over time across the county (Utdanningsdirektoratet, 2018c).

Most written exams are taken on a computer and students must log in with a personal username and password. Students may use a limited set of tools during exams, such as calculators, dictionaries and online databases. A small selection of subjects also allows free use of the internet. The guidelines for each exam define which tools are allowed (Utdanningsdirektoratet, 2016b). Students are given access to exam guidelines one day before a written exam and two days before an oral exam, to allow them to practice under the supervision of their teacher (Utdanningsdirektoratet, 2017).

Grading system

The grading system, shown in the table below, is typically applied to both internal and external assessments for each subject with a pass mark of grade 2 (UK NARIC, 2017).

Table 3: General grade scale for Norwegian upper secondary school assessment (Utdanningsdirektoratet, 2016a)

Grade	Description
6	Exceptionally high degree of competence in the subject
5	Very high degree of competence in the subject
4	High degree of competence in the subject
3	Fair degree of competence in the subject
2	Low degree of competence in the subject (lowest pass grade)
1	Very low degree of competence in the subject

External exams are graded by external assessors based on exam and assessor guidelines, which are sent to all assessors prior to marking the exams. Guidelines explain how much weighting should be applied to each question and parts of the exam. The suggested weighting may be adjusted after a group of experienced assessors conduct a *forhåndssensur* (pre-assessment) on a selection of the completed exam answers in order to identify whether any questions were more difficult to answer than expected. The final grade is, however, determined by the assessors' holistic evaluation of all the answers and how the candidate's answers show the degree of understanding of the curriculum.

Students who have met the minimum requirements for university admissions are known to have achieved the *studiekompetanse;* noted on the top left-hand side of the student's academic transcript. Students who have not met the minimum graduation requirements will receive a certificate of competence known as *Kompetansebevis* (UK NARIC, 2017).

1.2 Structure of the Report

Section 2 of the report includes the methodology used to complete the study. Section 3 outlines the main findings of the comparative analysis and addresses each research question in turn. Section 4 provides the conclusions and key points from the analysis while Section 5 lists the references cited within the report.

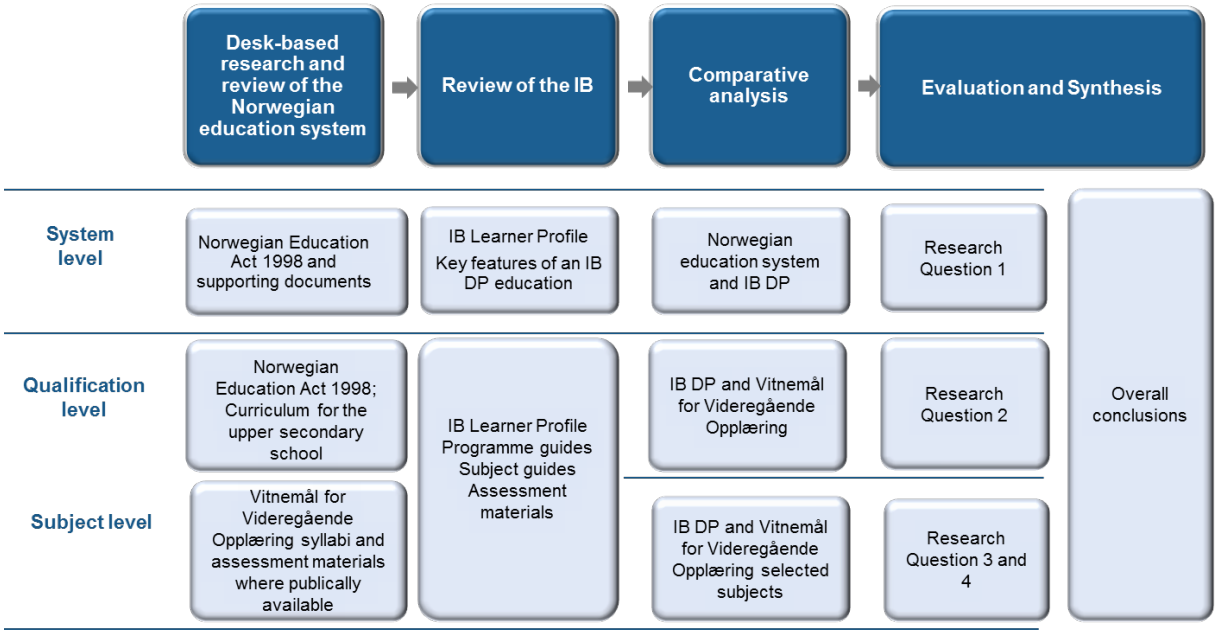
2. Methodology

To address the research questions and conduct a reliable comparison of the IB qualifications against the previously identified focal points in the Norwegian education system, the study included three key phases:

- Desk-based research and document review:
  - For the Norwegian school system
  - For the IB DP
- Comparative analysis
- Evaluation and synthesis.

The process can be illustrated as follows:

Figure 3: Methodological process



2.1 Desk-based research and document review

This stage involved firstly collating information pertaining to the IB DP, including the programme content, structure, assessment methods, learning outcomes and the educational philosophy, aims and objectives that underpin it. Similar information was also gathered on the Norwegian school system, as available in the public domain. This included the Vitnemål for Videregående Opplæring subject specifications and curriculum documentation. The Norwegian Education Act of 1998 and National Curriculum documentation were used to identify the underpinning philosophies, overarching goals and programme-specific intended learning outcomes, and the pedagogical approaches advised.

A full list of the sources cited within the report can be found in Section 5.

Next, the project team conducted a review of the education policies and goals, alongside curriculum and programmes as a whole, to contextualise the review of the IB DP and Vitnemål for Videregående Opplæring subject specifications and inform any methodological considerations. For Research Questions 1 and 2, the analysis centred on the Norwegian Education Act of 1998, National Curriculum documentation and relevant policy and subject curriculum documents.

A second, comprehensive qualitative analysis was undertaken to code emerging themes in the Norwegian upper secondary system in preparation for the subsequent comparative analysis.

2.2 Comparative analysis

The second stage of the project, the comparative analysis, comprised three tiers as shown in Figure 3:

- System level analysis: comparison of the IB DP aims and underpinning philosophies with key objectives for the Norwegian school system as set out in the Norwegian Education Act of 1998 and the Norwegian National Curriculum documents
- Qualification level analysis: comparison of the IB DP principles, practices and standards with the pedagogical and learning approaches, and the intended learning outcomes for the Vitnemål for Videregående Opplaering
- Subject level analysis: comparison of the IB DP curriculum and assessment, in particular to:
  - Compare the IB DP content, structure and intended learning outcomes with the Vitnemål for Videregående Opplæring in selected mathematics, biology, chemistry and physics subjects.
  - Compare the IB DP assessment methods and demand with the Vitnemål for Videregående Opplæring.

The overall focus of the comparative analysis was on identifying the extent to which the salient principles and features of the Norwegian upper secondary school education (Vitnemål for Videregående Opplæring) identified within the preceding stage (described in 2.1), were evident within the IB DP, being mindful of inevitable variations in terminology.

2.2.1 System and qualification-level analysis [Research Questions 1 and 2]

As outlined above, the comparative analysis began with the system-level analysis, comparing the philosophical underpinnings of the IB and Norwegian school education, since the principles and goals established at a national / overarching level should be reflected in the national school curriculum and assessment. This referenced the salient themes of the Norwegian system identified during the review, presenting them in the following format:

✔ Key theme 1
✔ Key theme 2…

These are accompanied by supporting detail on the Norwegian system. Using these themes as the benchmark, the project team then reviewed the IB DP materials to identify any similar

themes, thus determining whether the IB DP was aligned to the Norwegian upper secondary system.

In doing so, the report intends to provide a transparent yet concise comparative analysis of the Norwegian and IB upper secondary school goals, learning outcomes and approaches.

The expected knowledge, skills and competences of the Norwegian upper secondary school system are, to some extent, discussed within the comparison of overall goals. Nevertheless, the intended learning outcomes are briefly explored and compared by looking at the *Basic Skills* specified for the Vitnemål for Videregående Opplæring.

For the IB DP, reference has been made to documents such as:

- Diploma Programme: From principles into practice
- Diploma Programme assessment: principles and practice
- Approaches to teaching and learning in the Diploma Programme
- Programme Standards and Practices
- Learning in a language other than mother tongue in IB programmes
- IB Educator and Leadership certificates: University Directory 2018.

2.2.2 Subject level analysis [Research Questions 3, 4 and 5]

As outlined in the Introduction, analysis of the IB DP against the Vitnemål for Videregående Opplæring centred on the five subjects chosen by the IB: Mathematics (SL and HL), Mathematical Studies (SL), Biology (SL), Chemistry (SL), and Physics (SL).

The analysis identified and compared the Vitnemål for Videregående Opplæring and IB, for each subject, in terms of skills, aims and learning outcomes, structure and content, assessment methods and demand. No judgement of quality is made or intended on the programmes.

The findings of this comparative analysis were documented in tabular format, so that where sufficient evidence of similarity/alignment was found between the IB DP and the Norwegian system, a check mark (✓) was used. Where any aspect of the Norwegian system was not considered to be included within the IB, the cell was left blank and further explanation provided below the table. If there was evidence to show that the IB can be considered *partially* similar, a check mark with an asterisk was used (✓*). An example of the table format can be seen below:

Table 4: Example mapping table

[Reference Point in the Norwegian System]	Included in the IB
Key theme 1	✓*
Key theme 2	
Key theme 3	✓
Key theme 4	✓
Key theme 5	

For each table, a supporting analysis is provided to ensure transparency in the decision-making process. Any relevant key features or components of the IB which were not similarly found within the Norwegian upper secondary school system reference points were also identified within the text, where appropriate.

The table below identifies the syllabi used as the basis for comparison.

Table 5: Syllabi reviewed

Subject	Vitnemål for Videregående Opplæring	IB DP
Mathematics	Matematikk R1 og R2	Mathematics HL and SL
	Matematikk S1 og S2 and Matematikk R1 og R2	Mathematical Studies SL
Biology	Biologi 1	Biology SL
Chemistry	Kjemi 1	Chemistry SL
Physics	Fysikk 1	Physics SL

Content and Structure (Research question 3)

For each subject, we reviewed the number and range of topics studied to determine and compare the general breadth and depth of the courses. The core topics studied were also compared using the mapping table (Table 4) demonstrated above.

The analysis also compared the recommended teaching hours of the course (as a proportion of the full qualification) where comparable data was identified.

The skills, aims and intended learning outcomes of the IB DP and Vitnemål for Videregående Opplæring for the selected subjects were also compared in this section to inform the content and structure comparison.

Assessment methods and demand (Research questions 4 and 5)

The comparison of the IB DP and Vitnemål for Videregående Opplæring assessment first involved a comparison of overall assessment methods for the selected subjects; this noted where external and/or internal assessment is used and the relative weighting of the assessments to the overall grade.

Next, as the mandatory assessment for the Vitnemål for Videregående Opplæring courses is developed and delivered internally, and there are no prescribed guidelines or recommendations for this assessment, a more detailed comparison of assessment was conducted using the external written examinations and associated grade descriptors for each course, where available in the public domain.

The demand of the assessment in each subject was also considered in this analysis. Whilst there are a number of factors which can impact assessment demand, the difference in the

use of internal and external assessment in the Vitnemål for Videregående Opplæring and IB DP make this difficult to compare in-depth.

Where Vitnemål for Videregående Opplæring examination papers were available (all four of the mathematics courses (R1, R2, S1 and S2) the analysis focussed on the overall type(s) of assessment employed, the number and type(s) of questions posed and the duration of the exam(s).

The science courses reviewed for this study (Biology 1, Physics 1 and Chemistry 1) are assessed entirely through internal assessment methods and therefore, no external written examinations are available for these subjects. As an alternative, the science subjects offered in the final year of the Vitnemål for Videregående Opplæring (Vg3) were examined at this stage of the analysis (i.e. Biology 2, Physics 2 and Chemistry 2) as external written examinations are conducted in these courses; however only the Biology 2 external written examination was available publically.

Grade descriptors are used by both the Norwegian and IB DP courses to distinguish the characteristics of student performance at different grades and these were available publically for all Norwegian courses reviewed in this study. As such a detailed comparison of the IB DP and Vitnemål for Videregående Opplæring grade descriptors was conducted for each subject. The analysis, whilst accounting for differences in the construct and application of the descriptors, focussed on identifying any similarities and / or differences in the range of assessed skills and compared the expected levels of student performance at different grades.

Consideration was also given to the marking approaches used between the two programmes, including overall processes and guidance for markers, as it was observed that, despite the presence of grade descriptors and occasional mark allocation within the Vitnemål for Videregående Opplæring examinations, examiners are instructed to award an overall grade based on their own judgement of the examination as a whole.

2.2.3 Evaluation and synthesis

The final stage of the project involved drawing together the key findings and conclusions from the review and comparative analysis.

3. Findings

3.1 Research Question 1: Principles and General Objectives for Education

To what extent does the Diploma Programme align with Norwegian principles and general objectives for education including student personal development, the development of values in Christian and humanist heritage and traditions (e.g. equality and respect for human dignity and nature) and values that also appear in different religions and beliefs, active participation in society and the fostering of a lifelong desire to learn?

Education in Norway is governed by the Norwegian Education Act of 1998 that came in effect on 1st August 2010 with amendments made in 2014. The Education Act coupled with the national curriculum (i.e. core curriculum, quality framework, subject curricula and distribution of teaching hours) shape the objectives and principles of the Norwegian education system. Review of this found close alignment with the IB DP education.

✔ Education should develop knowledge, skills and attitudes that prepare students for the next stage of study, work and life to become active members of the society

The Education Act emphasises that education should "open doors to the world" and "develop knowledge, skills and attitudes so that they can master their lives and can take part in working life and society". The core curriculum further expands on these statements "The purpose of upper secondary education is to develop the skills, understanding and responsibility that prepare pupils for life at work and in society, to provide a foundation for further education, and to assist them in their personal development".

The IB DP programme closely aligns with this principle; specifically designed to "equip students with academic skills needed for university study" in addition to supporting the "development of the values and life skills needed to live a fulfilled and purposeful life". The IB DP intends to develop in-depth subject knowledge across a range of subject groups and, through the DP core, 21st Century skills. In particular, the DP is designed to develop and assess independent research, extended writing, constructing arguments, drawing conclusions, making inferences and academic referencing from an Extended Essay element; reflective learning, oral communication and critical thinking from Theory of Knowledge and creativity, planning and organisational skills from Creativity, Activity and Service (CAS) element.

Furthermore, in the GSU list (*Generell studiekompetanse for utenlandske søkere* / Higher Education Entrance Qualification for foreign applicants list), the IB DP is one of the accepted international higher education entrance qualifications for admission by higher education institutions in Norway; with the minimum grade requirements specified to be grade 3 or above in all subjects (i.e. 3 subjects at standard level and 3 subjects at higher level or 2 subjects at standard level and 4 subjects at higher level), at least 20 points including any points for Theory of Knowledge and Extended Essay and authenticated participation in the CAS element (NOKUT, 2018).

The higher education performance of IB DP students have been reviewed in a number of independent studies. In general, IB DP students perform well in university; IB DP students benefit from 21st century skills developed from the three DP core elements that prepare them for coursework and independent university study. For example, a study on the postsecondary outcomes of IB DP alumni in leading universities in Asia-Pacific region, reported that IB DP alumni have higher capacities of a range of 21st century skills compared to non IB DP students that prepared them for higher education, particularly in classroom discussions, group work and written and oral communication (Lee,M., Spinks,J., Wright,E., Dean, J., Ryoo,J.H., 2017).

Further, the IB DP aims to provide a holistic education experience, going beyond acquisition of knowledge and skills to concern the "whole person" including the students' social, emotional and physical wellbeing.

As part of this, IB DP emphasises on students' active participation in society with the CAS element of the DP core, offering students the opportunity to participate in community activities. In addition "students also need to develop the "will to act" and the skills and values necessary to make a positive contribution to society. Responsible citizenship is based upon compassionate and well-informed citizens who become proactively involved in their communities. It is also important to encourage young people to enjoy life to the full, and educating the whole person includes exposure to artistic, recreational and sporting activities that can enrich experience".

✔Education should be based on fundamental values of Christian and humanist heritage and traditions and values that also appear in different religions and beliefs and are rooted in human rights

The Education Act describes the fundamental values in Christian and humanist heritage and traditions as respect for human dignity and nature, intellectual freedom, charity, forgiveness, equality and solidarity.

In the theme of equality, the Education Act states that "education is a statutory right of all students", "education should promote democracy" and "education establishments should treat students with trust and respect without discrimination".

The IB encompasses several aspects that closely align with this principle. In particular IB aims to develop international minded people that recognise "their common humanity and shared guardianship of the planet, help to create a better and more peaceful world" coupled with attitudes in the IB learner profile that include:

- A principled learner that acts with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere and take responsibility for our actions and their consequences
- A caring learner that shows empathy, compassion and respect and commitment to service, and act to make a positive difference in the lives of others and in the world around us.

The IB DP, although secular, promotes acceptance of religion. The attributes of an IB principled and caring learner shares many similarities to the Christian and humanist values specified in the Norway Education Act such as respect for human dignity, charity, forgiveness, equality, solidarity and tolerance.

These aspects are also integrated into the teaching and learning approach of IB DP, that is based on a cycle of inquiry, action and reflection that promotes a democratic environment in the context of classroom where principled actions that "encompasses a concern for integrity and honesty, as well as a strong sense of fairness that respects the dignity of individuals and groups" are valued.

The concept of education equality is evident across all IB materials; in particular the emphasis of adapting a tailored teaching approach termed differential learning to cater to the diverse learning styles and needs of all students.

✔Education should develop knowledge and understanding of the national cultural heritage and common international cultural traditions

An important objective and principle of the Education Act is to develop national and international cultural awareness, as part of which, education should provide insight into cultural diversity, show respect for the individual's convictions" and provide historical and cultural insight and anchorage.

Intercultural understanding and cooperation is at the heart of IB's mission and is infused into the curriculum (i.e. subject aims, objectives, content and assessment criteria) where learning fosters appreciation of many beliefs, experiences, ways of knowing and understanding of the local/national and global rich culture and heritage.

The DP core elements encourage "multicultural perspectives and experiential learning beyond the traditional classroom" and on a subject level, most subjects incorporate cultural elements. For example arts stresses on the "exploration of arts within the students' own and other cultural contexts with respect for, and understanding of, cultural and aesthetic differences", mathematics emphasise on "the universal language of mathematics and its origins in the world's great civilizations" and languages encourages developing "skills that enable learners to mediate between people from different societies and cultures".

In addition the IB intends to develop an open minded learner that critically appreciates their own cultures and personal histories, as well as the values and traditions of others and seek and evaluate a range of points of view, and is willing to grow from the experience. The attributes of an IB open minded learner exhibits understanding of own culture heritage and history and cultural diversity; closely aligned to the principles of the Norwegian education.

✔Education should teach students to act ethically with environmental awareness

As outlined in the Education Act, education should teach students to "learn to think critically and act ethically and with environmental awareness. They shall have joint responsibility and the right to participate". The core curriculum further describes that industrial nations with a

high level of education have a special responsibility for ensuring the common future of the world thus education should provide a “broad awareness of the interconnections in nature and about the interplay between humans and their habitat”.

Global engagement is central to the IB education philosophy with the aim of producing global citizens who are committed to addressing global humanity challenges that include sustainability issues and “recognize that they hold the Earth and its resources in trust for future generations”.

This vision extends to the teaching and learning in the IB, particularly in the prominence of principled action learning that stresses on acting ethically “making responsible choices, sometimes including decisions not to act” and IB World schools are encouraged to provide education outside the classroom that involve “Adventure” activities such as field work, giving students a valuable opportunity to develop environmental awareness and engage in discussions and debates about sustainability issues.

✔Education should develop creative, critical, inquisitive and scientific thinking that facilitates a lifelong desire to learn

The Education Act outlines that education should give students’ the opportunity to be “creative, committed and inquisitive”, promote scientific thinking and give them challenges that promote formation and the desire to learn. The core curriculum reiterates this principle “Education shall impart in the learner a zest for life, the courage to tackle it, and a desire to use and extend what they learn”.

An essential goal of the IB’s mission statement is to encourage students to become lifelong learners, in particular, as set out in the IB Learner Profile, the IB strives to develop learners that are “inquirers” with inquiring and research skills that fuel lifelong learning; critical and creative “thinkers” with problem solving skills; “risk takers” with the ability to approach challenges with creative and innovative strategies and “reflective” with reflective learning and critical thinking skills.

3.2 Research Question 2: Qualification Principles, Practices and Standards

How do the principles, practices and standards of the DP compare with the overarching pedagogical and learning approaches, as well as the intended learning outcomes, for the 'Vitnem å l for Videreg å ende Opplæring'?

3.2.1 Pedagogical approaches

The pedagogical approaches implemented in all Norwegian schools are defined by the Norwegian Directorate of Education and Training in the Norwegian national curriculum. The Norwegian national curriculum encompasses the core curriculum, quality framework, subject curricula and distribution of teaching hours. These pedagogical approaches are further described in supporting documents provided by the Norwegian Directorate of Education and Training on customised training, assessment practices, school environment and classroom management (Utdanningsdirektoratet, 2018a). As mentioned in Section 1.1.2., although the curriculum and subject content is stipulated by the Norwegian Directorate of Education and Training; schools and teachers have the flexibility to select teaching material and methods within the national curriculum framework.

The overarching pedagogical practices in Norway are drawn from the national curriculum, and supporting documents on teaching provided by the Norwegian Directorate of Education and Training. Teachers in Norway should:

✔Create a supportive and safe psychosocial learning environment

The Norwegian national curriculum states that the classroom environment should promote the physical and mental health and well-being of the students. In particular, all schools must "safeguard the worth and virtue of childhood and adolescence".

The IB DP education is holistic in nature; addressing the social, emotional and physical well-being of the student along with their cognitive development. Although the IB does not specifically describe safeguarding, the IB World Schools have systems in place to provide counselling to all IB DP students on their social and emotional learning including assessment. Counsellors serve as a link between school and families to ensure students receive a holistic education (International Baccalaureate, 2015).

✔Create an effective and motivating learning environment by employing a range of learning strategies

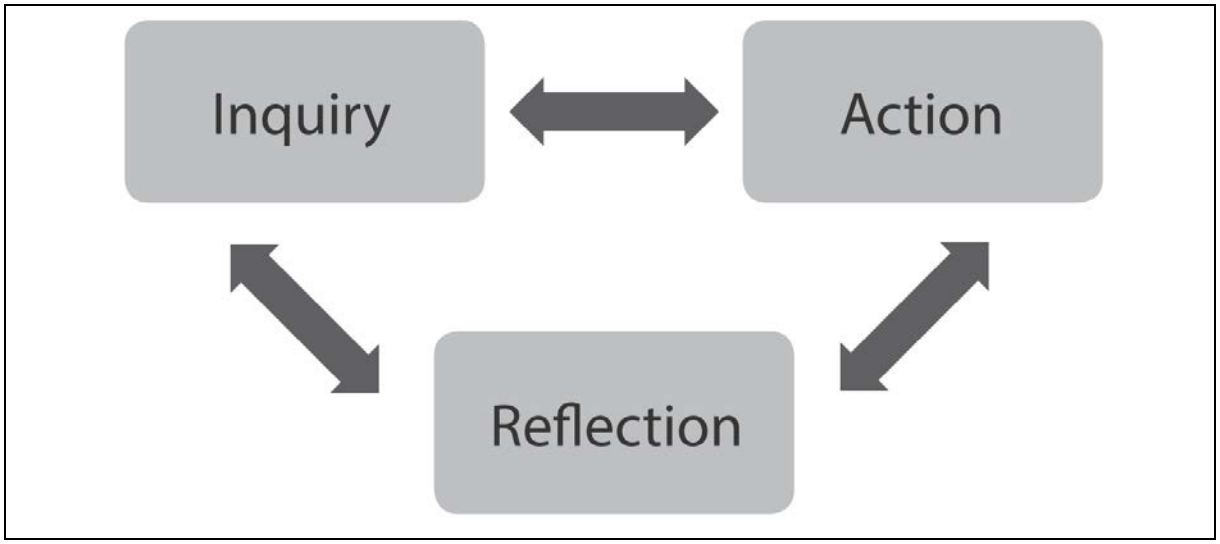
The National curriculum and the supporting documents on learning strategies by the Norwegian Directorate of Education and Training emphasises that students should be exposed to a variety of teaching and learning strategies to keep them engaged and motivated to learn ("Teaching must be seasoned so that the young can savour the joy of discovery to be found in new skills, in practical work, research, or art"). In order to be effective learners, the Norwegian national curriculum specifies that teaching should enable students to be self-regulated learners with metacognitive skills. Teachers are also

encouraged to challenge students with problem solving and practical activities and give students the opportunity to explore (Utdanningsdirektoratet, 2015b).

Similar to the Norwegian system, the IB DP aims to use a range of teaching and learning methods to support students to be responsible for their own learning. The IB DP stresses on a constructivist approach to teaching and learning, where the "teacher is viewed as a supporter of student learning, rather than a transmitter of knowledge".

Less explicitly described in the Norwegian system is the design and implementation of teaching practices. Alternatively the IB DP documents describe how IB principles can be put into practice using a range of methods, specifically, the cycle of inquiry, action and reflection (shown in the figure below) is recommended as a basis upon which the design and implementation of classroom teaching practices can be built on.

Figure 4: Cycle of inquiry, action and reflection



Source: Diploma Programme: From Principles into Practice (International Baccalaureate, 2015)

A key pedagogical principle of the IB is inquiry based learning that includes experimental learning and problem-based learning. Teachers are encouraged to promote inquiry based learning through facilitating students to inquire and find answers for themselves, rather than simply giving them the answers.

Further, teachers are expected to develop cognitive, affective and metacognitive skills in students that enable them to become self-regulated learners that "have learned how to set learning goals, ask good questions, self-interrogate as they learn, generate motivation and perseverance, try out different learning processes, self-monitor the effectiveness of their learning, reflect on achievement, and make changes to their learning processes where necessary" (International Baccalaureate, 2015).

✔Prepare students to be active members of a democratic and multi-cultural society

The Norwegian national curriculum emphasises on developing democratic ideals and broad cultural understanding in students, in particular, teachers are expected to:

- "Encourage students to take part in decisions on one's own and the group's learning

- Encourage cooperation, dialogue and difference of opinion in the classroom
- Enable students to acquire knowledge on different cultures and experience a wide range of forms of expressions
- Promote cultural understanding and develop self-insight and identity, respect and tolerance".

The IB DP constructivist approach to teaching and learning promotes open classroom discussions where different views and perspectives are valued. The IB DP emphasise on an inquiry based learning method that is "driven by student's own decisions about appropriate ways in which an issue or scenario might be approached". Further, the IB DP recommends that each student is actively engaged in a range of collaborative activities including group projects, debates and role plays, with a high degree of interaction, discussion and cooperation between the students and teachers and also between the students themselves.
As discussed in research question 1, intercultural understanding is central to an IB education where one's own perspective, as well as the perspectives of others, are acknowledged and respected. IB education also promotes multilingualism that facilitates intercultural understanding. Further the IB strives to develop learners that are communicators, open minded and carers (International Baccalaureate, 2015).

✔Customise and differentiate teaching to meet the needs of all students

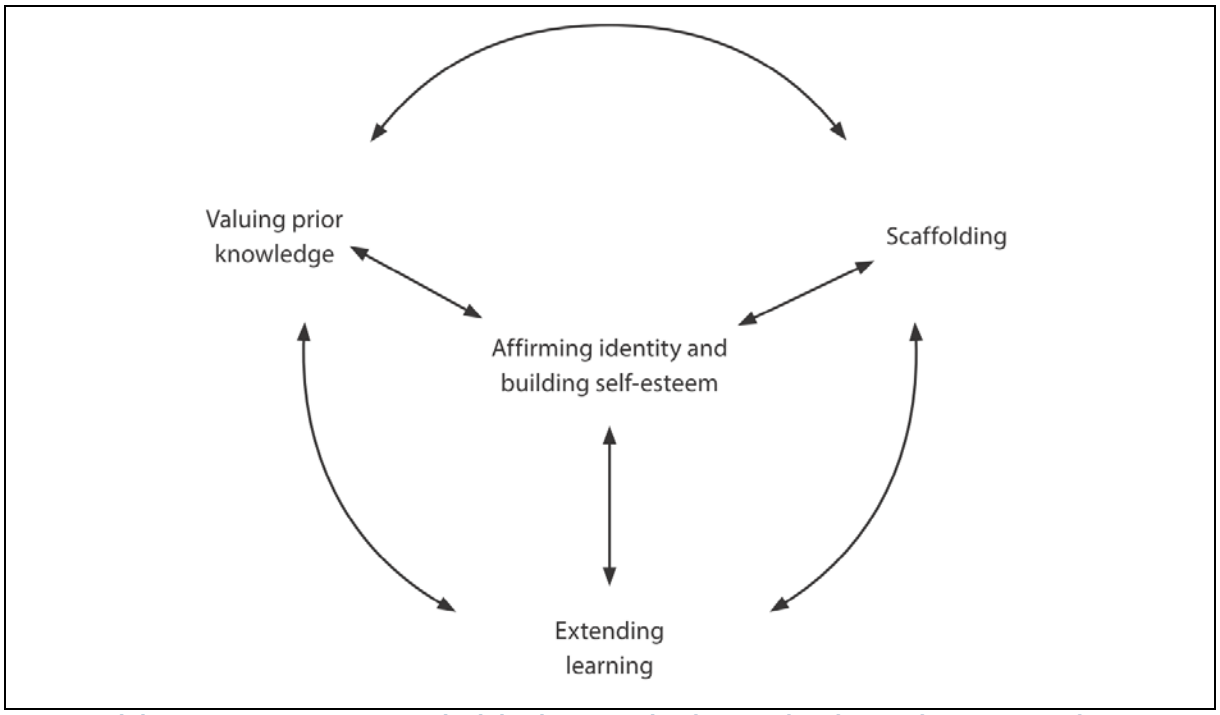
The Norwegian national curriculum and supporting documents on customised training by the Norwegian Directorate of Education and Training outlines several teaching methods to adapt and customise teaching to meet the different needs of individual learners and the mixed abilities of the entire class. These teaching methods are:

- "All students should learn in an inclusive community where equal opportunities are provided to all students
- The students experience, skills and potential will be taken into use and challenged in the classroom
- Students are taught to appreciate themselves and experience being appreciated by the school and fellow students
- Design technology supported teaching and learning courses for different student groups
- Guide students' learning in technology classrooms
- Use varied images and mind maps to make a point or demonstrate a common pattern and draw material and illustrations from diverse experiences of different students" (Utdanningsdirektoratet, 2015c).

A key element of the teaching and learning approaches of the IB DP is to provide an inclusive education and differentiate learning to meet the individual needs of all students. All IB World Schools are expected to respond positively to each individual's unique needs and actively seek to remove barriers to learning and participation. Further, the IB addresses the diverse language profiles of students in teaching including those for students learning in a language other than their mother tongue; particularly relevant for education in Norway, where IB programmes may not be taught in Norwegian (International Baccalaureate, 2008).

Differentiated teaching in the IB DP is implemented through four main principles, (shown in the figure below) which support the development of the whole person through differentiated teaching and learning.

Figure 5: Principles of good practice for differentiated learning



Source: Diploma Programme: From Principles into Practice (International Baccalaureate, 2015)

These four principles share many similarities to the customised teaching practices implemented in Norway. Similar to the teaching practices in Norway, the teaching practices of the IB DP place value on the different cultures and perspectives of students. Likewise prior knowledge of students are valued and used as a foundation upon which new learning occurs. The IB DP implement scaffolding to enhance and support learning through a variety of teaching tools that include but are not limited to visual aids, graphic organisers, demonstrations, mind maps, collaborative learning groups and peer support. The learning of IB students is further supported through the use of information technology to allow communication and collaboration between students on different sides of the world and to complete coursework assignments.

✔Provide sound subject knowledge that is relevant to their present and future

The Norwegian national curriculum states that “a teacher must know a subject well in order to teach it with skill and authority and to be able to sate children’s thirst for knowledge and zest for action”. Further the knowledge students acquire in schools should be “relevant to their present and future” and that “different parts of education are related to each other”.

The IB DP offers a broad and balanced curriculum where students study six subjects alongside three core elements that provide students the opportunity to apply knowledge acquired in real-life contexts. The six subjects cover a wide range of subject fields including

languages, individual and societies, arts, science, mathematics and interdisciplinary subjects such as environmental systems and societies, and literature and performance.

Teaching of the IB DP curriculum is based on the principles of "conceptual understanding" and "concurrency of learning". Teaching through concepts allows students to organise ideas and formulate understandings that have relevance within and across subjects, develop a deeper understanding of the subjects and promotes interdisciplinary and transdisciplinary learning.

In the IB DP, all subjects and the core elements are taught concurrently, enabling students to approach concepts from a variety of perspectives and build a degree of interdisciplinary and transdisciplinary as well as subject specific understanding.

Moreover, teaching in the IB is developed in local and global contexts where students are provided opportunities to explore a range of local and global issues such as climate change, international conflicts and the global economy (International Baccalaureate, 2015).

✔ Regularly assess and document student learning and provide learning-based feedback

The Norwegian national curriculum states that the most important pedagogical task is to convey to students that they are continuously making headway so that they gain trust in their own learning. Further the supporting documents provided by the Norwegian Directorate of Education and Training on assessment practices describe four principles of good assessment. These are:

- Students will understand what to learn and what is expected of them
- Students will receive feedback telling them about the quality of their work or performance
- Students will be advised on how they can improve
- Students will assess their own learning (Utdanningsdirektoratet, 2015a).

Similar to the Norwegian system, the IB DP emphasises the value of assessment for learning. Teachers have the responsibility to design ongoing formative assessments that provide detailed feedback to teachers and students on the students learning progress. Formative assessments also enable teachers to modify teaching or help students improve their learning to address the strengths and weakness of individual students (International Baccalaureate, 2004).

In addition, IB World Schools are expected to have systems in place to record and report students' progress and ensure that all students can demonstrate a consolidation of their learning through the completion of the IB DP core extended essay.

Some of the assessment instruments used by IB World Schools include but are not limited to:

- Student self-evaluation supported by the teacher
- Systematic use of detailed assessment criteria, rubrics or matrices

- Peer evaluation mediated by the teacher including face to face or information communication technology (ICT) resources such as blogs (International Baccalaureate, 2015).

✔ Receive support and training to fulfil their wider pedagogical responsibilities

The Norwegian national curriculum specifies that schools should actively support teachers to update their professional expertise and teaching qualifications through competence raising measures, in-service training and further education. Teachers should also be encouraged to collaborate with other teachers to plan, implement and assess their teaching and work together with parents, other professionals and authorities to address education matters.

Further, the competence of teachers should be assessed according to the requirements stipulated in the Norwegian Education Act, regulations and national curriculum.

The IB offers a range of professional development opportunities for all teachers that include:

- IB workshops and conferences that provide tailored support to teachers and address implementation of the IB programmes. Further IB endorsed workshops are offered across the world that can address education issues in a local context
- Educational programmes offered by the IB (the IB certificate in teaching and learning, IB advanced certificate in teaching and learning research, IB certificate in leadership practice and IB advanced certificate in leadership research) that can be taken at a number of universities worldwide. For example, the IB certificate in teaching and learning for the IB Diploma programme is offered in 25 universities across the world (International Baccalaureate, 2018)
- The Programme Resource Centre (PRC) is a website that provides teachers access to subject materials, teaching guides and forums that allow teachers to engage with other teachers.

Further, IB World Schools are expected to hire qualified staff, ensure staff comply with the IB professional development requirement for the DP and allocate time for teachers' collaborative planning and reflection (International Baccalaureate, 2014).

IB World Schools also work closely with local, state, provincial and national governments to address any local and state curriculum requirements that the IB DP needs to accommodate for and take into consideration (International Baccalaureate, 2015).

3.2.2 Intended Learning Outcomes

No overarching learning outcomes are set out for the Vitnem å l for Videreg å ende Opplæring or the different programme streams (i.e. general study or vocational study programmes). The Norwegian Education Act of 1998 sets out the main objectives for the education system as a whole, and the approaches to learning, examined in Section 3.1 and Section 3.2.1, respectively.

On a subject level, basic skills and competence aims for the content are prescribed; these are split into five categories of oral, writing, reading, numeracy and digital. The competence

aims are subject specific and relate to the content being taught. These include statements related to having and applying knowledge and understanding, making calculations, or carrying out studies. The basic skills, however, are common across all of the subject curriculums; although each subject curriculum provides further detail on how the skills should be developed within that subject. Overall the basic skills include:

- Oral
- Writing
- Reading
- Numeracy
- Digital.

These five skills were developed in the 2006 reform; all subject curriculums now state how these skills contribute to developing the competence as they are considered fundamental to the learning in each subject. They are seen as being the skills needed toward learning in school, work and social life. These basic skills are found across all of compulsory and secondary education in Norway and therefore a *Framework for Basic Skills* (Norwegian Directorate for Education and Training, 2012) further identifies how each skill should be developed throughout the students education with sub-categories defined on five levels, from Level 1 to Level 5, with the final level (Level 5) being the expectation for the end of upper secondary school and therefore the Vitnem å l for Videreg å ende Opplæring. The requirements for Level 5 are seen in the table below.

Table 6: Norwegian Framework for Basic Skills – Level 5

Oral	Writing	Reading	Numeracy	Digital
Understand and reflect: Can critically assess content and purpose of complex speech.	Plan: Can choose relevant writing strategies and use sources critically and verifiably. Can critically revise one's own texts.	Understand: Can choose and use reading strategies relevant to a wide variety of text types and purpose. Can assess one's own reading and reflect on the strategies applied.	Recognize and Describe: Can analyze a wide range of issues which can be described with a model. Can convert and formulate a model for further work.	Search and process: Can find, organize and update digital information. Can use advanced search strategies and sources in subject-related work.
Produce: Can apply spoken language and non-verbal resources independently and critically.	Construct: Can apply and make full use of specialized subject-related terminology and text types.	Find: Can obtain detailed and implicit information in texts without prior knowledge of text type and content.	Apply and process: Can apply a varied selection of problem solving strategies and is able to substantiate choice of methods. Can express connections with words and algebraic expression.	Produce: Can choose and use target group relevant digital tools and digital formal requirements. Can administer copyright rules to one's own digital products and master digital source referencing.
Communicate: Can discuss complex subject-related topics and	Communicate: Can build up a holistic argumentation. Can critically explore	Interpret: Can show holistic as well as detailed comprehension of	Communicate: Can present results from numeratic processes in texts	Communicate: Can choose, assess and apply digital communication

procedures using accurate subject-related terminology. Can present a holistic argumentation.	and problematize subject-related topics.	complex texts. Can systematize and draw conclusions based on implicit information.	in different subjects and in everyday life.	tools according to different subject-related needs.
Reflect and Assess: Can give responses and take turn fluently, effectively in different subject-related roles and situations. Can use different listening and speaking strategies and assess one's own performance.	Reflect and Assess: Can reflect critically on product and assess one's own learning when working with subject-related texts.	Reflect and Assess: Can assess complex texts about unfamiliar topics in a critical manner and incorporate subject-related as well as general perspectives.	Reflect and assess: Can compare different models and evaluate them in light of the problems they relate to.	Digital judgement: Can reflect ethically

✔Knowledge and understanding of subject content

The first overarching learning outcome shared by both the Norwegian and IB DP courses is the development of knowledge and understanding of subject-related content. Although the Norwegian *Framework for Basic Skills* (Norwegian Directorate for Education and Training, 2012) does not make this a key aim or skill, all of the skills relate to subject knowledge and understanding overall. For example, the skills and sub-categories that make reference to texts, content, sources and topics are subject dependent. Further, in some instances reference is made to part of the skill being "subject-related"; for example, subject-related terminology and subject-related topics and texts. Many of these skills, although related to knowledge and understanding, are linked to other learning outcomes, but overall the Norwegian students are expected to have comprehension and be able to discuss and apply what their knowledge of the subject content.

Similarly, according to the IB Learner Profile (International Baccalaureate, 2013), DP students are expected to be *Knowledgeable* and "develop and use conceptual understanding". On a subject level, the Group 4 aims specify acquiring subject related knowledge. Knowledge and understanding of concepts and terminology is also a Group 4 assessment objective.

✔Communicate and present arguments through various methods

One of the main Norwegian sub-categories across the five skills is to communicate (i.e. orally, in writing, through numeracy and digital means). Discussion of subject content and written arguments is expected. Similarly, the IB DP Learner Profile specifies that students should be *Communicators* that can express themselves through many means. IB DP students are further expected to be able to collaborate with others and listen to different perspectives. Listening strategies are also expected as part of the Norwegian student's ability to orally reflect and assess.

Communication through digital means is also emphasised in both the Norwegian and IB DP courses. In particular, the IB DP Group 4 (i.e. sciences) includes the aim for students to "develop and apply 21st century communication skills in the study of science" which may include the use of electronic communication and technology to conduct work or present results in project work (International Baccalaureate Organization, 2017). Similarly, the Norwegian skill *Digital* expects that students will develop the ability to use digital tools to find, communicate, and present information.

Developing and presenting (i.e. communicating) arguments is expected in both the Norwegian and IB DP courses. In the Norwegian courses, it is expected that students can present both verbal and written arguments. Although the IB DP similarly develops these skills, more emphasis is placed on expressing arguments in written form; however the Group 4 project may involve presenting findings in front of the fellow students.

✔Critical, reflective, and ethical thinking

Across all of the five Norwegian skills there is frequent reference to understanding the subject knowledge and being able to critically analyse or assess this information and relevant texts and sources. Similarly the IB DP Learner Profile aims for students to be *Thinkers* who demonstrate "critical and creative thinking skills to analyse and take responsible action on complex problems". Analysis and evaluation of information (including numeric information) is also emphasised in both courses; the Norwegian skills frequently refer to critically exploring subject topics, evaluating and assessing numerical models and issues. Analysing, evaluating and synthesising information is a key aim and assessment objective for the Group 4 subjects.

Critically reflecting on one's own abilities and work is also found in both courses. The Norwegian reading and writing skills reference that students should be able to reflect on and revise their own written text and assess what they have understood (from reading) and reflect on their reading strategies. Reflection is also key in the IB DP; the Learner Profile specifies that a *Reflective* student would "thoughtfully consider… [their] own ideas and experience[s]" and their own "strengths and weaknesses". Further, most of the Norwegian skills have the sub-category to *Reflect and Assess* which includes the ability for students to assess their own performance or learning.

Norwegian and IB DP students are further expected to be ethical thinkers. The IB DP Learner Profile expects *Reflective* students to be able to "exercise initiative in making reasoned, ethical decisions". The Norwegian *Digital* skill requires that students can reflect on the ethics surrounding the use of the internet and social media as a tool to communicate and present information. The ethical implication of using science and technology is also referenced in the IB DP Group 4 aim.

✔Mathematics – apply knowledge in new contexts

One overarching learning outcomes that is similar between the Norwegian *Framework for Basic Skills* and the IB DP mathematics courses (i.e. Group 5 courses) is for students to be able to apply their knowledge in new contexts. In particular, the Norwegian *Numeracy* skill

references presenting results for numeric processes in different subjects and in everyday life. Similarly, the IB DP expects that students taking a Group 5 course will be able to apply and transfer their mathematics skills in new situations. Application to real-world examples is also seen in the curriculum.

3.3 Research Question 3: Subject Content and Structure

In what ways does the content and structure of DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL compare with similarly-focussed upper secondary subjects in Norway?

3.3.1 Biology

Aims - Basic Skills

The Norwegian Biology guide includes a set of basic skills that are intended to be developed alongside and integrated with the topic level aims. These apply to both Biology 1 and Biology 2 and can be seen in the table below:

Table 7: Basic skills of the Vitnemål for Videregående Opplæring and IB DP Biology

Vitnemål for Videregående Opplæring– Biology 1		Included in the IB DP
Being able to express oneself orally and in writing in biology:	Involves accounting for one's own observations and indications from nature and the laboratory by applying subject-specific concepts	✓
	Includes being able to formulate questions and hypotheses that can be investigated, reasoned and discussed in relation to other biological information	✓
	Involves being able to critically assess various types of biological information in professional journals and the media	✓
Being able to read in biology:	Involves the ability to gather, interpret and reflect on the information found in newspapers, periodicals, books and brochures and on the Internet	✓*
	Involves being able to understand formulae, tables, diagrams and symbols	✓*
	Means studying new areas of the subject by understanding more advanced biological literature	✓*
Numeracy in biology:	Involves the ability to use numbers and mathematical computations, take readings and carry out simple statistical analyses, and work with and present the results of one's own observations	✓
	Means being able to understand and apply mathematical models from biological research	✓
	Involves understanding results in the form of graphs and tables	✓
Being able to use digital tools in biology:	Means gathering information and research, taking readings, and working with and presenting the results of one's own observations	✓
	Covers the use of animations and simulations to illustrate and explain scientific material	✓
	Involves evaluating scientific information found on the Internet.	

Overall, as seen in the table above the IB DP intends for students to develop similar skills to those referenced in the Norwegian Biology 1 guide. In particular, communicating scientific information and ideas is similarly expected. In regards to numeracy, the IB DP sets mathematical requirements. Further, use of ICT is encouraged in the IB DP and both animations and simulations are referenced as suggested practical tasks that teachers could engage students in.

The IB DP internal assessment indicates that experimental and investigative skills are intended to be developed, as set out in the table above. In particular, IB DP students are expected to develop skills related to developing research questions, making observations, collecting and analysing data and presenting the results. As indicated in the assessment objectives, IB DP students are also expected to be able to formulate, analyse and evaluate hypotheses within the course.

One difference is seen with the last Norwegian skill from the table above. The IB DP does not explicitly reference evaluating information from the internet; however, it is acknowledged that use of different sources and media is expected within the IB DP curriculum, including the internal assessment.

Aims - Subject Area

On a topic level the Norwegian Biology 1 programme prescribes 'competence aims' that indicate the aims of each main subject area. The below Biology 1 aims are compared with the IB DP in the table below:

Table 8: Aims of the Vitnemål for Videregående Opplæring and IB DP Biology

Vitnemål for Videregående Opplæring - Biology 1		Included in the IB DP
The Young Biologist	**The aims of the studies are to enable pupils to:**	
	Plan and implement tests in the laboratory from all the main areas, report on the work with and without digital tools, and point out sources of error in the tests	✓
	Carry out a major field study and use scientific methods to gather, chart and research different types of organisms, as well as present the results from the study	✓
	Observe and identify species from various biotopes and compare these with respect to common features and variation by using biological systematics	✓*
	Extract information from biological reports, brochures, newspapers, books and the Internet, and analyze how the information is supported	✓*
Cell biology	Give an account of the structure of eukaryotic cells and explain the functions of the various parts of the cells	✓
	Explain transport between the cell membrane based on an understanding of passive and active transport mechanisms	✓

Vitnemål for Videregående Opplæring - Biology 1		Included in the IB DP
	Give an account of the structure and reproduction of bacteria and viruses, and relate this to processes in nature, industry and healthcare	
Human physiology	Give an account of the structure and function of the central organ system in the body, and discuss causes of diseases associated with lifestyle	✓*
	Compare the hormonal and nervous systems and explain how these systems are affected by various substances	✓
	Give an account of the immune system and other elements of the body's defence mechanism against infection	✓
	Discuss problems associated with organ donations and medical criteria for death	✓
Function and adaptation	Compare the structure and function of organs in various animal groups, with emphasis on circulation, gaseous exchange and secretion, in the context of adapting to different environments and conditions	✓
	Give an account of the main features in the reproduction of plants and animals in the context of the development of life on earth	✓
	Explain how plants absorb and transport water and solutions, and discuss how plants can adapt to different environments and conditions	✓
	Discuss how external factors affect the growth and development of plants	✓
	Explain and substantiate how behaviour as a result of evolution is part of the adaptation to the surroundings	✓
Biological diversity	Explain what the term biological diversity covers, and discuss issues concerning the responsibility for safeguarding biological diversity locally and globally	✓
	Explain how a species is defined and how biological diversity is organized in a taxonomical system	✓
	Give an account of variation within and between populations of the same species, and explain what this variation means	✓
	Explain how biological diversity is linked with variation in habitat and niches in the ecosystem.	✓*

As seen in the table above, the majority of the Norwegian Biology 1 aims are covered in the IB DP Biology SL programme. As the aims are topic specific, many of these correlate to sections of the IB DP content curriculum.

The Norwegian aims related to the topics on *Function and adaptation* and *Biological diversity* are similarly included in the IB DP. Both aim for students to develop an understanding of circulation, gas exchange, reproduction in plants and animals, transport of water and

solutions, ethology (changes to behaviour as a result of evolution) and the influence of external environments on these processes. Further, biodiversity (referred to as biological diversity in the Norwegian curriculum) is similarly included in the aims of both programmes; in particular the IB DP Topic 5 and Topic C include the aims for students to develop knowledge of the concept and how to safeguard it, in addition to content related to taxonomy, variation, and that "two species cannot survive indefinitely in the same habitat if their niches are identical."

Some differences were noted where some of the Norwegian aims covered topics not directly linked to the IB DP curriculum. For example, although both cover the identification of species, biological systematics is not directly referenced in the IB DP. In some cases, it reflects a moderately different scope of biology that is covered in both programmes. For example, the Norwegian aims regarding reproduction of bacteria and viruses are not a focus in the IB DP; nonetheless, the IB DP aims for students to understand concepts related to diseases and the blood system.

The Norwegian programme also has an aim for students to extract information from a large range of sources and to analyse how the information is supported; it is acknowledged that similar skills are likely developed in the IB DP, but the wide range of sources in relation to this Norwegian aim are not directly referenced in the IB DP.

Content

Table 9: Content in the Vitnemål for Videregående Opplæring and IB DP Biology

	Vitnemål for Videregående Opplæring – Biology 1	IB DP Biology SL
Topics	• The Young Biologist • Cell Biology • Human Physiology • Function and Adaptation • Biological Diversity	**Core and SL topics** • Cell biology • Molecular biology • Genetics • Ecology • Evolution and biodiversity • Human physiology **Optional topics (teacher picks one)** • Neurobiology and behaviour • Biotechnology and bioinformatics • Ecology and conservation • Human physiology **Practical scheme of work activities** • Practical activities • Individual investigation • Group 4 project.
Number of topics	5	7
Recommended teaching hours	140 hours	150 hours

The main subject areas of the Biology 1 programme include five topics; each topic in the guide comes with a description of what the subject area should involve or cover. These are presented and compared with the IB DP in the table below:

Table 10: Content comparison of the Vitnemål for Videregående Opplæring and IB DP Biology by topic and sub-topic

Vitnemål for Videregående Opplæring - Biology 1		Included in the IB DP
The Young Biologist	**The main subject area deals with:**	
	The use of biology-specific working methods in ecological fieldwork, investigation and laboratory experimentation	✓
	The subject area also involves various environmental challenges, and evaluating information in the media	✓
	It also covers the ethical aspects of such problems	✓
Cell biology	The complex internal structure of eukaryotic cells, how the various parts function, and transport of material through the cell walls	✓
	The subject area also covers the structure and reproduction of bacteria and viruses	✓
Human physiology	Different types of tissue, organs and organ systems and how they function	✓*
	It also deals with the interaction between different processes in the body and the regulation of these processes	✓*
	The main subject area also covers the body's natural immune system and problems relating to organ donation	✓
Function and adaptation	The development of life on earth and how this has resulted in a diversity of organisms that display various ways of adapting to different living conditions	✓
	Selected features from the structure, function, reproduction and behaviour of organisms are seen in relation to this development	✓
Biological diversity	Biological diversity, both locally and globally, and how the threat against biodiversity is one of the great challenges facing mankind today	✓
	Other elements in this subject area are the classification of species and the degree of variation within and between populations, as well as the relationship between diversity, habitat and niches.	✓

Overall, all of the Norwegian Biology 1 topics and sub-topics are included (or at a minimum, partially included) in the IB DP programme. Two sub-topics were identified as partially included. First, the interaction between and regulation of processes in the human body is not directly included in the IB DP as a key or separate topic to be taught, it is however acknowledged that various more in-depth topics may cover this area; for example, Topic 6 on Human Physiology describes specific processes including the functions of the pancreas, enzymes, and villi. Second, although some organs of the human body are included in the IB

DP, a smaller scope of organs and organ systems may be covered than what is indicated in the sub-topic above; tissues are also not a major focus in the IB DP.

Overall, human physiology is studied less in depth in the IB DP. The majority of the content in the IB DP on organs are within an optional topic. Nonetheless, Optional Topic D (Human Physiology) in the IB DP covers the digestive system, functions of the liver, and the heart; and Optional Topic A (Neurobiology and behaviour) covers the brain.

The Norwegian key topics of *Cell biology* and *Biological diversity* are similarly taught as key topics in the IB DP. Further, experimental and investigative skills as defined in the Norwegian topic of *The Young Biologist* are similarly developed in both courses, with the IB DP including practical work within the course where students can apply these skills. The content related to life on earth, diversity, reproduction, and behaviour of organisms is also taught throughout the IB DP curriculum.

3.3.2 Chemistry

Aims – Basic Skills

The Norwegian Chemistry guide includes a set of basic skills that are intended to be developed alongside and integrated with the topic level aims. These apply to both Chemistry 1 and Chemistry 2 and can be seen in the table below:

Table 11: Basic skills of the Vitnemål for Videregående Opplæring and IB DP Chemistry

Vitnemål for Videregående Opplæring– Chemistry 1		Included in the IB DP
Being able to express oneself orally and in writing in chemistry:	Involves the precise evaluation and presentation of one's case in scientific discussions, as well as the planning and implementation of experiments and field trips	✓
	Includes describing observations and experiences from nature and the laboratory in the terminology of chemistry	✓
	Means formulating questions and hypotheses and presenting results	✓
Being able to read in chemistry:	Means gathering relevant information from a document and understanding articles on chemistry that vary in degree of difficulty	✓
	Means understanding texts, tables and diagrams from textbooks, reference works, newspapers, journals, advertisements and the Internet	✓*
Numeracy in chemistry:	Involves calculating quantities, concentrations and pH values, and evaluating the results	✓
	Means working with and interpreting formulas, models and various types of data, as well as solving equations	✓
Being able to use digital tools in chemistry:	Involves collecting scientific information and examining, recording, processing and presenting results from personal observations	✓
	Means being able to use digital tools to simulate experiments that can be time-consuming, costly or hazardous	✓

Vitnemål for Videregående Opplæring– Chemistry 1		Included in the IB DP
	Means using animations to illustrate and explain chemistry-related concepts.	✓

Overall, the table above shows that the IB DP aims to develop similar skills to those specified in the Norwegian Chemistry 1 guide, in particular chemistry communication skills, numeracy skills and application of digital tools in chemistry.

The IB DP practical element (i.e. practical work, individual investigation and Group 4 project) recommends developing communication skills through scientific discussions, use of chemistry terminology to describe experimental and natural phenomena, planning and performing experiments and scientific inquiry activities. Moreover, the individual investigation that is internally assessed (accounting for 20% of the final assessment) stresses on the ability to formulate questions, analyse, evaluate and present results. Likewise, the IB DP practical element emphasises on the use of data loggers to record and process data, simulations to model experiments and animations to illustrate chemistry concepts.

The IB DP Chemistry SL guide states that a data booklet (a document, developed by the IB DP for use in IB World Schools, which contains useful equations, constants, data, structural formulas and tables of information) should be an integral part of the chemistry programme, where each IB DP topic includes links to specific sections in the data booklet. Moreover, the Group 4 project, depending on the topic and type of project undertaken, may allow students to collate data that include audio-visual material, text, graphs and images from scientific journals, external websites and databases of international scientific and environmental organisations, science and technology industries and government reports.

The IB DP outlines mathematical requirements that all IB DP Chemistry students should develop, in addition to prescribing numeracy related aims for each chemistry topic.

Aims – Subject Area

On a topic level the Norwegian Chemistry 1 course prescribes ‘competence aims’ that indicate the aims of each main subject area and these aims are compared to the IB DP Chemistry SL in the table below.

Table 12: Aims of the Vitnemål for Videregående Opplæring and IB DP Chemistry

Vitnemål for Videregående Opplæring - Chemistry 1		Included in the IB DP
Language and models in chemistry	**The aims of the studies are to enable pupils to:**	
	Give an account of the historical development of the concept of the atom and describe and compare Bohr’s atomic model and today’s model	✓
	Explain, illustrate and evaluate the composition, valency and properties of matter using the periodic table	✓
	Give names to simple inorganic compounds using nomenclature	✓

Vitnemål for Videregående Opplæring - Chemistry 1		Included in the IB DP
	rules	
	Write chemical equations with state symbols, and use chemical equations in calculations with amounts of matter	✓
	Explain the concepts entropy and enthalpy and use them to assess whether or not a reaction is spontaneous	✓
	Give an account of conditions that affect the rate of chemical reactions	✓
	Carry out calculations on chemical equilibriums and discuss the equilibriums	✓
Methods and experimentation	Plan and carry out experiments and evaluate risk, sources of error and results	✓
	Write reports from experiments and present processes, methods and results with or without digital tools	✓
	Discuss and evaluate the chemical content in media reports and advertisements	✓*
Water chemistry	Give an account of the properties of water	✓
	Give an account of water as a solvent for polar and non-polar substances	✓
	Evaluate the solubility and precipitation of salts in water based on experiments and calculations	✓
	Make aqueous solutions with different concentrations by weighing and diluting	✓
	Carry out experiments with water treatment and give an account of the contamination of drinking water sources	✓*
	Explain how the key components in detergents work	
Acids and bases	Define the terms acid and base and give an account of acid-base reactions	✓
	Calculate values of K_a, K_b and K_w	✓
	Measure pH by different methods and calculate pH in strong and weak acids and bases	✓
	Plan and carry out acid-base titrations; justify choice of indicator and interpret titration curves	✓
	Give an account of protolysis of salts and gases in water	✓
Organic chemistry 1	Give an account of the structure, nomenclature, production, properties and use of aliphatic hydrocarbons, alkyl halides, alcohols, aldehydes, ketones, carboxyl acids, esters, ethers and amines	✓
	Give an account of the structure of benzene and some simple benzene derivatives, and give examples of their uses	✓

Vitnemål for Videregående Opplæring - Chemistry 1		Included in the IB DP
	Give an account of different forms of isomerism.	✓*

As shown in the table above, IB DP Chemistry SL is closely aligned to most of the aims of the Norwegian Chemistry 1 course.

Similar to the Norwegian Chemistry 1 course, the IB DP Chemistry SL subject aims to enable students to describe chemistry concepts and perform chemistry related calculations. These aims include, enabling students to explain atomic structure phenomena (paradigm shifts, Bohr model and the quantum mechanics model), apply the periodic table, write balanced chemical equations and perform chemical equilibrium related calculations.

All the aims of the Norwegian Chemistry 1 course in the topic *Acid and bases*, are included in the IB DP Chemistry SL course, in particular, for students to develop the ability to explain acid-base reactions and the dissociation of bases (salts and gases) in water that involves a protolysis process. Similarly, for the topic *Organic chemistry*, both courses aim to enable students to describe the structure, properties and applications of a range of organic compounds including benzene and understand isomers. The IB DP Group 4 project is a collaborative activity that gives students the opportunity to discuss and investigate a topic and, depending on the project type, to evaluate external sources including scientific journals, websites and government reports. Further, the IB DP chemistry guide makes reference to experimental determination of amounts, masses, volumes and concentrations of solutions and performing titration experiments to calculate the concentration of a solution with reference to a standard solution.

Minor differences are found for a small number of Norwegian Chemistry 1 aims, where explicit references in the IB DP are not found for discussion and evaluation of chemistry in media sources, describing the mechanism of detergents and explaining the structure and use of benzene derivatives.

The IB DP does not cover water chemistry as a separate topic as done in the Norwegian course, however, the IB DP addresses concepts of water chemistry in different contexts in terms of bonding, energy, periodicity, acid-base reactions and the Winkler method. Water treatment is covered more extensively in one of the optional IB DP topics at HL level (*Materials*).

Further, although the IB DP does not explicitly reference to benzene derivatives, the structure and application of a range of functional groups that represent the benzene derivatives are discussed. The IB DP Chemistry SL introduces structural isomers including the application of IUPAC (International Union of Pure and Applied Chemistry) rules in the nomenclature of straight-chain and branched-chain isomers with more in-depth coverage of the different types of isomerism provided in the HL programme.

Content

Table 13: Content in the Vitnemål for Videregående Opplæring and IB DP Chemistry

	Vitnemål for Videregående Opplæring –Chemistry 1	IB DP Chemistry SL
Topics	• Language and models in chemistry • Methods and experimentation • Water chemistry • Acids and bases • Organic chemistry 1	**Core and SL Topics** • Stoichiometric relationships • Atomic structure • Periodicity • Chemical bonding and structure • Energetics/thermochemistry • Chemical kinetics • Equilibrium • Acids and bases • Redox processes • Organic chemistry • Measurement and data processing **Optional topics (teachers pick one)** • Materials • Biochemistry • Energy • Medicinal chemistry **Practical scheme of work activities** • Practical activities • Individual investigation • Group 4 project.
Number of topics	5	12
Recommended teaching hours	140 hours	150 hours

As shown in the table above, the IB DP Chemistry SL course structure includes more key chemistry topics than the Norwegian Chemistry 1 course; the IB DP includes similar key topic areas to those seen in the Norwegian Chemistry 1 course except for *Language and models in chemistry*. The IB DP also includes additional core chemistry topics that include *Chemical bonding and structure*, *Chemical kinetics* and *Redox processes* and four optional topics (*Biochemistry, Materials, Energy* and *Medicinal chemistry*).

The main subject areas of the Norwegian Chemistry 1 course include five topics; each topic in the guide comes with a description of what the subject area should involve or cover. These are presented in the table overleaf:

Table 14: Content comparison of the Vitnemål for Videregående Opplæring and IB DP Chemistry by topic and sub-topic

Vitnemål for Videregående Opplæring - Chemistry 1		Included in the IB DP
Language and models in chemistry	**The main subject area deals with:**	
	Chemical nomenclature, and chemical phenomena are explained by models at a micro level	✓
	How chemical reactions are described by equations and how these equations are used to evaluate and estimate resource use and yield	✓
	Gives an insight into how models have changed in the course of history	✓
Methods and experimentation	How knowledge in chemistry is gained through processes that involve hypotheses, experimentation, observations, evaluation and reasoned conclusions	✓
	The fact that chemistry is a practical discipline that uses laboratory equipment and analytical processes, and how theories and models are tested and illustrated through experiments	✓
Water chemistry	The structure and properties of water and aquatic solutions	✓
	The evaluation of the solubility of substances in water in everyday life as well as environmental and industrial contexts	✓
Acids and bases	Acids, bases and pH	✓
	How chemical processes in water are affected by pH	✓
	Experiments and calculations linked to everyday life, healthcare, industrial processes and research	✓
Organic chemistry 1	Natural and synthetic organic substances	✓
	The structure of organic substances and how they react	✓
	Nomenclature, which is used to systemize the increasingly large number of organic compounds.	✓

Overall as shown in the table above, the IB DP Chemistry SL course covers all of the Norwegian Chemistry 1 sub-topics.

Although the IB DP does not cover language and models in chemistry as a standalone topic, the concepts covered in this topic are taught under other IB DP chemistry topics. For example chemical reactions and equations are discussed under the topic *Stoichiometric relationships* and chemical phenomena related to atoms and periodic table are covered under the topics *Atomic structure*, *Periodic table* and *Chemical bonding and structure*.

The IB DP Chemistry SL course does not cover water chemistry as a standalone topic; nevertheless the IB DP Chemistry SL course provides a detailed overview of chemical bonding, in particular hydrogen bonding that is responsible for the unique structure and properties of water. Moreover, the IB DP Chemistry SL course also includes explanation of a

range of physical properties, in addition to solubility, of ionic and covalent compounds. In comparison, the Norwegian Chemistry 1 course does not cover chemical bonding and other physical properties such as volatility, electrical and conductivity.

For the topic *Acids and bases*, both courses include experiments and calculations in relation to acid and bases, including applications in everyday life and industrial processes. Likewise for the topic *Organic chemistry*, both courses cover the IUPAC nomenclature and the structure of organic compounds.

Overall, the content breadth and depth of the IB DP Chemistry SL course is greater than the Norwegian Chemistry 1, where the IB DP Chemistry SL course covers additional concepts such as collision theory in the topic chemical kinetics; various types of bonding and intermolecular forces in the topic chemical bonding and redox processes.

3.3.3 Physics

Aims - Basic Skills

The Norwegian Physics guide includes a set of basic skills that are intended to be developed alongside and integrated with the topic level aims. These apply to both Physics 1 and Physics 2 and can be seen in the table below:

Table 15: Basic skills of the Vitnemål for Videregående Opplæring and IB DP Physics

Vitnemål for Videregående Opplæring– Physics 1		Included in the IB DP
Being able to express oneself orally and in writing in physics:	Describing observations and experiences from nature, experiments, field trips and information in the media	✓
	Formulating questions and hypotheses and using concepts and expressions in physics	✓
	Make a case for one's own evaluations, offer feedback and present results – that is to say, master a clear and precise language, including being able to differentiate between everyday use of ideas and use of the same concepts in physics	✓
Being able to read in physics:	Extracting, interpreting and reflecting on information in physics documents, brochures, newspapers, popular science magazines, books and on the Internet	✓*
	Understanding instruction manuals, tables, diagrams, symbols and physics documents, as well as the contents of tables, graphs, illustrations, written text and equations	✓*
Numeracy in physics:	Using figures and mathematical calculations to record and process results from one's own measurements, as well as producing tables and diagrams in a physics context	✓
	Applying and interpreting formulas and models of reality, and processing and interpreting various types of data	✓
	[*Being able to do calculations means*] applying methods from mathematics	✓

Vitnemål for Videregående Opplæring– Physics 1		Included in the IB DP
	Use of vectors, parameter curves and differential and integral calculus	
Being able to use digital tools in physics:	Investigating, measuring, recording, analysing, documenting and publishing results by digital means	✓
	Applying animations and using the Internet to collect physics-related information	✓
	The ability to use digital tools in physics also includes simulating phenomena and experiments that are difficult to study otherwise.	✓

As seen in the table above, IB DP Physics SL intends to develop similar skills to the Norwegian Physics 1 course, particularly in communicating physics, numeracy skills related to physics and use of digital tools in physics.

Key aims of the IB DP practical element (practical work, investigations and Group 4 project) is to develop the ability to describe observations, formulate questions, hypotheses, evaluate and present results. Moreover, the aims of the Group 4 project are to develop an ability to analyse, evaluate and synthesise scientific information and develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge. The Group 4 project also encourages the collation of information from a variety of sources that include scientific journals, external websites, industrial and government reports.

The data booklet[8] is an important element of the IB DP Physics SL course, where each IB DP topic includes a link to a specific section in the data booklet. The use of this data booklet enables students to understand equations, constants, data, electric circuit symbols and tables of information; developing reading skills in physics.

The IB DP stresses the use of mathematics in physics; the mathematical requirements for IB DP Physics SL include performing arithmetic functions, trigonometric functions, solving simple algebraic equations and linear simultaneous equations and plotting and interpreting graphs to perform calculations and analyse experimental results. Vector analysis skills are taught and developed across relevant topics within the course and addressed as a standalone sub-topic. However parameter curves and differential and integral calculus are not included the in IB DP Physics course[9].

The IB DP encourages the use of computer technology for measuring, recording, analysing and presenting data where data loggers, spreadsheets and online databases are recommended for collection of data or information. The IB DP also intends for students to learn to use digital images, presentation software, websites and digital videos for presenting data. Computer simulations are proposed in the IB DP Physics guide, especially when experimentation is not possible. For example, the IB DP topic on *Electricity and Magnetism*

[8] The data booklet is a document that contains useful equations, constants, data, electric circuit symbols and tables of information.

[9] It should be noted that these topics are taught within IB DP Mathematics HL in a physics context; for example, kinematic equations are treated in calculus form.

suggests the use of computer simulations to enable students to measure microscopic interactions that are typically very difficult in a school laboratory.

Aims - Subject Area

On a topic level the Norwegian Physics course prescribes 'competence aims' that indicate the aims of each main subject area and these aims are compared to the IB DP Physics SL course in the table below.

Table 16: Aims of the Vitnemål for Videregående Opplæring and IB DP Physics

Vitnemål for Videregående Opplæring - Physics 1		Included in the IB DP
Classical physics	**The aims of the studies are to enable pupils to:**	
	Identify contact forces between objects and gravitational forces on objects, draw force vectors and apply Newton's Three Laws of Motion	✓
	Give an account of the concepts of energy, work and effect, carry out arithmetic calculations and discuss situations where mechanical energy is conserved	✓
	Give an account of situations where friction and air resistance mean that the mechanical energy is not conserved, and perform calculations in situations with constant friction	✓*
	State and discuss the first and second laws of qualitative thermophysics	✓
	Define the terms current, voltage and resistance, and apply the principles of conservation of charge and energy to simple and branched direct current circuits	✓
	Define and carry out calculations with the terms frequency, period, wavelength and wave speed, and explain qualitative bending and interference phenomena	✓
Modern physics	Describe Bohr's atom model and use it to work out frequencies and wavelengths of spectral lines in emission and absorption spectra	✓*
	Use conservation laws to describe fission and fusion processes and calculate the energy released in such processes	✓
	Apply Stefan-Boltzmann's law and Wien's displacement law	✓
	Give an account of how information about stars are systemized in an HR diagram	✓
	Describe the life-cycle of a star and explain how elements are produced in stars	✓
	Describe and discuss the standard model for the evolution of the universe	✓
Explaining nature through	Use parameter presentation to describe the rectilinear movement of a particle, and use derivation to calculate velocity and	✓

Vitnemål for Videregående Opplæring - Physics 1		Included in the IB DP
mathematics	acceleration when the position is known, with and without digital tools	
	Create one or more mathematical models for correlations between physical quantities found experimentally	✓
	Use mathematical models as sources for qualitative and quantitative information, present results and evaluate the area of validation of the models	✓
The young researcher	Elaborate on and discuss key features of scientific method in physics	✓
	Give examples of some explanation models that are inconsistent with physics, nor based on scientific methodology	✓
	Give an account of how a researcher's approach, expectations and experiences can affect research	✓
	Plan and implement experiments and carry out relevant experiments within the various main subject areas	✓
	Collect and process data and present and evaluate the results and conclusions of experiments and investigations, with and without digital tools	✓
	Use simulation programs to show phenomena and physical relations	✓
Physics and technology	Give an account of the difference between conductors, semi-conductors and insulators based on the current atom model, and explain doping of semi-conductors	
	Compare the construction of a diode and transistor, explain how they work, and give examples of their use	✓*
	Give an account of how light detectors work in digital photography or digital video	✓*
	Give an account of how modern sensors are characterized, and how the sensors' characteristics set limits for measurements.	✓*

As seen in the table above, the IB DP has broadly similar aims to the Norwegian Physics 1 course. Both courses aim to provide students a solid physics background by enabling students to apply Newton's laws, perform calculations in relation to conservation of mechanical energy and charge and understand wave phenomena.

The IB DP Physics SL subject also addresses the Norwegian Physics 1 aims related to the topic *Modern physics*, in particular, solving problems involving the energy release in nuclear fission and fusion processes and applying Stefan-Boltzmann's law and Wien's displacement law.

The IB DP Physics SL course intends for students to develop experimental and mathematical skills, in relation to physics, by recommending experiments and the use of mathematical models and equations across all topics.

Some Norwegian Physics 1 aims are covered in the IB DP optional topics. In particular, thermodynamic laws are described in one of the optional topics (*Engineering physics*) and concepts relating to astrophysics (i.e. HR diagrams and life cycle of a star) are addressed in one of the IB DP optional topics (*Astrophysics*).

A few differences are observed, that include the coverage of friction by IB DP where students are expected to be able to describe solid friction (static and dynamic) by coefficients of friction and apply friction in circular motion; however no direct reference to friction and air resistance in relation to mechanical energy conservation is found in the IB DP. The IB DP covers non-ohmic conductors and conductors in relation to magnetic fields; however the IB DP Physics SL guide does not explicitly state the difference between conductors, semi-conductors and insulators based on the current atom model and explanation of doping of semi-conductors. Similarly, the IB DP addresses diode bridges, but does not explicitly reference the construction, mechanisms and application of diodes and transistors. Students may be provided the opportunity to discuss the use of physics in modern sensors such as LCD (Liquid crystal display), CCD (charge coupled device) and modern medical scanners; however, these concepts are not comprehensively covered in the IB DP Physics SL curriculum.

Further, emission and absorption spectra is covered by IB DP Physics SL, however, content on Bohr atom are covered in IB DP Physics HL and IB DP Chemistry SL rather than the IB DP Physics SL course; therefore, the Norwegian aim related to Bohr atom and spectra is considered to be partially covered in the table above.

Content

Table 17: Content in the Vitnemål for Videregående Opplæring and IB DP Physics

	Vitnemål for Videregående Opplæring –Physics 1	IB DP Physics SL
Topics	• Classical physics • Modern physics • Explaining nature through mathematics • The young researcher • Physics and technology	**Core topics** • Measurements and uncertainties • Mechanics • Thermal physics • Waves • Electricity and magnetism • Circular motion and gravitation • Atomic, nuclear and particle physics • Energy production **Optional topics (teachers select one)** • Relativity

	Vitnemål for Videregående Opplæring –Physics 1	IB DP Physics SL
		• Engineering physics • Imaging • Astrophysics **Practical scheme of work activities** • Practical activities • Individual investigation (internal assessment – IA) • Group 4 project.
Number of topics	5	9
Recommended teaching hours	140 hours	150 hours

The table above shows that the IB DP Physics SL course offers more key topics than the Norwegian Physics 1 course; however, the Norwegian Physics 1 topic *Classical physics* encompasses several fundamental physics topic areas (mechanics, thermal physics, electricity and waves). As seen in the table above, the IB DP Physics SL course similarly includes these, but as key topics rather than sub-topics.

In addition, the IB DP also includes four optional key topics (teachers select one to teach) including: *Relativity*, *Engineering physics, Imaging* and *Astrophysics*; out of which only one topic (*Astrophysics*) is covered by the Norwegian Physics 1 course.

The IB DP Physics SL course also contains practical components (practical activities, individual investigation and Group 4 project) that are not part of the Norwegian Physics 1 course.

The main subject areas of the Norwegian Physics 1 course include five topics; each topic in the guide comes with a description of what the subject area should involve or cover. These are presented in the table below:

Table 18: Content comparison of the Vitnemål for Videregående Opplæring and IB DP Physics by topic and sub-topic

Vitnemål for Videregående Opplæring - Physics 1		Included in the IB DP
Classical physics	**The main subject area deals with:**	
	The oldest and most applied laws of physics, and how they find expression in mechanics, electrotechnology and thermophysics	✓
	A central principle is the conservation of energy in different processes	✓
	Fundamental concepts that are necessary for working with wave phenomena	✓
Modern physics	The building blocks of nature and how they are joined together, from microcosm to macrocosm	✓

Vitnemål for Videregående Opplæring - Physics 1		Included in the IB DP
	Information that can be obtained from radiation in various contexts, and how it can be used to create models to explain the world	✓
Explaining nature through mathematics	How mathematics is applied in physics, particularly in the main subject areas of Classical Physics and The Young Researcher	✓
	Mathematics is used to systematize observations through the laws of physics	✓
	The use of mathematics to describe phenomena and predict how a system will behave in the future	✓
The young researcher	Physics as an experimental science, where training to plan, implement and evaluate experiments is the key	✓
	Learning about and training in the use of measuring instruments, documenting experiments, collecting data and presenting results	✓
	How scientific knowledge is established and with conflicts and dilemmas that might arise during this process	✓
Physics and technology	Principles of physics that form the basis of certain components in modern technology	✓
	Important assumptions and limitations in the technology.	✓

Overall as shown in the table above, the IB DP covers all the Norwegian Physics 1 sub-topics. The IB DP topics on mechanics, circular motion and gravitation, thermal physics, electricity and magnetism and waves cover all concepts addressed in the Norwegian Physics 1 topic *Classical physics*. The IB DP topic *Atomic, nuclear and particle physics* covers all the sub-topics in the Norwegian Physics 1 topic *Modern physics*. The IB DP topic *Measurements and uncertainties* address measurements in physics, uncertainties and errors and vectors and scalars and therefore include the sub-topics from three Norwegian Physics 1 topics (*Explaining nature through mathematics*, *The young researcher* and *Physics and technology*). Further, the IB DP integrates experimental work, analysis of experimental data, application of mathematics in physics, understanding the link between physics and technology and developing an appreciation for the possibilities and limitations of science and technology across all topics.

Furthermore, the IB DP Physics SL course includes additional concepts that are not covered by the Norwegian Physics 1. For example, the IB DP topic *Thermal physics* addresses modelling a gas; not referenced by Norwegian Physics 1. Similarly the IB DP topic *Electricity and magnetism* covers magnetic fields and force; not explicitly stated by Norwegian Physics 1.

3.3.4 Mathematics R1 and R2

Aims – Basic Skills

The Norwegian Mathematics R1 and R2 guide includes a set of basic skills that are intended to be developed alongside and integrated with the topic level aims; as shown in the table below:

Table 19: Basic skills of the Vitnemål for Videregående Opplæring and IB DP Mathematics

Vitnemål for Videregående Opplæring– Mathematics R1 and R2		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
Being able to express oneself orally and in writing in Mathematics:	Involves the ability to formulate logical arguments, explain a way of thinking, and articulate findings, concepts and hypotheses	✓	✓	✓
	Includes formulating on paper mathematical proofs using correct mathematical notation and relevant logical conclusions	✓	✓*	✓*
	Means writing mathematical symbols and expressions and setting up or drawing tables, diagrams, graphs and geometrical figures	✓	✓	✓
Being able to read in Mathematics:	Involves the ability to extract relevant mathematical information from written text, i.e. understanding mathematical symbols and expressions and logical arguments	✓	✓	✓
	Means understanding and interpreting organized visual information such as tables, diagrams, graphs and geometrical figures	✓	✓	✓
Numeracy in Mathematics:	Means confidence in choice of operation and confidence in applying various arithmetical operations without the use of digital tools	✓	✓	✓
	To do arithmetic means learning new operations, such as derivation and integration, i.e. making practical estimates and assessing the reasonableness of a solution	✓	✓	✓*
Being able to use digital	Involves using digital tools for comprehensive computations and	✓	✓	✓

Vitnemål for Videregående Opplæring– Mathematics R1 and R2		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
tools in Mathematics:	visualisation			
	Means retrieving, processing and presenting mathematical information in electronic form	✓	✓	✓
	Means evaluating the suitability, possibilities and limitations of the digital tool.	✓*	✓*	✓*

Overall, the table above shows that the IB DP aims to develop similar skills to those specified in the Norwegian Mathematics R1 and R2 guide.

The assessment objectives of all three IB DP Mathematics courses emphasise on the ability to construct mathematical arguments through the use of precise statements, logical deduction and inference and investigative skills (investigation of unfamiliar situations, organising and analysing information, drawing conclusions and testing their validity). Further the assessment objectives of the IB DP Mathematics SL and HL courses stress on mathematical inquiry skills in abstract situations.

Further, all IB DP Mathematics courses aim to enable students to communicate clearly and confidently in a variety of contexts. IB DP students are encouraged to learn mathematics through active participation in learning activities and mathematical inquiry; each IB DP topic links to discussions of real-life mathematical situations and problems and ideas for further investigation.

The IB DP Mathematics HL guide stresses on enabling students to formulate mathematical proofs, with appropriate proofs covered under different topics. For instance, proof of binomial theorem and proof by mathematical induction are addressed under the topic algebra. Alternatively, formulating specific mathematics proofs are not required in both the IB DP Mathematics SL and IB DP Mathematical Studies SL courses; although discussions in relation to mathematical proofs are recommended in both these courses. Further, the examination papers of IB DP Mathematics SL and IB DP Mathematical Studies SL courses include “show that” questions that require students to obtain the required result without the formality of a proof. Therefore, as the Norwegian course expects students to be able to formulate mathematical proofs on paper (i.e. presumably a range of proofs are expected), and “formal proofs” are not required in the IB DP Mathematics SL and IB DP Mathematical Studies SL courses, this skill is considered partially covered in these IB courses.

The ability to use and understand appropriate mathematical language (i.e. notation, symbols and terminology) and multiple forms of mathematical representation such as formulae, diagrams, tables, charts, graphs, models and geometric diagrams are developed across all topics in the IB DP Mathematics courses, in particular these skills are emphasised in the assessment objectives of the IB DP Mathematics courses.

The IB DP Mathematics individual internal assessment (i.e. the mathematical exploration in IB DP Mathematics HL and SL, and the project in IB DP Mathematical Studies SL) element aims to provide opportunities for students to show, with confidence, how they have developed mathematically. Arithmetical operations (i.e. addition, subtraction, multiplication and division; using integers, decimals and fractions and order of operations) are infused across all topics in all three IB DP Mathematics courses. For example, arithmetic operations are used to solve arithmetic and geometric series and to calculate the lengths of right angled triangles.

The use of technology is encouraged by all IB DP Mathematics courses to enhance visualisation, support student understanding of mathematical concepts and assist in the collection, recording, organization and analysis of data. Moreover, the assessment objectives for IB DP Mathematics courses emphasise on the use of technology, accurately, appropriately and efficiently to explore new ideas and to solve problems. However, the Norwegian Mathematics R1 and R2 courses aim to enable students to evaluate the suitability, possibilities and limitations of digital tools; not explicitly referenced in all three IB DP Mathematics courses.

Aims - Subject Area

On a topic level the Norwegian Mathematics R1 and R2 programme prescribes 'competence aims' that indicate the aims of each main subject area. The aims of Mathematics R1 and R2 are compared separately to all three IB DP Mathematics courses in Table 20 and 21 respectively.

Table 20: Aims of the Vitnemål for Videregående Opplæring Mathematics R1 and IB DP Mathematics courses

Vitnemål for Videregående Opplæring - Mathematics R1		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
Geometry	**The aims of the studies are to enable pupils to:**			
	Use lines and circles as geometric loci together with congruence and the inscribed angle theorem in geometrical analysis and calculations			
	Execute and analyze constructions defined by straight lines, triangles and circles in the plane, with and without the use of dynamic software	✓	✓	✓
	Derive and apply the intersection theorems for the heights, angle bisectors, perpendicular bisectors and medians in a triangle			
	Give an account of different proofs	✓*	✓	✓

Vitnemål for Videregående Opplæring - Mathematics R1		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
	for Pythagoras' equation, in terms of cultural history as well as mathematics			
	Visualize vectors in the plane, both geometrically as arrows and analytically in co-ordinate form	✓	✓	
	Calculate and analyze lengths and angles to determine the parallelity and orthogonality by combining arithmetical rules for vectors	✓	✓	✓*
Algebra	Factorize polynomials with the help of zeros and polynomial division, and use this to solve equations and inequalities with polynomial and rational expressions	✓		
	Transform and simplify complex rational functions and other symbolic expressions with and without the use of digital aids	✓* Expected Prior Learning	✓* Expected Prior Learning	✓* Expected Prior Learning
	Derive the basic arithmetical rules for logarithms, and use these and the power rules to simplify expressions and solve equations and inequalities	✓*	✓*	
	Give an account of implication and equivalence, and implement direct and contrapositive proof			✓*
Functions	Give an account of the concepts of boundedness, continuity and differentiability, and give examples of functions that are not continuous or differentiable	✓		
	Use formulae for the derivative of power, exponential and logarithmic functions, and differentiate composites, differences, products, quotients and combinations of these functions	✓	✓	
	Use first derivative and second derivative to elaborate on and discuss the path of functions and interpret the derivatives in models	✓	✓	✓*

Vitnemål for Videregående Opplæring - Mathematics R1		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
	of practical situations			
	Draw graphs to functions with and without digital means, and interpret the basic characteristics of a function using the graph	✓	✓	✓
	Find the equation for horizontal and vertical asymptotes to rational functions and draw the asymptotes	✓	✓	✓
	Use vector functions for a parameter presentation of curves in the plane, draw the curve and differentiate the vector function to find velocity and acceleration	✓*	✓*	
Combinatorics and probability	Give an account of the concepts of statistical independence and conditional probability, and derive and apply Bayes' equation for two events	✓*	✓*	✓*
	Elaborate on and discuss combinatoric problems linked to non-random selection with or without replacement and random selection without replacement, and use this to derive rules for calculating probability.		✓*	✓*

As seen in the table above, there are broad similarities between the aims of Norwegian Mathematics R1 course and the IB DP Mathematics SL and HL courses. Similar aims, albeit fewer, are also found between the Norwegian Mathematics R1 course and IB DP Mathematical Studies SL course.

The Norwegian aims related to the topic *Geometry*, intend to enable students to execute and analyse geometric diagrams. All three IB DP Mathematics courses expect students to develop the ability to construct and analyse geometric diagrams, both on paper and using technology.

The Norwegian Mathematics R1 course also aims to teach students to connect between vector and geometry concepts, where students are expected to represent vectors in different forms and use vector arithmetic rules to perform calculations and determine parallel and orthogonal vectors. Different representations of vectors are described in both the IB DP Mathematics SL and HL guides but not in the IB DP Mathematical Studies SL guide. Moreover, both the IB DP Mathematics SL and HL courses intend to enable students to apply the vector arithmetic rules to determine parallel and orthogonal vectors, and the scalar product in tandem with the cosine rule to calculate lengths and angles of triangles. The IB

DP Mathematical Studies SL guide applies the cosine rule to vectors to perform calculations but does not determine parallel and orthogonal vectors.

In addition, the Norwegian Mathematics R1 course aims to cover concepts of inscribed angle theorem, congruence and intersection theorems (in relation to angle sectors and triangles) that are not explicitly referenced in the IB DP Mathematics courses. Pythagoras' equation in terms of cultural history and mathematics are described in both the IB DP Mathematics SL and IB DP Mathematical Studies SL courses. The IB DP Mathematics HL course includes the application of Pythagoras' equation but does not refer to the cultural history of the Pythagoras' equation. Thus the Norwegian aim related to Pythagoras' equation and its cultural history is considered only partially included in the IB DP Mathematics HL course, but fully included in both the IB DP Mathematics SL and IB DP Mathematical Studies SL courses. All three IB DP Mathematics courses cover algebra and functions; however, factorising polynomial functions are only covered in the IB DP Mathematics HL course. For polynomials, the IB DP Mathematics HL course aims to enable students to factorise polynomials with the help of zeros and polynomial division (i.e. apply factor and remainder theorems) and use this to solve equations and inequalities.

The IB DP Mathematics SL guide addresses the transformation of circular functions and translation of functions while the IB DP Mathematics HL guide aims to make students aware of the effect of transformation on algebraic expressions. Further, the expected prior knowledge of both the IB DP Mathematics SL and HL include the simplification of expressions involving roots (surds or radicals) and expansion and manipulation of simple algebraic expressions including quadratic expressions. Alternatively, the IB DP Mathematical Studies SL guide only specifies the simplification of simple algebraic expressions (as expected prior learning) but not the transformation of functions.

Logarithms including their related laws are covered in both IB DP Mathematics SL and HL; however there is no direct reference to the derivation of laws. The IB DP Mathematical Studies SL course does not address logarithm functions.

One of the Norwegian Mathematics R1 aims related to the topic *Algebra* is for students to be able to give an account of the concepts of implication and equivalence and implement direct and contrapositive proof. The IB DP Mathematics HL guide touches upon equivalence; but does not include implication, direct and contrapositive proof and therefore this Norwegian aim is not similarly included in the IB DP Mathematics HL course. Nevertheless, the concepts of implication, equivalence, contrapositive, logical equivalence, inverse and converse are comprehensively covered in the IB DP Mathematical Studies SL course within the topic on *Logic*; although concepts of direct and contrapositive proofs are not addressed in IB DP Mathematical Studies SL. Hence, this Norwegian aim is only partially included in the IB DP Mathematical Studies SL course.

Similar to the Norwegian Mathematics R1 aims related to the topic *Functions*; both the IB DP Mathematics SL and HL courses aim to enable students to perform derivation on power, exponential and logarithm functions; apply the chain rule to composite functions; apply the product and quotient rules; understand first, second and higher derivatives; application of derivatives in profit, area and volume calculations; use technology to explore derivatives and interpret derivative as gradient functions and as rate of change. Alternatively, the IB DP

Mathematical Studies SL course only addresses first derivatives of power, exponential and polynomial functions; thus all the Norwegian aims related to both first and second derivatives are only partially included in the IB DP Mathematical Studies SL course. Further derivation of logarithmic and composite functions are not referenced in the IB DP Mathematical Studies SL guide and hence all the Norwegian aims related to the derivation of the aforementioned functions are considered not similarly covered in the IB DP Mathematical Studies SL course.

All three IB DP Mathematics courses intend to enable students to draw and interpret graphs of functions with key features, including the maximum and minimum values, intercepts, horizontal and vertical asymptotes, symmetry, and consideration of domain and range.

The Norwegian aim related to continuity and differentiability is covered in the IB DP Mathematics HL optional topic (*Calculus*). Moreover, both the IB DP Mathematics SL and HL courses address the determination of velocity and acceleration from the differentiation of vector functions, although no direct reference is found for the use of vector functions for the parameter presentation of curves in the plane and drawing of curves. Moreover, the IB DP Mathematical Studies SL course does not cover vector functions.

For the Norwegian Mathematics R1 topic *Combinatorics and probability*, all three IB DP Mathematics courses cover conditional and independent events; nevertheless IB DP Mathematics HL additionally covers the use of Bayes' theorem for a maximum of three events, although the IB DP Mathematics HL guide does not specify the derivation of the Bayes' theorem. Further, both the IB DP Mathematics SL and IB DP Mathematical Studies SL courses include probability with and without replacement, but do not make reference to non-random selection.

Next the aims of the Norwegian Mathematics R2 are compared to all three IB DP Mathematics courses, as shown in the table below.

Table 21: Aims of the Vitnemål for Videregående Opplæring Mathematics R2 and IB DP Mathematics courses

Vitnemål for Videregående Opplæring - Mathematics R2		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
Geometry	**The aims of the studies are to enable pupils to:**			
	Perform calculations with three-dimensional vectors that are represented both geometrically and in co-ordinate form	✓	✓	
	Use and interpret the scalar and vector product in the calculation of distances, angles, area and volume	✓	✓*	
	Use vector calculus to find equation and parameter presentations for lines, plane and spherical surfaces	✓*	✓*	
	Calculate longitudinals, angles and			

Vitnemål for Videregående Opplæring - Mathematics R2		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
	areas in bodies limited by plane and spherical surfaces			
Algebra	Find and analyse recursive and explicit formulae for numerical patterns with or without digital means, and implement and present simple proofs linked to these formulae	✓		✓*
	Implement and give an account of proof by induction	✓		
	Sum finite series with or without digital means, derive and use the formulae to the sum of the first n members in arithmetic and geometric series, and use this to solve practical problems	✓	✓	✓
	Calculate with infinite geometric series with a constant and variable quotients, determine the area of convergence for these series and present the results	✓	✓*	
Functions	Simplify and solve linear and quadratic equations in trigonometric expressions by using relations between the trigonometric functions	✓	✓	
	Derive central functions and use first and second derivatives to elaborate on and discuss such functions	✓	✓	✓*
	Transform trigonometric expressions of the type a sin kx + b cos kx , and use these to model periodic phenomena	✓	✓	
	Give an account of the definition of a definite integral as a limit of a sum and an indefinite integral as an anti-derivative	✓	✓	
	Calculate integrals of the central functions by anti-derivation, substitution, partial fraction decomposition with linear denominators and integration by parts	✓	✓	
	Interpret the definite integral in	✓	✓	

Vitnemål for Videregående Opplæring - Mathematics R2		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
	models of practical situations and use it to compute plane areas and volumes of rotating bodies			
	Formulate a mathematical model with the help of central functions on the basis of observed data, process the model and elaborate on and discuss the result and method	✓	✓	✓
Differential equations	Model practical situations by converting the problem to a differential equation, solving it and interpreting the result	✓	✓	✓
	Solve the first order linear and separable differential equations by calculation and give an account of some important areas of application	✓		
	Solve homogenous second order differential equations and use Newton's second law to describe free oscillations by periodic functions			
	Solve differential equations and draw vector diagrams and integral curves, and interpret them using digital tools.			

As seen in the table above, the aims of the Norwegian Mathematics R2 course are broadly similar to the aims of both the IB DP Mathematics SL and HL courses. However many differences are encountered between the aims of the Norwegian Mathematics R2 course and the IB DP Mathematical Studies SL course.

Similar to the Norwegian Mathematics R2 aims related to the topic *Geometry*, both the IB DP Mathematics SL and HL courses aim to enable students to perform calculations with three dimensional vectors, apply the scalar product and use vector equation of a line in two and three dimensions. Although, both the IB DP Mathematics SL and HL courses do not cover vector calculus for spherical surfaces and the calculation of longitudinal, angles and areas in bodies limited by plane and spherical surfaces. In addition, the IB DP Mathematics SL guide does not directly reference to the vector product. Alternatively, the IB DP Mathematical Studies SL course does not include any of the Norwegian Mathematics R2 course aims related to the topic *Geometry*.

Concepts of algebra that pertain to series and sequences (arithmetic sequences and series; sum of finite arithmetic series and sequences; geometric sequences and series and sum of finite and infinite geometric series) are covered by both the IB DP Mathematics SL and HL

courses, including its application in compound interest and population growth. IB DP Mathematical Studies SL also covers these concepts with the exception of infinite geometric series.

The IB DP Mathematics HL course further addresses recursive functions, recurrence relations, initial conditions, recursive definition of a sequence, proof by mathematical induction, application of proof by induction to a wide range of topics including sums of series and limits of convergence of an infinite geometric series. Similarly, the IB DP Mathematical Studies SL course expects students to understand arithmetic and geometric series and their applications and recursive formulae; however the IB DP Mathematical Studies SL course does not include concepts of infinite geometric series, convergence and formal proofs of formulae, in relation to series and sequences.

Both the IB DP Mathematics SL and HL courses aim to enable students to solve trigonometric equations in finite intervals using algebraic and graphical methods; find the first, second and higher derivatives of functions; describe definite and indefinite integrals; perform integration by inspection, substitution, anti-differentiation and by parts and use integration to calculate area under/between curves and volumes of revolution.

The guide for all three IB DP Mathematics courses state that students should be able to use mathematics to solve problems in the real world that includes developing, testing, applying and critically analysing the model. Further, modelling of various concepts is referenced across all topics.

Both the IB DP Mathematics SL and HL courses refer to first and second derivatives and their application in economics and chemistry. The IB Mathematical Studies SL course only refers to first derivatives and the application of first derivatives in optimisation problems.

The IB DP Mathematics HL course further makes reference to the application of first order separable and homogeneous differential equations in Newton’s law of cooling, population growth and carbon dating.

In addition, the Norwegian Mathematics R2 course expects students to solve homogenous second order differential equations and use Newton’s second law to describe free oscillations by periodic functions; not referenced by the IB DP Mathematics courses. Further, the IB DP Mathematics courses reviewed do not make explicit reference to integral curves.

Content

Table 22: Content in the Vitnemål for Videregående Opplæring and IB DP Mathematics courses

	Vitnemål for Videregående Opplæring – Mathematics R1 and R2	IB DP Mathematics SL and HL	IB DP Mathematical Studies SL
Topics	Mathematics R1: • Geometry • Algebra • Functions • Combinatorics and probability Mathematics R2: • Geometry • Algebra • Functions • Differential equations	Mathematics SL (core studies): • Algebra • Functions and Equations • Circular Functions and Trigonometry • Vectors • Statistics and probability • Calculus • *Mathematical exploration (individual internal assessment)* Mathematics HL (core studies): • Algebra • Functions and Equations • Circular Functions and Trigonometry • Vectors • Statistics and probability • Calculus • *Mathematical exploration (individual internal assessment)* (elective studies): • Statistics and Probability • Sets, Relations and Groups • Calculus • Discrete Mathematics	• Number and algebra • Descriptive statistics • Logic, sets and probability • Statistical applications • Geometry and trigonometry • Mathematical models • Introduction to differential calculus • *Project (individual internal assessment)*
Number of topics	Mathematics R1 : Four topics Mathematics R2 : Four topics	Mathematics SL: Six core topics and a *Mathematical exploration (individual internal assessment)*	Seven topics

	Vitnemål for Videregående Opplæring – Mathematics R1 and R2	IB DP Mathematics SL and HL	IB DP Mathematical Studies SL
		Mathematics HL: Six core topics and a *Mathematical exploration (individual internal assessment);* one elective topic	
Recommended teaching hours	Mathematics R1 : 140 hours Mathematics R2 : 140 hours	Mathematics SL: 150 hours Mathematics HL: 240 hours	150 hours

As seen in the table above, there are structural differences between the Norwegian Mathematics R1 and R2, in comparison to all three IB DP Mathematics courses.

Overall, the IB DP Mathematics courses in the table above have more topics than the Norwegian Mathematics R1 and R2; although some Norwegian Mathematics R1 and R2 topics are overarching themes that group several topic areas. For example, Norwegian Mathematics R1 and R2 cover functions, circular functions and trigonometry under the topic *Functions* while the IB DP Mathematics SL and HL address functions and trigonometry as two standalone topics and the IB DP Mathematical Studies SL course describe functions in two topics (*Geometry and trigonometry* and *Mathematical models*). The Norwegian Mathematics R1 and R2 integrate vector concepts in other topics while both the IB DP Mathematics SL and HL cover vector concepts as a standalone topic.

All three IB DP Mathematics courses include an individual investigation component (the mathematical exploration in the IB DP Mathematics SL and HL courses and the project in the IB DP Mathematical Studies SL course) not included by the Norwegian Mathematics R1 and R2 courses. Further, the IB DP Mathematics HL course offers additional optional topics that include *Sets, relations and groups* and *Discrete mathematics*.

The main subject areas of the Norwegian Mathematics R1 and R2 programme include four topics; each topic in the guide comes with a description of what the subject area should involve or cover. These are presented in Table 23 for Norwegian Mathematics R1 and Table 24 for Norwegian Mathematics R2.

Table 23: Content comparison of the Vitnemål for Videregående Opplæring Mathematics R1 and IB DP Mathematics by topic and sub-topic

Vitnemål for Videregående Opplæring – Mathematics R1		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
Geometry	**The main subject area deals with:**			
	Measurement, calculation and analysis of figures in the plane	✓	✓	✓
	Geometric construction using a compass and straightedge is based	✓	✓	✓

Vitnemål for Videregående Opplæring – Mathematics R1		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
	on these concepts			
	Use of vectors and coordinates to convert geometrical problems to algebra	✓	✓	
	Development of formal logical arguments and proofs in a geometrical context	✓*	✓*	
Algebra	Fundamental language of symbols in mathematics	✓	✓	✓
	Calculation, manipulation and argumentation using mathematical symbols	✓	✓	✓
	Argumentation involves the use of different types of proof and logical relations	✓	✓*	✓*
	Polynomials, polynomial division and rational, logarithmic and exponential expressions	✓	✓	
Functions	Analysis of the dependence between two quantities	✓	✓	✓
	Relations between quantities from algebra, geometry or practical areas, which are analysed by functions and graphs	✓	✓	✓
	Relation between a function and its derivative	✓	✓	✓
	Polynomial functions, power functions, rational functions, logarithmic functions, exponential functions and combinations of these	✓	✓	✓*
	Boundedness, continuity and differentiability	✓	✓*	✓*
Combinatorics and probability	Systematic counting methods that form the basis for calculating probability	✓	✓*	
	Fundamental concepts of statistical independence and conditional probability and about random and non-random selection.	✓*	✓*	✓*

All three of the IB DP Mathematics courses reviewed above cover most of the Norwegian R1 sub-topics; albeit IB DP Mathematics SL and HL courses include more of the Norwegian R1 sub-topics than the IB DP Mathematical Studies SL course.

The IB DP Mathematics HL course comprehensively addresses all the Norwegian R1 sub-topics except for concepts of specific geometric proofs and non-random selection. Likewise, the IB DP Mathematics SL course does not directly reference to the use of counting principles for calculating probability, continuous functions and specific mathematical proofs.

Further the IB DP Mathematical Studies SL course does not include concepts of vectors, formal mathematical proofs, logarithm functions, continuous functions, counting principles and non-random selection. Although the IB DP Mathematical Studies SL course addresses concepts of geometric constructions, algebra, logic, linear, quadratic and exponential functions, probability and differentiation, that are similarly covered by the Norwegian Mathematics R1 course.

Next, the sub-topics of the Norwegian Mathematics R2 course are compared to all three IB DP Mathematics courses, as shown in the table below.

Table 24: Content comparison of the Vitnemål for Videregående Opplæring Mathematics R2 and IB DP Mathematics by topic and sub-topic

Vitnemål for Videregående Opplæring – Mathematics R2		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
Geometry	**The main subject area deals with:**			
	Measurement, calculation and analysis of figures in space	✓	✓	
	Coordinates, equations and vectors, which are used to determine figures and calculate lengths, angles, area and volume	✓	✓	✓
	Three-dimensional vectors, scalar and vector products and parameter presentation	✓	✓*	
Algebra	Analysis and calculation of numerical patterns, finite sums and infinite series	✓	✓	✓*
	Recursion and induction	✓		
	Series, convergence and proof by induction	✓	✓*	
Functions	Application of periodic functions for modelling periodic phenomena	✓	✓	
	Derivation and integration of central functions in modelling and calculations	✓	✓	✓*
	Polynomial functions, power functions,	✓	✓	✓*

Vitnemål for Videregående Opplæring – Mathematics R2		Included in the IB DP Mathematics HL	Included in the IB DP Mathematics SL	Included in the IB DP Mathematical Studies SL
	rational functions, logarithmic functions, exponential functions, periodic functions and combinations of these			
Differential equations	Applying mathematics for the analysis and calculation of dynamic phenomena	✓	✓	✓
	Standard methods for linear and separable differential equations that are applied to practical problems	✓		
	Initial conditions, vector diagrams and integral curves.	✓*	✓*	

Similar to the Norwegian Mathematics R1 course, both the IB DP Mathematics SL and HL course cover most of the sub-topics in the Norwegian Mathematics R2 course. The few differences encountered are where proof by induction and first order linear and separable differential equations are not directly addressed by the IB DP Mathematics SL guide, and integral curves are not covered by either the IB DP Mathematics SL or HL.

In contrast to the many similarities found between the Norwegian Mathematics R1 course and the IB DP Mathematical Studies SL course; many differences are encountered between the sub-topics of the Norwegian Mathematics R2 course and the IB DP Mathematical Studies SL course. For the topic *Geometry*, the IB DP Mathematical Studies SL course includes the calculation of lengths, angles, area and volume but does not cover geometry in space, scalar and vector products. Algebra concepts related to series and sequences are addressed in the IB DP Mathematical Studies SL course, but concepts of infinity, convergence and proof by induction are not covered. In addition, the IB DP Mathematical Studies SL course does not cover integration, vectors and linear and separable differential equations.

Furthermore, all three IB DP Mathematics courses include additional content and topics, mainly concepts of statistics and calculus, which are not explicitly addressed by Norwegian Mathematics R1 and R2; these are:

- Statistical concepts of regression, Venn and tree diagrams, box-and-whisker plots, frequency distributions, linear correlation of bivariate data and Pearson's product–moment correlation coefficient, covered by all three IB DP Mathematics courses
- Binomial distribution concepts, included by both IB DP Mathematics SL and HL courses
- Statistical concepts of Poisson distribution and the central limit theorem and calculus concepts of higher derivatives, optimization problems, Euler's method, Rolle's theorem, Maclaurin series, Taylor polynomials, Taylor series developed from differential equations and l'Hôpital's rule, referenced in the IB DP Mathematics HL guide

- Additional optional topics of *Sets, relations and groups* and *Discrete mathematics,* covered by the IB DP Mathematics HL course.

3.3.5 Mathematics S1 and S2

Aims - Basic Skills

The Norwegian Mathematics S1 and S2 courses both prescribe the same set of basic skills that indicate the mathematical skills students are intended to develop on completion of the courses. These have been compared with expectations set in the IB DP Mathematical Studies SL course.

Table 25: Basic skills of the Vitnemål for Videregående Opplæring and IB DP Mathematical Studies SL

Vitnemål for Videregående Opplæring– Mathematics S1 and S2		Included in the IB DP
Being able to express oneself orally and in writing in Mathematics for the social sciences:	Involves the ability to explain a mode of thought and articulate findings, concepts and hypotheses	✓
	Means posing questions, participating in talks and discussions of mathematical situations and problems, and presenting a reasoned argument for one's own proposed solution	✓
	Involves using logically consistent formulations with mathematical symbols to set up or draw tables, diagrams, graphs and figures	✓
Being able to read in Mathematics for the social sciences:	Involves the ability to extract relevant mathematical information from written text	✓
	Means understanding mathematical symbols and logical reasoning, as well as interpreting organized visual information such as tables, diagrams, graphs and figures	✓
Numeracy in Mathematics for the social sciences:	Involves carrying out various arithmetical operations with confidence and without use of digital tools	✓
	Means making practical estimates and assessing the reasonableness of a solution	✓
Being able to use digital tools in Mathematics for the natural sciences:	Involves using digital tools for comprehensive computations, visualization and simulation	✓
	Means obtaining, processing and presenting mathematical information in electronic form, as well as evaluating the suitability, potential and limitations of the digital tool.	✓*

Similar to the Norwegian basic skills seen above, the IB DP prescribes a set of aims and assessment objectives that indicate what students are expected to be able to do. Further, the assessment and syllabus outline indicates skills that students are expected to develop.

Overall, both aim for students to develop communication skills (i.e. speaking, writing and reading are specified in the Norwegian programme) in mathematics. Communication is also expected in the IB DP project and is graded within Criterion F: Structure and Communication. As seen in the table above, the Norwegian programme goes more in depth than the IB DP

on the specific communication skills that are expected; participating in talks and giving presentations on a mathematical argument are not direct aims in the IB DP but overall are elements included within the individual internal assessment (i.e. the project) and within the Theory of Knowledge (TOK) section of the syllabus which are intended to be used for discussions.

Further, confidence in using mathematics and communicating mathematically is a similar aim of both programmes. Both also expect students to complete calculations without the use of a calculator (i.e. digital tool); however this is more of an emphasis in the Norwegian course. Nonetheless, reference to IB DP students using mathematical notation rather than calculator notation is included in some sections of the IB DP Mathematical Studies SL Guide. Both courses also prescribe aims and expectations for students to use technology and tools, such as calculators, to solve problems. The Norwegian skill seen above also further elaborates that the digital tools should be used for visualisation and simulation; this is similarly included within the IB DP through use of computer software, programming, and graphical software to apply, visualise, and simulate mathematical problems. Further, using a graphic display calculator to allow for visual and kinaesthetic approaches to teaching is referenced in the IB DP.

Both programmes expect students to develop skills related to understanding and interpreting mathematical information and graphs and diagrams; drawing their own graphs and diagrams is also expected. Logical reasoning and deduction is a skill similarly emphasised in both programmes, with students expected to be able to determine if a solution is reasonable.

Aims - Subject Area

In addition to the basic skills above, the Norwegian courses set aims for each subject area. The below table demonstrates how the Norwegian Mathematics S1 course aims compare with the IB DP Mathematical Studies SL course.

Table 26: Aims of the Vitnemål for Videregående Opplæring Mathematics S1 and IB DP Mathematical Studies SL

Vitnemål for Videregående Opplæring – Mathematics S1		**Included in the IB DP**
Algebra	**The aims of the studies are to enable pupils to:**	
	Work with powers, formulae, brackets and rational and quadratic expressions with numerals and letters	✓
	Convert a practical problem into an equation, an inequality or a system of equations, solve it and assess the validity of the solution	✓* Expected Prior Learning
	Solve equations, inequality and systems of equations of the first and second degree, in longhand and by digital means	✓* Expected Prior Learning
	Calculate with logarithms and use them to simplify expressions	

Vitnemål for Videregående Opplæring – Mathematics S1		Included in the IB DP
	and solve exponential equations and logarithmic equations	
	Use the concepts of implementation and equivalence in mathematical reasoning	✓
Functions	Draw graphs of polynomial functions, exponential functions, power functions and rational functions with linear numerators and denominators with and without digital means	✓*
	Create and interpret functions as models and describe practical problems in economics and social science, analyze empirical functions and use regression to find a polynomial approximation of a function, power function or exponential function	✓*
	Determine zero points and intersection points between graphs, with and without digital means	✓
	Find the average growth rate for a function arithmetically, and find approximate values for momentary growth in practical applications	
	Give an account of the definition of the derivative, work out the derivative for polynomial functions and use this to discuss polynomial functions	✓
Probability	Work with binomial coefficients and construct Pascal's Triangle	
	Give an account of non-random selection with and without replacement and random selection without replacement, and carry out simple probability calculations linked to such selections	✓*
	Create binomial and hypergeometric probability models from practical situations, and work out probabilities for such models	✓*
Linear optimization	Model practical optimization problems in economics using linear equations and incongruence	
	Give an account of the geometrical interpretation of the linear optimization problem in two variables	
	Solve linear optimization problems graphically, using longhand and digital means.	

As seen in the table above, some of the aims of the Norwegian Mathematics S1 course are similarly expected in the IB DP Mathematical Studies SL course. For example, both aim for students to learn to use formulas, rational and quadratic expressions, and to understand key algebra concepts (i.e. equivalence and implication from the IB *Logic* topic). In relation to the Norwegian topic of *Functions*, both courses include content related to intersections and intercepts (i.e. zero points).

In some cases, rather than being fully included in the IB DP, only a portion of the Norwegian aim has been identified within the IB DP (i.e. partially included). In *Algebra*, although converting a practical problem into an equation is similarly found in both courses and inequality and systems of equations for quadratic equations and equations of the second degree are not included in the IB DP. It should be noted, however that solving first degree

equations, systems of linear equations in two variables, and linear equations are part of the expected prior learning for the IB DP Mathematical Studies SL course.

Further, some of the Norwegian aims; although not included or partially included in the IB DP; intend to teach skills and concepts that on a more general level can be identified within the IB DP. For example, drawing and interpreting graphs, functions and equations are concepts and skills found in both courses.

The term *optimization*, although used in both the Norwegian S1 and IB DP Mathematical Studies SL courses, are applied in different contexts and is therefore not covered in the IB DP. The IB DP teaches optimization in relation to calculus and differential equations rather than for linear equations as seen in the Norwegian S1 course.

In addition to the Norwegian Mathematics S1 course, aims are also separately set in the Norwegian Mathematics S2 course. These are seen in the table below.

Table 27: Aims of the Vitnemål for Videregående Opplæring Mathematics S2 and IB DP Mathematical Studies SL

Vitnemål for Videregående Opplæring – Mathematics S2		Included in the IB DP
Algebra	**The aims of the studies are to enable pupils to:**	
	Find patterns in numerical series and use them to sum finite arithmetical and geometrical series and other series, with and without digital means	✓
	Determine whether an infinite geometric series is convergent and calculate the sum of the series	
	Use series to solve practical problems related to savings, loans and hire-purchase	✓
	Factorize polynomials using zero points and polynomial division, and use the result to solve equations with polynomial and rational functions	
	Model practical problems using systems of linear equations with several unknowns, and solve them with and without digital means	✓* Expected Prior Learning
Functions	Derive polynomial functions, power functions, exponential functions and logarithmic functions, and sums, differences, products and quotients of these functions, and use the chain rule to derive combined functions	
	Elaborate on and discuss the path of functions and interpret the derivative in practical contexts by using first and second derivatives	✓*
	Interpret the basic characteristics of a function using the graph	✓
	Solve economic optimization problems in connection with income, cost and demand functions, and calculate and use marginal costs and income in simple models	✓*

Vitnemål for Videregående Opplæring – Mathematics S2		Included in the IB DP
	Model exponential and logistical growth rate by using exponential functions and logarithmic functions	✓*
	Calculate the area under graphs by digital means and interpret this in practical situations	
Probability and statistics	Give an account of the concepts distribution and stochastic variable for finite probability spaces, and find expectation, variance and standard deviation for a stochastic variable	✓
	Give an account of the significance of the normal distributions and calculate probabilities linked to these	✓
	Give an account of the central limit theorem and use it to calculate probabilities for sums of independent stochastic variables and binomial distributions	
	Carry out simple hypothesis testing using p-values and interpret results.	✓

The IB DP Mathematical Studies SL and Norwegian Mathematics S2 courses share similar overall subject level aims, as seen in the table below. Similar expectations are set related to probability and statistics with both courses covering distribution, stochastic (random) variable, expectation, standard deviation, normal distributions, and p-values. However the Norwegian aim related to central limit theorem and binomial distributions was not similarly found in the IB DP.

Two additional aims included in both programmes are for students to interpret functions using graphs and to solve practical problems related to saving, loans and hire-purchase (referred to compound interest and annual depreciation in the IB DP). The remaining aims related to the Norwegian topics of Functions and Algebra are either partially included or not similarly expected in the IB DP course. For example, although sum of geometric series is broadly included in the IB DP, students are not required to determine whether infinite geometric series is convergent. Further, Norwegian content and aims related to exponential and logarithmic functions, using the chain rule, deriving functions, and the area under a graph is not included in the IB DP.

Additional concepts from the Norwegian aims identified in the IB DP include arithmetic and geometric series, using systems of linear equations in problems and interpreting derivatives.

Content

For the Norwegian Mathematics S1 and S2 courses and the IB DP Mathematical Studies SL course, the table overleaf contains a broad outline of the subject areas covered.

Table 28: Content in the Vitnemål for Videregående Opplæring and IB DP Mathematical Studies SL

	Vitnemål for Videregående Opplæring – Mathematics S1	Vitnemål for Videregående Opplæring – Mathematics S2	IB DP Mathematical Studies SL
Topics	• Algebra • Functions • Probability • Linear Optimization	• Algebra • Functions • Probability and Statistics	• Number and algebra • Descriptive statistics • Logic, sets and probability • Statistical applications • Geometry and trigonometry • Mathematical models • Introduction to differential calculus • *Project*
Number of topics	4	3	7
Recommended teaching hours	140 hours	140 hours	150 hours

The table above demonstrates that the Norwegian and IB DP courses cover similar key topics areas in mathematics over a similar duration of teaching hours. The following tables further examine whether the mathematical content from the Norwegian topics can be identified within the IB DP Mathematical Studies SL course.

Table 29: Content comparison of the IB DP Mathematical Studies and Mathematics S1

Vitnemål for Videregående Opplæring – Mathematics S1		Included in the IB DP Mathematical Studies SL
Algebra	**The main subject area deals with:**	
	The fundamental language of symbols in mathematics	✓
	Working with letters and symbols, and transformation of and use of formulae	✓
	Core concepts in the subject area are linear, quadratic and rational expressions, logarithmic expressions, exponential expressions and exponential growth	✓*
Functions	Analyzing the dependence between two quantities	✓
	Relations between quantities from algebra and practical areas, which are analyzed by the use of functions and their graphs	✓

Vitnemål for Videregående Opplæring – Mathematics S1		Included in the IB DP Mathematical Studies SL
	Empirical functions, polynomial functions, power functions, rational functions, logarithmic functions and exponential functions	✓*
	Regression, average and momentary growth rate, and the derivative and graph of a function	✓*
Probability	Calculus of probability theory as a basis for statistical methods, which are used to obtain information about a population on the basis of a random selection	✓*
	Independence and conditioned probability, random and non-random selection and binomial and hypergeometric probability models	✓*
Linear optimization	Linear optimization as a useful tool in economics	
	The use of linear optimization to find the best possible solutions to practical problems that are naturally modelled by linear equations and incongruence.	

As seen in the table above, the majority of the Norwegian Mathematics S1 sub-topics are similarly taught in the IB DP. Although some difference in the focus of the topics was identified, enough content is in common between the courses for the sub-topics to be considered partially included, in most cases.

Overall, both courses teach content related to using mathematical symbols, letters and formula. Further, linear, quadratic, rational, and exponential expressions are similarly covered. Analysing the dependence between two quantities (i.e. through equations and graphs), and application of algebra and functions is also expected. Nonetheless, the IB DP does not include the Norwegian content related to specific functions (empirical and logarithmic), random and non-random selection, and hypergeometric probability models.

In relation to the topic *Functions*, both courses cover regression, the derivative, the graph of a function, but the IB DP does not go as in depth on growth, in particular average or momentary growth. In relation to the topic of *Algebra,* it is assumed, as identified from the comparison of the aims, that both courses cover similar content related to equivalence and implication, as taught in the IB DP Mathematical Studies SL *Logic* topic.

As found previously with the aims, the concept of optimization is taught in a different context in both courses and therefore these sub-topics are not covered in the IB DP. Further, for *Probability*, as found with the aims these are partially included as the IB DP includes content related to statistical methods, independence and conditioned probability, random events, and probability with and without replacement.

Overall, the IB DP Mathematical Studies SL course covers a larger breadth of mathematics topics; in addition to the above, the IB DP teaches *Descriptive Statistics,* further content related to *Logic*, and covers a different scope of content related to geometry, trigonometry,

statistics and probability. For example, although the Norwegian course also teaches probability, the IB DP covers different content related to tree diagrams, Venn diagrams, and conditional probability.

In addition to the Norwegian Mathematics S1 course, the Mathematics S2 course content is seen in the table below:

Table 30: Content comparison of the IB DP Mathematical Studies and Mathematics S2

Vitnemål for Videregående Opplæring – Mathematics S2		Included in the IB DP Mathematical Studies SL
Algebra	**The main subject area deals with:**	
	The use and manipulation of polynomials and rational expressions, and analysis and calculation of finite sums and infinite series	✓*
	Core concepts in the main programme area are polynomials and polynomial division, linear equations, series and convergence	✓*
Functions	General derivation rules; the use of these rules to elaborate on and discuss and calculate with functions composed of polynomials, power functions, rational functions, logarithmic function and exponential functions	✓*
	Use of functions for modelling, both in economics and for different growth phenomena	✓
Probability and statistics	The use of probability theory to describe and analyze random variations and systematic trends in a number of practical situations	✓*
	Fundamental concepts in this main subject area are stochastic variables, expectation, variance and standard deviation, normal distribution, the central limit theorem and hypothesis testing.	✓*

IB DP Mathematical Studies SL and the Norwegian Mathematics S2 course teach similar topics and sub-topics within their curriculums. As seen in the table above, both cover content related to rational expressions, linear equations, series, exponential functions, and using functions for modelling in an economics and growth context. Key probability and statistics content is also similarly taught; however the IB DP does not cover variance and central limit theorem. Further, although the IB DP covers probability and methods to determine the likelihood of random events, it does not cover 'random variations and systematic trends' as seen in the Norwegian course.

Other Norwegian mathematics content that sits outside of the scope of the IB DP Mathematical Studies SL course includes rational functions and logarithmic functions.

The IB DP Mathematical Studies SL course teaches additional mathematics content to the above and overall includes a wider breadth of content within the course. For example, the IB

DP covers *Descriptive Statistics*, *Statistical Applications, Geometry and Trigonometry*, *Logic* and introduces *Differential Calculus*.

3.4 Research Question 4: Subject Assessment and Cognitive Demand

In what ways do the DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL approaches to assessment align or differ with similarly-focussed upper secondary subjects in Norway?

Are there differences in the cognitive demand between DP Mathematics SL and HL, Mathematical Studies SL and Sciences (Biology, Chemistry and Physics) SL; and similarly-focussed upper secondary subjects in Norway?

In each Norwegian subject, *Examination Guidance* is publically available for the 2018 externally conducted written examinations. This provides information to parents, students, and examination markers on the structure of the external examination and how it will be marked. The examinations are designed to assess how competent the student is in the subject on a grading scale from 1-6, from a very low degree competence (Grade 1) to an exceptionally high degree of competence (Grade 6); further information on grading can be found in Section 1.1.2. Examination markers evaluate the students' ability to complete each activity or task in the examination but also determine an overall competence mark based on the whole examination; therefore although a mark scheme is provided for the examinations, the *Examination Guidance* indicates that examiners use their own judgement on the overall competency demonstrated by the student, awarding a single grade for each subject from 1-6.

For each Norwegian subject, three competency descriptors are provided: grade 5/6, grade 3/4, and grade 2. These are intended to be used by examination markers as a guide on determining the competence level achieved for each task and the examination as a whole. Although standalone descriptors are provided for Grade 2 which provides a helpful indicator of the lowest skills and competencies expected, the descriptors for Grades 5 and 6 are combined making it difficult to differentiate what a student needs to demonstrate in order to receive the highest grade.

In comparison, the IB DP awards a grade on a scale from 1-7 based on all completed assessments; grade descriptors are provided for each grade, mark schemes are used for external assessments and assessment criteria is provided for the internal assessments.

3.4.1 Biology

Assessment Methods

Internal and external assessment methods are used throughout the Vitnemål for Videregående Opplæring; the type depends on the year, subject and course. In the Norwegian Biology 1 course, students are assessed via an oral-practical examination that is prepared and marked internally. As these are not standardised or publically available, the external written examination given in Biology 2 (for selected students), which is taken in the year following Biology 1, has been reviewed in the below section. This examination is prepared and marked centrally.

Assessment methods in the IB DP are a combination of external assessment, which makes up 80% of the final subject grade, and internally marked (externally moderated) assessment,

which makes up 20% of the final subject grade. The table below compares these overall assessment methods.

Table 31: Vitnemål for Videregående Opplæring and IB DP Biology assessment formats

	Vitnemål for Videregående Opplæring Biology 2	IB DP Biology SL
Number and type of assessments each examination series	One written external examination (where a student is selected) or an oral-practical examination	Three written external examinations One internal assessment
Duration	Written examination: 5 hours	Paper One: 45 minutes Paper Two: 1 hour 15 minutes Paper Three: 1 hour Internal assessment: 10 hours
Type(s) of question	Written examination: Multiple-choice, short, long and extended response questions	Paper One: multiple choice questions Paper Two: data-based questions, short answers and extended response questions (students answer one out of two extended response questions) Paper Three: • Section A: short answer questions based on experimental skills and techniques, analysis and evaluation, using unseen data • Section B: short answer and extended response questions from one optional topic content Internal assessment: one scientific investigation and 6 to12 page write-up
Total marks available	n/a	Paper One: 30 marks Paper Two: 50 marks Paper Three: 35 marks Internal assessment: 24 marks

As seen in the table above, IB DP Biology SL consists of three written examinations over a total of three hours, with an additional practical internal assessment. In comparison, the Norwegian Biology 2 course is either assessed by an internal oral-practical examination or an external written examination, which is developed and marked externally; further internal assessments may take place in the Biology 2 course to determine the overall achievement mark for the course, which is a separate mark to the written examination assessment mark. Therefore, similar assessment methods are used between the two courses, but the overall volume of assessment in the Norwegian course is unknown and therefore cannot be compared with the IB DP.

When comparing the IB DP three written papers with the Norwegian external written examination, similar question types are used, including multiple-choice, short and extended response. Both offer a mixture of questions that either permit or do not permit the use of a calculator.

The Norwegian assessment includes a total of 24 multiple-choice questions. Most of these questions require students to read and understand graphs, figures or tables with data; therefore these assess the students understanding and application of their knowledge and some analysis of data and information. Similarly the IB DP includes 30 multiple-choice questions with diagrams and graphs included for many of the questions.

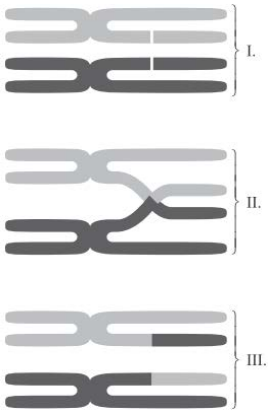
In addition to the multiple-choice questions, the first part of the Norwegian examination includes an extended answer question with four sub-questions. For this part, no calculators or digital tools are allowed, and students can write a response up to a maximum of one page. Students are required to a) sketch a food chain and provide a justified description of increases/decreases in energy, b) compare how genetic and natural selection can change a population, c) describe two processes in photosynthesis, and d) using a population growth graph provided, determine where a specified point is and provide and interpretation and reasoning for the data shown in the graph.

Similarly, the IB DP provides short and long answer questions and sub-questions where a graph or table and associated data are provided to the student. These allow the use of a calculator, but similar skills are tested. Students are required to interpret a graph or table with data, and identify key information from these and evaluate the data further. The data presented is typically either familiar to the student from experiments conducted during the programme, or is previously unseen and therefore unfamiliar to the student. To evaluate unseen data, the student must apply their knowledge and understanding to a new situation.

Within some of these IB DP sub-questions, students are also asked to state or compare biological processes, such as in the below question example:

Figure 6: Sample IB DP Biology SL question

5. The diagrams show two chromosomes at three stages in meiosis.



(a) The diagrams show a process that promotes genetic variation. Describe this process.

(b) State the type of life-cycle that includes meiosis and the reason for it being needed in this type of life-cycle.

One extended question is provided in the final section of the IB DP Paper 2, which may require a similar extended response to the Norwegian extended response questions described above. Although no diagram, graph or tables are provided for this question, similar skills are assessed in that students are asked to explain a biological process in detail and provide a suggestion of what kind of ethical research could be used to study that process, or distinguish between the structure of two types cells and evaluate tests done by scientists in that field (i.e. students presumably must also demonstrate their knowledge and understanding of these historical tests as no further information is provided to the student on these tests) and explain reasoning behind the ineffectiveness of a drug.

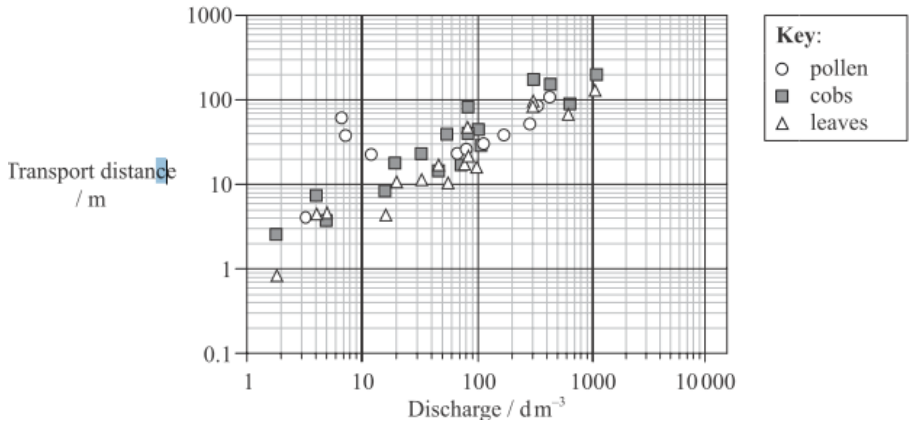
The second part of the Norwegian examination includes three questions with each including a set of sub-questions (for a total of 11 sub-questions); calculators and digital tools are allowed for this section of the examination. In one question, students are presented with a problem; a National Park wants to know why herbivores are dying, and whether predators are to blame. A graph displays the proportion of the herbivores that die due to predation in relation to their average body weight. Students are then a) asked to describe the relationship between the data on the x and y axis in the graph; and, b) to discuss how the population growth of herbivores would be affected by a sharp decrease in predators.

Two further sub-questions are provided which are based on an additional diagram and information. In the first, in regard to a diagram related to the effects of hunting on the population of elephants in Mozambique, students must explain the effects of hunting on allele and gene variations. In the final question, information on giraffe spots, gene variations, and which alleles are linked to pigment or albinism. Students must then list three possible genotypes of a giraffe with albinism and which of those genotypes must be linked to albinism by drawing a Punnett square diagram which is used to predict genotypes.

Similar questions are also found in the IB DP with questions requiring students to read from graphs, such as in the example question below:

Figure 7: Sample IB DP Biology SL question 2

Leaves, cobs and pollen were stained with a pigment and then released into the streams to find the average transport distance. The volume of waterflowing in the streams (discharge) was also measured. The results are shown in the graph.



[Source: adapted from Rosi-Marshall, et al., (2007), Proceedings of the National Academy of Sciences, 104, pages 16204 16208.Copyright (2007) National Academy of Sciences, U.S.A.]

(c) Estimate the maximum transport distance for cobs.

(d) State the relationship between discharge rates and transport distance for debris from the corn crop.

(e) Distinguish between the transport distance of cobs and leaves.

Overall, Paper 2 in the IB DP includes similar short, long and extended question types to the Norwegian questions described above. These are used to assess the student's knowledge and understanding of key biological topics, diagrams and graphs; drawing diagrams is also expected. In some questions, students in both courses are also required to demonstrate analysis and evaluation skills where they are required to justify why a process occurs or certain data exists. In regards to the overall volume and skills assessed in the Norwegian written examination, this compares well to the volume and demand of the questions in the IB DP Paper 1 and 2; however the IB DP Biology SL course further includes Paper 3 which assesses experimental skills and techniques and the content learned in the optional biology topic taught in the course. The internal assessment also takes place.

As the Norwegian course includes internal assessment techniques it is possible that the overall volume of work and assessment completed is similar between the two courses, but in regards to the external written assessment, the IB DP has a higher volume of assessment.

Grade Descriptors

The Norwegian competency descriptors for Biology 2 are split into three categories:

- Biological concepts, theories and processes
- Problem solving
- Practical skills and fieldwork.

Across these three areas, the descriptors indicate the level of vocabulary, knowledge, understanding and practical skills expected. From the IB DP Biology assessment objectives it is clear that both programmes assess similar skills and competencies, in particular knowledge and understanding of the subject content, terminology, and how to communicate scientific information. Furthermore, both assess the students' practical and investigation skills.

At grade 2, the descriptors refer to simple knowledge and understanding of the subject content and application of vocabulary; simple responses when solving problems and simple descriptions of experiments and completed fieldwork. In the IB DP, the descriptors for grade 2 and 3 indicate students have either little or limited knowledge of basic information and either no ability or a weak ability to apply their knowledge. The ability to solve some problems and communicate responses doesn't become a skill until grade 3 in the IB DP; however limited investigative skills are demonstrated at both grade 2 and 3.

The top grades for the Norwegian Biology course, grade 5 and 6 broadly compare to descriptors set for grade 4 through 7 in the IB DP. The Norwegian descriptors refer to discussing the concepts and finding connections between concepts in the curriculum, independently solving problems and conducting fieldwork. These skills are similarly expected

in the IB DP with completing investigations independently starting at grade 5, and adequate communication, therefore likely to include discussion, from grade 4.

In regards to the investigative and practical skills expected at the Norwegian grade 5 and 6, the descriptors include a set of skills that should be demonstrated to achieve this grade. For example, independently creating hypotheses, planning practical work, considering safety, and evaluating results against hypothesis and sources of error are expected. Many of these are similarly assessed in the IB DP, and in some cases, are defined in the IB DP descriptors, but with varying levels of competence described. For example, grade 7 IB DP students are "fully capable of working independently" on investigative work whereas grade 5 students are "sometimes capable of working independently". It should be further noted that the Norwegian grades 3 and 4 descriptors make no reference to independent work, therefore indicating that these compare to IB DP grade 4 where students need supervision during practical work.

3.4.2 Chemistry

Assessment Methods

The Norwegian Chemistry 2 written examination is not provided in the public domain.

Grade Descriptors

The Norwegian competency descriptors for Chemistry 2 are split into the following five categories:

- Professional language
- Concept System
- Qualitative contexts and reviews
- Quantitative contexts and reviews
- Experiments.

At a minimum, at grade 2, understanding of concepts and terminology is limited and language is unclear. Further, simple qualitative and quantitative problems are understood and solved but with simple or incomplete presentation. Simple experimental work can be reproduced with simple risk assessments and calculations conducted. These skills are similarly expected in the IB DP; at grade 2 a student may give incomplete and irrelevant presentations (i.e. communication) and have a very limited range of investigative techniques including a little awareness of safety factors. However, some similar descriptors are found at IB DP grade 3 including some ability to manipulate data and solve basic or routine problems.

To earn a grade 5 or 6 in the Norwegian course, the student must demonstrate the ability to make convincing arguments using precise language, concepts and in-depth terminology. This reflects the skills expected at grade 7 in the IB DP where comprehensive knowledge of information and concepts is expected and the ability to communicate concisely with appropriate terminology. Similar, but albeit slightly lower skills are also expected at grade 6 which also reflect the Norwegian skills; effective communication, use of terminology, and broad and relevant knowledge is expected. Insight and originality in suggesting experiments

or making arguments, assumption and predictions is also expected to be awarded a Norwegian grade 5-6 or the IB DP grade 7-6.

Further, handling of quantitative and qualitative data and information is a core skill across the Norwegian descriptors. At grade 5-6 it is expected that the student can work with and explain complex qualitative problems and confidently and accurately solve quantitative problems, presenting coherent solutions. Overall, these compare to the problem solving expectations to receive a grade 6 in the IB DP; in particular, to analyse quantitative and qualitative data with a high level of competence and to "solve basic or familiar problems and most new or difficult quantitative and/or qualitative problems". However, analysis of the data and problems is expected at a high level at the IB DP grade 5 as well and further demonstrate how the Norwegian descriptors may reflect a range of the IB DP grades and skills expected.

In the middle of these top and bottom grades, students can receive a grade 3 or 4 in the Norwegian course when they have a mostly correct understanding of concepts and can use most terminology correctly. Further they can present solutions to problems coherently. This reflects the skills required to earn a Grade 4 in the IB DP, in particular to have adequate comprehension of concepts and adequate communication techniques. Further both courses require that students can evaluate simple and routine problems and data; some investigative and practical skills are expected.

3.4.3 Physics

Assessment Methods

The Norwegian Physics 2 written examination is not provided in the public domain.

Grade Descriptors

The Norwegian competency descriptors for Physics 2 are split into the following four categories:

- Presentation
- Justifications and descriptions
- Troubleshooting and calculations
- Treatment of values and experimental data.

At a minimum, at grade 2, the Norwegian Physics 2 course expects students to be able to solve simple problems and present solutions in a simple manner, using basic terminology. Some descriptions of procedures and processing of data occurs. This level of ability is reflected within the IB DP as demonstrated mostly at grade 3 where partial comprehension of basic concepts and principles is expected. Further some ability to manipulate data and solve basic or routine problems. Communication (i.e. presentation and use of terminology) lacks clarity.

The Norwegian descriptors for grade 5 and 6 are combined and compare well to the IB DP descriptors for Grade 7 and 6. In particular, Norwegian students are expected to be able to

present neat, orderly, and accurate solutions and arguments using expert language. This compares well to the expectation of Grade 7 IB DP student who "communicates logically and concisely using appropriate terminology and conventions". Further, both courses expect students to be able to solve complex problems at the top grade (i.e. IB DP Grade 7). In regards to the Norwegian skills that compare to both Grade 7 and 6, this includes having comprehensive (grade 7) or very broad knowledge (grade 6) of information and concepts, and the ability to applies in many contexts. Analysis of data, using mathematics, and application to physics theories is found across both courses at these grades; further confidently and accurately completing calculations is expected; this is completed thoroughly and proficiently at IB DP Grade 7 and with a high level of competence and on most new or difficult problems in Grade 6.

3.4.4 Mathematics

Assessment methods

Norwegian Mathematics R1 and R2

Norwegian Mathematics R1 and R2 students may be selected for a written or oral exam. The written exam is externally conducted and marked. The oral exam is prepared and marked internally. In the table below, the Norwegian Mathematics R1 and R2 external written exams are compared to the exams of all three IB DP Mathematics courses.

Table 32: Vitnemål for Videregående Opplæring and IB DP Mathematics assessment format

	Vitnemål for Videregående Opplæring Mathematics R1 and R2	IB DP Mathematics courses
Number and type of assessments each examination series	Mathematics R1: one written external examination (where a student is selected) or an oral examination Mathematics R2: one written external examination (where a student is selected) or an oral examination	Mathematical Studies SL: two written external examinations and one individual internal assessment (the project; a written investigation) Mathematics SL: two written external examinations and one internal mathematical exploration (a written investigation) Mathematics HL: three written external examinations (Paper 1 and 2 on core topics and Paper 3 on one optional topic[10]) and one internal mathematical exploration (a written investigation)
Duration	Mathematics R1 and R2: Total 5 hours each (Part 1 to be submitted within 3 hours)	Mathematical Studies SL: • Paper 1: 1.5 hours • Paper 2: 1.5 hours • Project: approx. 25 teaching hours

[10] Optional topics include: discrete mathematics; calculus; sets, relations and groups; and statistics and probability.

	Vitnemål for Videregående Opplæring Mathematics R1 and R2	IB DP Mathematics courses
		Mathematics SL: • Paper 1: 1.5 hours • Paper 2: 1.5 hours • Mathematical exploration: 10 teaching hours Mathematics HL: • Paper 1: 2 hours • Paper 2: 2 hours • Paper 3: 1 hour • Mathematical exploration:10 teaching hours
Type(s) of question	Mathematics R1: short answer questions and multi-part structured questions Mathematics R2: short answer questions and multi-part structured questions	Mathematical Studies SL: Short answer[11], multi-part structured, extended problem, and combination of multi-part structured and extended problem Mathematics SL: Short answer[12], multi-part structured, extended problem, and combination of multi-part structured and extended problem Mathematics HL: Short answer[13], multi-part structured, extended problem, and combination of multi-part structured and extended problem
Total marks available	Mathematics R1 and R2: 60 marks each	Mathematical Studies SL: • Paper 1: 90 marks • Paper 2: 90 marks • Project: 20 marks Mathematics SL: • Paper 1: 90 marks • Paper 2: 90 marks • Mathematical exploration: 20 marks Mathematics HL: • Paper 1: 100 marks • Paper 2: 100 marks • Paper 3: 50 marks

[11] The IB Mathematical Studies SL papers include a number of short answer sub-questions as part of a larger multi-part question.
[12] The IB Mathematics SL papers include a number of short answer sub-questions as part of a larger multi-part question.
[13] The IB Mathematics HL papers include a number of short answer sub-questions as part of a larger multi-part question.

	Vitnemål for Videregående Opplæring Mathematics R1 and R2	IB DP Mathematics courses
		• Mathematical exploration: 20 marks

The overall volume of external assessment is greater for all three IB DP Mathematics courses compared to the Norwegian Mathematics R1 and R2 courses. Both the IB DP Mathematical Studies SL and Mathematics SL courses are assessed through two external written examination papers each while the IB DP Mathematics HL course is assessed through three external written examination papers. In comparison, the Norwegian Mathematics R1 and R2 courses are both examined through one written exam paper each, further noting that the exam is only taken by a selection of students.

The Norwegian Mathematics R1 and R2 exams each include a total of 12 multi-part short answer questions. Both exam papers encompass two parts; part one is to be completed without digital tools within three hours whilst part two is to be completed within an additional two hours (five hours total). Norwegian students can opt to commence on part two in the first three hours of the exam, but are only permitted digital tools after three hours from the start of the exam.

In the IB DP Mathematics SL and HL courses, the first exam paper consists of 10 (combination of multi-part short answer and extended response) and 11 (combination of multi-part short answer and extended response) questions, respectively, to be completed without the aid of a calculator. Students have less than half the time permitted to Norwegian students to complete the exams (1.5 hours in SL and two hours in HL). Therefore, the IB DP courses included more questions that must be answered without a calculator, and within a shorter timeframe in comparison to the Norwegian Mathematics R1 and R2 courses.

When also considering the additional external written papers in the IB DP Mathematics HL and SL courses, a much higher volume of external assessment is given to IB DP students in comparison to the Norwegian students selected to take the Mathematics R1 or R2 examinations. In particular, the second IB DP Mathematics SL exam paper is composed of 7 multi-part short answer questions and approximately 3 multi-part structured and extended problems; to be completed within 1.5 hours. The second IB DP Mathematics HL exam paper encompasses 11 questions (combination of multi-part short answer and extended response questions) to be completed within two hours. While the third exam paper of the IB DP Mathematics HL course is to be completed within one hour, and the number of questions vary from four to five extended response questions depending on the optional topic selected by the student.

The first and second exam papers of the IB DP Mathematical Studies SL course are composed of fifteen (multi-part short answered) and six (large multi-part and extended problem) questions respectively, with a time duration of 1.5 hours each. Calculators are allowed for both exam papers.

Overall, all of the IB DP Mathematics courses written examinations require students to complete a greater number of questions in shorter time duration than the students sitting the Norwegian Mathematics R1 and R2 exams.

In terms of cognitive skills, the exams for all three IB DP Mathematics courses and Norwegian Mathematics R1 and R2 courses test the students' knowledge and understanding of a range of mathematical concepts. However, more difficult questions types are used in the IB DP Mathematics courses. For example, the Norwegian Mathematics R1 and R2 courses have a greater number of questions than the IB DP that require students to perform routine procedures (i.e. students are expected to differentiate, integrate and simplify functions). The IB DP examinations include a great number of questions that build in difficulty; they build from assessing routine procedures to application of procedures. One example is in the first exam paper of the IB DP Mathematical Studies SL course; students are expected to differentiate a curve function for the first short answer sub-question and then apply the answer from the first sub-question to answer the preceding sub-questions (i.e. apply the derivative of the curve function answer from part (a) of the question to find the gradient of the tangent to the curve in part (b) of the question).

Further the assessments of both the IB DP Mathematics SL and HL courses assess the ability to perform more complex procedures than those tested in the Norwegian Mathematics R1 and R2 exams. For example, the IB DP Mathematics SL exam expects students to find the first four derivatives of a function, in contrast to the Norwegian Mathematics R1 and R2 exam that assesses the student's ability to find only up to the second derivative of a function. Moreover, the IB DP Mathematics HL exam includes more complex integration problems that require students to recall and employ a range of multi-step procedures and techniques not examined by the Norwegian Mathematics R1 and R2 exam questions.

Similar to the examinations of the Norwegian Mathematics R1 and R2 courses, the assessments of all three IB DP Mathematics courses examine the student's ability to communicate and interpret mathematical information. Exam questions from the Norwegian Mathematics R1 and R2 courses and the three IB DP Mathematics courses assess the ability of students to transform problems into mathematical contexts and interpret and sketch mathematical graphs. Further, interpreting mathematical diagrams is assessed across all the courses. However the IB DP Mathematical Studies SL, IB DP Mathematics SL and IB DP Mathematics HL (in the *Calculus* elective topic) courses further examine the ability to sketch mathematical diagrams; not examined in either the Norwegian Mathematics R1 or R2 exam papers.

Other cognitive skills assessed by both the Norwegian Mathematics R1 and R2 and the IB DP Mathematics courses are the ability to justify, reason, deduce, draw conclusions and construct logical arguments. The exams of both the IB DP Mathematical Studies SL and IB DP Mathematics SL courses included questions that require students to formulate logical reasoning and make deductions, akin to the exam questions of the Norwegian Mathematics R1 and R2 courses.

Nevertheless the exam papers of the IB DP Mathematics HL course contain a considerably greater number of questions assessing the ability to construct logical arguments. Further the IB DP Mathematics HL exam questions are more complex than the exam questions found in

the Norwegian Mathematics R1 and R2 courses. The figure below shows an example from the IB DP Mathematics HL exam that examines the student's ability to formulate long arguments by applying a variety of mathematical techniques and formulas with limited guidance provided in the question. Comparatively, the Norwegian Mathematics R1 and R2 exams expect students to construct much shorter arguments with more guidance provided in the question.

Figure 8: Sample IB DP Mathematics HL question

In triangle ABC,

$$3\sin B + 4\cos C = 6 \text{ and}$$
$$4\sin C + 3\cos B = 1$$

(a) Show that $\sin(B + C) = \frac{1}{2}$ (6 marks)

Robert conjectures that $C\hat{A}B$ can have two possible values.

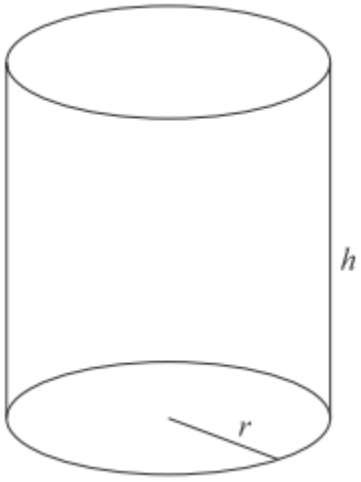
(b) Show that Robert's conjecture is incorrect by proving that $C\hat{A}B$ has only one possible value. (5 marks)

Moreover, the IB DP Mathematics HL exam papers assess the ability of the students to derive or formulate more complex proofs than those encountered in the Norwegian Mathematics R1 and R2 examinations. These skills are only assessed in the IB DP Mathematics HL course, and not in the SL courses.

Problem solving skills are assessed by both the Norwegian Mathematics R1 and R2 courses and all three IB DP Mathematics courses. Overall, the IB DP Mathematics courses include more extended problems that assess a range of other skills (transforming problems into mathematical context, deduction, drawing conclusions, formulating mathematical models or expressions and logical reasoning). For example the IB DP Mathematical Studies SL exam tests the ability of students to solve an extended problem pertaining to geometry concepts in the large multi-part question shown in the figure overleaf.

Figure 9: Sample IB DP Mathematical Studies SL question

Nadia designs a wastepaper bin made in the shape of an open cylinder with a volume of 8000 cm^3

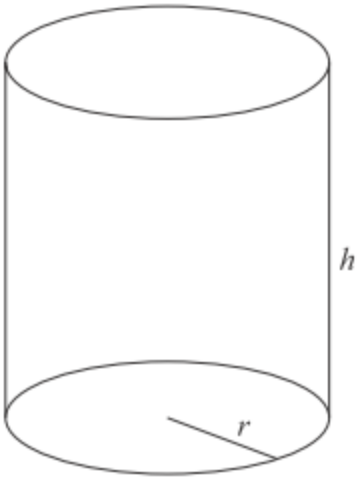


Nadia decides to make the radius, *r*, of the bin 5 cm.

(a) Calculate (7 marks)
(i) the area of the base of the wastepaper bin;
(ii) the height, *h*, of Nadia's wastepaper bin;
(iii) the total external surface area of the wastepaper bin.

(b) State whether Nadia's design is practical. Give a reason. (2 marks)

Merryn also design a cylindrical wastepaper bin with a volume of 8000 cm^3. She decides to fix the radius of tis base so that the total external surface area of the bin is minimized.



Let the radius of the base of Merryn's wastepaper bin be *r*, and let its height be *h*.

(c) Write down an equation in *h* and *r*, using the given volume of the bin. (1 mark)

(d) Show that the total external surface area, A, of the bin is $A = \partial r^2 + \frac{16000}{r}$ (2 marks)

(e) Write down $\frac{dA}{dr}$ (3 marks)

(f)
(i) Find the value of r which is minimizes the total external surface area of the wastepaper bin.
(ii) Calculate the value of h corresponding to this value of r. (5 marks)

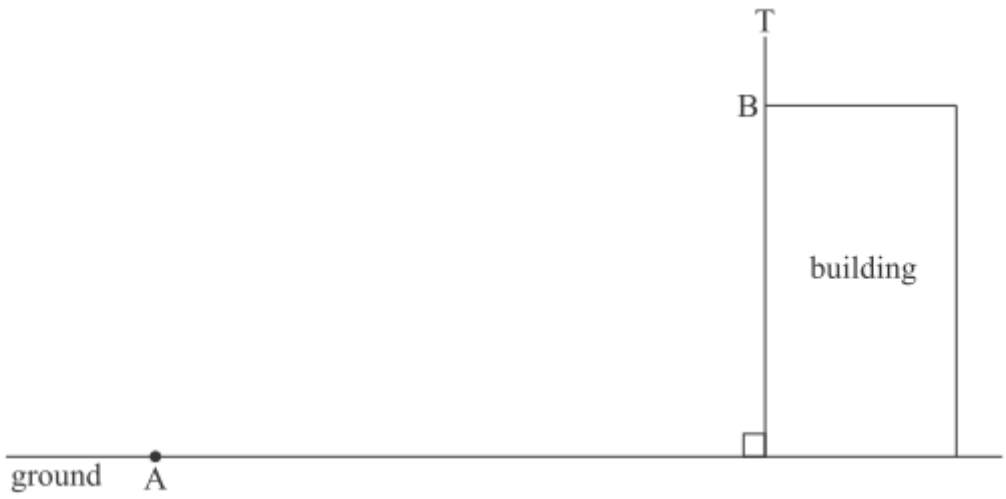
(g) Determine whether Merryn's design is an improvement upon Nadia's. Give a reason. (2 marks)

The extended problem question shown in the figure above includes seven sub-questions. First, it examines the student's knowledge and understanding of geometry concepts and the student's ability to find relationships between two variables, construct logical reasoning and arguments. Further, it assesses their ability to perform routine procedures such as differentiation in different contexts and to evaluate and test the validity of models and assumptions. The final sub-questions require the student to draw conclusions and make deductions. These types of extended problem questions are not encountered in the Norwegian Mathematics R1 and R2 exams.

In addition, the exam papers of both the IB DP Mathematics SL and HL courses include standalone extended response questions such as the question shown in the figure below.

Figure 10: Sample IB DP Mathematics SL question

The following diagram shows a pole BT 1.6 m tall on the roof of a vertical building. The angle of depression from T to a point A on the horizontal ground is 35°. The angle of elevation of the top of the building from A is 30°.



Find the height of the building. (7 marks)

In the above question, students are expected to apply their knowledge and understanding of concepts and problem solving skills in a multi-step approach to find a mathematical expression that enables them to calculate the height of the building; this tests the ability to

formulate a strategy independently with limited guidance. This type of standalone extended response question is not found in either the Norwegian Mathematics R1 or R2 exams.

Overall, when focussing on the external assessment of both programmes, the Norwegian R1 and R2 and all IB DP Mathematics examinations assess all the key topics covered in the syllabus and similar types of cognitive skills (i.e. knowledge and understanding of concepts, problem solving, ability to communicate mathematics and interpret mathematical graphs and diagrams and ability to make deductions). However, the assessments of the IB DP Mathematics courses have a greater breadth of topic coverage due to the greater volume of assessments, compared to the Norwegian Mathematics R1 and R2 courses.

The IB DP Mathematics courses also include questions of higher cognitive demand such as extended problems and standalone long response questions; not found in the Norwegian Mathematics external examinations. The IB DP Mathematics SL and HL courses assess more complex concepts than those encountered in the Norwegian Mathematics R1 and R2 exams.

Mathematics S1 and S2

Similar to Norwegian Mathematics R1 and R2 courses, students taking the Norwegian Mathematics S1 and S2 courses may be selected for a written or oral exam. The written exam is externally conducted and marked while the oral exam is prepared and marked internally. In this section, the written Norwegian S1 and S2 exam papers are compared to the IB DP Mathematical Studies SL examination.

Table 33: Vitnemål for Videregående Opplæring and IB DP Mathematics assessment format

	Vitnemål for Videregående Opplæring Mathematics S1 and S2	IB DP Mathematical Studies SL
Number and type of assessments each examination series	Mathematics S1: One written examination Mathematics S2: One written examination	Mathematical Studies SL: two written external examinations and one individual internal assessment (the project; a written investigation)
Duration	Mathematics S1 and S2: 5 hours each (Part 1 to be submitted within 3 hours)	Mathematical Studies SL: • Paper 1: 1.5 hours • Paper 2: 1.5 hours • Project: approx. 25 teaching hours
Type(s) of question	Mathematics S1: Short answer and multi-part structured Mathematics S2: Short answer and multi-part structured	Mathematical Studies SL: Short answer[14], multi-part structured, extended problem, and combination of multi-part structured and extended problem

[14] The IB Mathematical Studies SL papers include a number of short answer sub-questions as part of a larger multi-part question.

	Vitnemål for Videregående Opplæring Mathematics S1 and S2	IB DP Mathematical Studies SL
Total marks available	Mathematics S1: 60 marks Mathematics S2: 50 marks	Mathematical Studies SL: • Paper 1: 90 marks • Paper 2: 90 marks • Project: 20 marks

The Norwegian Mathematics S1 and S2 courses are assessed through one exam paper each whilst the IB DP Mathematical Studies SL course is assessed through two exam papers.

The Mathematics S1 and S2 exams are split into two parts and composed of short answer and large multi-part questions. Mathematics S1 includes 13 questions while Mathematics S2 includes 12. Students are allowed five hours to complete each examination, although part one can be completed within three hours without the aid of digital tools and part two is to be completed within the remaining two hours (students are permitted digital tools (i.e. calculators) for part two but only after part one is submitted).

The IB DP Mathematical Studies SL exam is composed of two papers; where paper one contains fifteen multi-part short answered questions and paper two is composed of six large multi-part and extended problem questions. A graphic display calculator is permitted for both papers and each paper is to be completed within 1.5 hours. Therefore, unlike the Norwegian exams, no questions assess the students without the use of a calculator.

Thus, the overall volume of external assessment in IB DP Mathematical Studies SL is greater than the Norwegian Mathematics S1 and S2 exams. Moreover, students taking the IB DP Mathematical Studies SL exam have to complete a greater number of questions in a shorter duration.

Overall the cognitive skills assessed by both the Norwegian Mathematics S1 and S2 and the IB DP Mathematical Studies SL exams are broadly similar. The student's knowledge and understanding of mathematical concepts, problem solving skills, ability to formulate logical reasoning and arguments, communicate mathematics and interpret graphs and tables are tested by both the Norwegian and IB DP exams. In particular, all of the exams include a high proportion of questions that examine the ability of students to apply knowledge in different contexts. For example in the IB DP Mathematical Studies SL question shown in the figure below, students are required to apply their knowledge of functions to transform the problem into a mathematical equation and solve the equation to make predictions of the temperature of liquid.

Figure 11: Sample IB DP Mathematical Studies SL question

A liquid is heated so that after 20 seconds of heating its temperature, T, is 25°C and after 50 seconds of heating its temperature is 37°C.

The temperature of the liquid at the time t can be modelled by $T = at+b$, where t is the time in seconds after the start of heating.

Using this model one equation that can be formed is $20a+b=25$ (a) Using the model, write down a second equation in a and b. (2 marks) (b) Using your graphic display calculator or otherwise, find the value of a and b. (2 marks) (c) Use the model to predict the temperature of the liquid 60 seconds after the start of heating. (2 marks).

Overall, the cognitive skills assessed by both the Norwegian Mathematics S1 and S2 and IB DP Mathematical Studies SL exams are broadly similar. Minor differences were noted in the topics assessed, but these reflect the findings of the analysis of the content taught. In particular, the Norwegian Mathematics S1 and S2 exams test the student's ability to solve inequalities which is not taught or assessed in the IB DP Mathematical Studies SL course (i.e. solving linear inequalities is part of the expected prior learning for the IB DP course). The Norwegian Mathematics S1 and S2 exams also have more questions on financial applications and assess the ability to perform regression using computer software. Alternatively, the IB DP Mathematical Studies SL exam covers the topics *Geometry* and concepts of implication and equivalence, not covered by the Norwegian Mathematics S1 and S2 exams.

Grade descriptors

For both the Norwegian and IB DP mathematics courses, the same set of grade descriptors applies across all of the mathematics courses examined[15] and are used to differentiate student performance and competence in terms of knowledge and understanding of concepts, problem solving skills, use of technology and mathematical communication skills. In particular, the Norwegian descriptors are separated into the following competencies:

- Concepts, understanding and skills
- Problem solving
- Communication.

Overall, direct comparisons of the IB DP and Norwegian grades shows many similarities with only a few differences observed. For example, in both the Norwegian and the IB DP Mathematics courses, students at grade 2 are able to demonstrate an understanding of basic concepts, attempt to solve simple problems, perform mathematical processes at a basic level, communicate some mathematics but often use inappropriate expressions, notation or terminology and attempt to use technology.

The IB DP grade 4 skills are closely aligned to the grade 3 and 4 skills of the Norwegian system. These skills includes the ability to understand most concepts, master most routine procedures, solve simple problems, formulate logical reasoning, draw conclusions, and communicate mathematics using some appropriate language, notation and terminology.

In the Norwegian system, students at grade 3 and 4 are also expected to demonstrate use of technology to a limited extent; that is a characteristic of IB DP grade 3 rather than grade 4. Further, Norwegian students at grade 3 and 4 are expected to show awareness of the

[15] One set of descriptors is used for IB DP Mathematics HL and SL, and Mathematical Studies SL; similarly, one set of descriptors is used across the Norwegian Mathematics R1, R2, S1 and S2.

relationships between different areas within the subject. In the IB DP, the student's demonstration of awareness of the relationship between different areas within a subject is part of grade 5 instead of grade 4.

The Norwegian grade 5 and 6 descriptors compare well with the descriptors for grade 6 and 7 of the IB DP, where students are expected to have a broad and thorough knowledge of concepts and content, use technology proficiently, confidently solve simple and complex problems in a variety of contexts, formulate logical reasoning, make assumptions, assess answers with certainty and communicate mathematics in a clear and effective manner using the correct terminology and language. The Norwegian grade 5 and 6 skills also include the ability to integrate concepts from different areas of the course with certainty, which is part of the highest IB DP grade (grade 7).

The Norwegian grade 5 and 6 descriptors also include the ability to evaluate the possibilities and limitations of digital tools; a skill not evident in the IB DP grade descriptors. Additionally the IB DP grades 4 to 7 expect students to be able to recognise patterns and structures at different levels (i.e. a grade 4 student is expected to show some ability to recognise patterns and structures whilst grade 7 students are expected to recognise all patterns and structures); this skill is not explicitly referenced in the Norwegian grade descriptors.

3.4.5 Marking

Although the Norwegian written examination questions are, in most cases, assigned a mark allocation, the instructions to the examination markers and students indicates that these marks are to be used as guidance (i.e. a suggested mark allocation) rather than a required maximum mark allocation.

Further, as discussed in Section 3.4, the instructions indicate that the marker can make a decision on the overall grade for the examination based on their own judgement. In addition to using the grade descriptors reviewed in Sections 3.4.4, the mathematics examinations, for example, may also be marked based on the students overall ability to demonstrate their computational skills and mathematical understanding, carry out logical reasoning, justify their answers, provide clear and accurate calculations with tables or graphical representations and on the reasonableness of their response. Therefore, the marking approach used for the Norwegian external examinations is less standardised and regulated in comparison to the IB DP.

In the IB DP, examination markers are expected to follow a detailed mark scheme that instructs markers on maximum mark allocations, which part of an answer can be awarded marks and possible answers a student may give (and how to mark these). Mark schemes are produced by the same senior examining team that designs the exam papers.

In the mathematics courses, both the Norwegian and IB DP examiners are instructed to provide some marks for correct workings or method, even though the final answer may be incorrect. Likewise both programmes allow for alternate methods than those stated in the mark scheme, unless the question specifies a method. Similarly full marks for a question are only awarded if a correct answer is accompanied with correct workings in all Norwegian and IB DP mathematics exams.

4. Conclusion

In conclusion, the comparative analysis of the Norwegian and IB upper secondary education systems at a policy- /system-, qualification- and subject-level has identified many areas where the two systems align. These are outlined in the following sections.

At an overarching level:

Overall, the Norwegian and IB upper secondary education set similar objectives and principles, with both seeking to provide a holistic education focussed on students' academic and personal development in order to develop students who are:

- Prepared for further study or work including the skills and values needed for work and life
- Critical thinkers and lifelong learners who are inquisitive, creative, and able to think scientifically
- Internationally-minded, and open-minded to the beliefs and cultures of others
- Principled (honest, respect for human dignity), ethical, understanding and caring (empathetic and compassionate).

At a qualification level:

From the comparative analysis, it can be concluded that the IB DP and Vitnem å l for Videreg å ende Opplæring closely align in the standards for teaching and learning. Overall, both intend for schools to:

- Ensure teaching is holistic and considers the physical, social and emotional well-being of students; students are safeguarded
- Use a range of teaching and learning methods to assist students in becoming self-motivated and regulated learners
- Provide a democratic and constructivist classroom environment and promote discussion and acceptance of others beliefs and opinions
- Ensure the needs of all students are met through customised and differentiated teaching
- Provide accurate and relevant subject curriculum and encourage connections to be made across the subject areas
- Provide assessment and feedback on student learning to record students' progress but also to ensure that students are aware of their progression
- Ensure teachers are supported and assisted in their delivery and professional development.

The overarching basic skills of the Norwegian courses and the IB DP Learner Profile, subject aims and assessment objectives provide similar expectations on the key cross-curricular skills students should develop on completion of the course or full programme, including:

- Relevant and applicable subject knowledge and understanding
- The ability to communicate or present arguments through a range of tools and methods (i.e. technology, writing and speaking)
- Critical and ethical thinking skills

- The ability to apply mathematics in new and non-mathematical contexts, including real-world scenarios.

At a subject level – the science courses

Overall, the basic skills developed across the IB DP and Norwegian science subjects demonstrate clear similarities in regards to communication, numeracy and use of digital tools (i.e. calculators). In particular, students are expected to develop:

- Key practical and investigative skills, including the ability to formulate hypotheses, conduct research, collect and interpret data and present results
- The ability to apply mathematical knowledge within the science contexts
- The ability to use various digital tools required for scientific study and to apply these when conducting investigations or to create simulations and graphs
- Deduction skills that allow the student to extract and understand information from sources (i.e. in the IB DP this includes the data booklet).

However, differences were observed in the basic skills in that:

- Although both programmes emphasise students conducting independent research, Norwegian students are expected to use and be familiar with specific resources, including science magazines, newspapers, advertisements and instruction manuals
- The Norwegian Biology 1 course focusses on evaluating scientific information found on the internet
- The Norwegian Physics 1 course focusses on using parameter curves and differential and integral calculus.

When comparing the aims and content of the science courses in the IB DP and Norwegian programme, it was found that the aims were subject-specific and reflected the content taught. Overall, it was found that:

- The IB DP covers a wider range of topics within each of the science courses, reflecting some differences in scope
- The courses have a similar number of teaching hours: considered in conjunction with the content, the volume of study is greater in the IB DP than in the Norwegian courses
- In Chemistry, many topic areas are shared, including: acid-base calculations and experiments, IUPAC nomenclature, organic compounds, atomic models, the periodic table, nomenclature rules, writing chemical equations and performing chemical equilibrium calculations
    - Minor differences were found in the topics covered in the Chemistry courses
- In Physics, both expect students to be able to use conservation laws to describe fission and fusion processes, apply Stefan-Boltzmann's and Wien's displacement law and describe a HR diagram, the life-cycle of a star and the standard model
    - Differences were noted in that some Norwegian topics (i.e. transistor and doping of semi-conductors) were not found in the IB DP
- In Biology both courses aim for students to learn practical skills and be able to think scientifically. Both also cover cell biology, organs (i.e. the liver, heart and brain are covered in optional IB topics), diversity, and reproduction; however the IB DP does

not cover the Norwegian topics on healthcare, reproduction of bacteria and human diseases.

The comparative analysis of the grade descriptors and external assessment methods in the IB DP and Norwegian science courses (i.e. Biology 2, Chemistry 2, and Physics 2) identified that overall, the assessment methods differ; the Norwegian courses include school-based internal assessment with external assessments conducted for selected students while the IB DP includes mandatory internal and external assessment. Where external assessment is conducted in the Norwegian courses, similarities can be seen with the IB DP, as summarised by subject below.

In Biology, key findings from the comparative review of assessment of the IB DP and Norwegian Biology 2 course can be summarised as follows:

- Both are designed to tests students' key knowledge and understanding of concepts, scientific terminology, and investigative methods
- At the higher grades, both courses expect students to work independently, and demonstrate a wide range of practical skills
- Both use similar question types and assess similar skills in the external exam papers
- The IB DP includes a greater volume of assessment and more questions related to experimental skill and techniques.

In Chemistry: both courses assess the student's ability to use investigative techniques, handle data and solve problems; however the IB DP places higher expectations for students to analyse data.

In Physics: both similarly emphasise solving problems, presenting solutions and arguments, using scientific language, and analysing data with mathematics skills.

At a subject level – the mathematics courses

Overall, the basic skills intended to be developed across the Norwegian R1 and R2 mathematics courses are similarly developed within all three of the IB DP courses reviewed. These include:

- The ability to communicate mathematically
- Numeracy skills
- The use of digital tools and the ability to use technology to produce visualisations and simulations
- The ability to formulate logical arguments and develop mathematical inquiry skills.

Differences, although minimal, were observed in that the Norwegian Mathematics R1 and R2 courses aim for students to:

- Develop the ability to formulate specific proofs; a skill not emphasised in the IB DP Mathematics SL and IB DP Mathematical Studies SL courses
- Develop the ability to evaluate the suitability, possibility and limitations of digital tools; this skill is only partially covered by all three IB DP Mathematics courses.

Comparative analysis of the aims and content of the IB DP Mathematics HL and SL and Norwegian Mathematics R1 and R2 courses found many skills and topics in common. All four courses include key topics related to geometry, algebra and functions; similarities were also found between the IB DP Mathematics HL and SL and topics related to combinatorics and probability in the Norwegian Mathematics R1 and with differential equations in Mathematics R2. In particular:

- For geometry, both expect students to be able to:
  - Understand different vector representations
  - Apply arithmetic vector rules to determine parallel and orthogonal vectors
  - Calculate lengths and angles
  - Perform various vector calculations.
- In Algebra and Functions, students should have knowledge and understanding of:
  - Transforming and simplifying functions
  - Finite and infinite arithmetic and geometric series
  - Trigonometric expressions
  - Differentiation and integration
  - Polynomial, logarithmic and exponential functions
- In combinatorics and probability, content related to conditional and independent events is also found in the IB DP Mathematics HL and SL; however the Bayes' theorem is included by IB DP Mathematics HL course but not IB DP Mathematics SL
- Differential equations are addressed in both the IB DP Mathematics HL and SL courses; however Mathematics HL covers a wider range of content related to this topic.

Differences, where found, indicate minor differences in the scope and focus of the overarching topics. For example each course includes the following additional topics:

- In the Norwegian Mathematics R1: inscribed angle and intersection theorems; concepts of implication, direct and contrapositive proofs
- In the Norwegian Mathematics R2: geometry of spherical surfaces; homogenous second order differential equations and integral curves
- In IB DP Mathematics HL: statistical concepts of Poisson distribution, the central limit theorem, calculus concepts of higher derivatives, optimisation problems, Euler's method, Rolle's theorem, Maclaurin series, Taylor polynomials, Taylor series developed from differential equations and l'Hôpital's rule.

Comparative analysis of the aims and content of the IB DP Mathematical Studies SL and Norwegian Mathematics R1 and R2 courses found significantly fewer aims and topics in common than the IB DP Mathematics SL and HL courses, nonetheless both aims to enable students to:

- Model practical situations and formulate mathematical models
- Understand arithmetic and geometric series and the concepts of implication and equivalence probability with and without replacement
- Construct geometric diagrams and draw and interpret graphs of functions
- Describe the different proofs of the Pythagoras' theorem and how to simply and differentiate functions.

Differences between the IB DP Mathematical Studies SL and Norwegian Mathematics R2 course were more significant than those with the Mathematics R1 course; overall, the IB DP Mathematical Studies SL course does not include the following overarching Norwegian topics:

- From the Norwegian Mathematics R1 course: geometric angle and intersection theorems, use of vectors in geometry, polynomial functions, logarithm functions, direct and contrapositive proofs and Bayes' equation
- From the Norwegian Mathematics R2 course: geometry in space, scalar and vector products, proof by induction, trigonometric expressions, integration, linear and separable differential equations, integral curves and homogenous second order differential equations.

Additional concepts and topics covered by all three IB DP Mathematics courses that are not evident in the Norwegian Mathematics R1 and R2 courses include:

- Concepts of angles of elevation and depression
- Statistical concepts of Venn and tree diagrams
- Box and whisker plots
- Linear correlation of bivariate data
- Pearson's product-moment correlation coefficient.

As with the Norwegian Mathematics R1 and R2 basic skills, the Norwegian Mathematics S1 and S2 skills are broadly comparable to the IB DP Mathematical Studies SL course. Overall, both aim for students to be able to:

- Communicate mathematically
- Use numeracy skills
- Use digital tools.

Overall, the basic skills of the Norwegian Mathematics S1 and S2 are similarly included within the IB DP Mathematical Studies SL course; in particular all of the courses aim for students to be able to:

- Think and communicate mathematically
- Extract and understand key information
- Develop key mathematical abilities such as understanding and using formulas and graphs,
- Carry out arithmetical operations and use digital tools.

Comparative analysis of the aims and content of the IB DP Mathematical Studies SL and Norwegian Mathematics S1 and S2 courses found many aims and topics in common between the courses, including for students to:

- Develop relevant knowledge, understanding and application skills in mathematics, focussing on algebra, functions, probability and statistics
- In Norwegian Mathematics S1:
    - Understand mathematical symbols and language,
    - Analyse the dependence and relations between quantities,
    - Use graphs and basic probability.
- In Norwegian Mathematics S2:
    - Use functions for modelling

  - Understand and use rational expressions, linear equations, exponential functions
  - Apply basic probability and statistics skills.

Minor differences were noted in that the IB DP Mathematical Studies SL has a moderately different focus than the Norwegian courses and does not include topics related to:

- Linear optimization, polynomials and growth (Norwegian Mathematics S1)
- Binomial distributions, determining whether infinite geometric series is convergent, chain rule, deriving functions and the area under a graph (Norwegian Mathematics S2).

When considering the grade descriptors and the external assessment methods in the IB DP and Norwegian mathematics programmes, although similar methods and skills are used, the IB DP exams are overall more demanding than the Norwegian exams. In particular, the following key observations were made across all the mathematics courses reviewed:

- Similar question types are used in the examinations, including a variety of short and multi-part questions
- The volume of IB DP external assessment is greater than the Norwegian Mathematics courses and IB DP students have more questions to answer in a shorter time than the Norwegian students
- All of the examinations (with the exception of the IB DP Mathematical Studies SL exams) assess the student's ability to perform mathematics without the aid of a digital tool or calculator
- Similar skills are developed in the IB DP and Norwegian courses, including:
  - Knowledge and understanding of concepts and content
  - Problem solving skills
  - Use of technology
  - Mathematical reasoning skills
  - Communication skills in mathematics.

When comparing the Norwegian Mathematics R1 and R2 external examinations and question types in comparison with the IB DP Mathematics HL and SL and Mathematical Studies SL external examinations, the IB DP exams were found overall to be more demanding, in particular because:

- The IB DP Mathematics SL and HL exams require students to perform more complex procedures (more complicated integration and differentiation)
- The IB DP Mathematics HL exam expects students to construct longer arguments and more complex proofs with limited guidance provided within the question
- All three IB DP Mathematics courses include questions of higher cognitive demand with limited guidance provided within the question (extended problem and standalone long response questions).

When comparing the Norwegian Mathematics S1 and S2 external examinations and question types in comparison with the IB DP Mathematical Studies SL external examinations, the analysis found:

- The cognitive skills assessed by the Norwegian and IB DP exams are broadly similar

- Minor differences included that the Norwegian exams assess the ability of students to use computer software to perform regression.

5. References

Education Act [Norway]. (2010). Act of 17 July 1998 no. 61 relating to Primary and Secondary Education and Training (the Education Act). Retrieved from https://www.regjeringen.no/contentassets/b3b9e92cce6742c39581b661a019e504/education-act-norway-with-amendments-entered-2014-2.pdf

European Commission. (2018a). Assessment in General Upper Secondary Education - Eurydice - European Commission. Retrieved 26 June 2018, from /national-policies/eurydice/content/assessment-general-upper-secondary-education-39_en

European Commission. (2018a). Norway - Eurydice - European Commission. Retrieved 13 June 2018, from /national-policies/eurydice/content/norway_en

International Baccalaureate. (2004, updated 2010). Diploma Programme Assessment: Principles and practice.

International Baccalaureate. (2008). Learning in a language other than mother tongue in IB programmes.

International Baccalaureate. (2013). IB Learner Profile. Retrieved from http://www.ibo.org/contentassets/fd82f70643ef4086b7d3f292cc214962/learner-profile-en.pdf

International Baccalaureate. (2014, updated 2016). Programme standards and practices.

International Baccalaureate. (2015). Diploma Programme: From principles into practice.

International Baccalaureate. (2018a). IB Educator and Leadership certificates: University Directory 2018.

Lee,M., Spinks,J., Wright,E., Dean, J., Ryoo,J.H. (2017). A study of the post-secondary outcomes of International Baccalaureate Diploma Programme alumni in leading universities in Asia-Pacific.

Ministry of Education and Research. (2018, March 28). The Education System [Redaksjonellartikkel]. Retrieved 13 June 2018, from https://www.regjeringen.no/en/topics/education/school/the-norwegian-education-system/id445118/

NOKUT. (2018). The GSU-list. Retrieved 17 July 2018, from https://www.nokut.no/en/surveys-and-databases/nokuts-country-database/GSU-list/

Norwegian Directorate for Education and Training. (2012). Framework for Basic Skills. Retrieved from https://www.udir.no/contentassets/fd2d6bfbf2364e1c98b73e030119bd38/framework_for_basic_skills.pdf

The Royal Ministry Of Education, Research and Church Affairs. (1994). Core Curriculum for Primary, Secondary and Adult Education in Norway. Retrieved from https://www.udir.no/globalassets/filer/lareplan/generell-del/core_curriculum_english.pdf

UK NARIC. (2017). UK NARIC International Comparisons - June, 2018. Retrieved 13 June 2018, from https://www.naric.org.uk/product/International%20Comparisons/information.aspx?Country ID=123&TextID=157

Utdanningsdirektoratet. (2015a). Fire prinsipper for god underveisvurdering. Retrieved 8 August 2018, from https://www.udir.no/laring-og-trivsel/vurdering/om-vurdering/underveisvurdering/

Utdanningsdirektoratet. (2015b). Læringsstrategier og tilpasset opplæring. Retrieved 9 August 2018, from https://www.udir.no/laring-og-trivsel/tilpasset-opplaring/laringsstrategier/

Utdanningsdirektoratet. (2015c). Sentrale verdier for tilpasset opplæring. Retrieved 9 August 2018, from https://www.udir.no/laring-og-trivsel/tilpasset-opplaring/sentrale-verdier/

Utdanningsdirektoratet. (2016a). Certificates and grading scales. Retrieved 13 June 2018, from https://www.udir.no/in-english/certificates-and-grading-scales/

Utdanningsdirektoratet. (2016b). Førebu og ta eksamen. Retrieved 26 July 2018, from https://www.udir.no/eksamen-og-prover/eksamen/forberede-og-ta-eksamen/

Utdanningsdirektoratet. (2016c). Norwegian vocational education and training (VET). Retrieved 13 June 2018, from https://www.udir.no/in-english/norwegian-vocational-education-and-training/

Utdanningsdirektoratet. (2016d). Påbygging til studiekompetanse. Retrieved 13 June 2018, from https://www.udir.no/utdanningslopet/videregaende-opplaring/andre-varianter/pabygging-til-studiekompetanse/

Utdanningsdirektoratet. (2016e). Videregående opplæring. Retrieved 13 June 2018, from https://www.udir.no/utdanningslopet/videregaende-opplaring/

Utdanningsdirektoratet. (2017). Rammeverk for eksamen. Retrieved 26 July 2018, from https://www.udir.no/eksamen-og-prover/eksamen/rammeverk-eksamen/

Utdanningsdirektoratet. (2018a). Hva er tilpasset opplæring? Retrieved 2 August 2018, from https://www.udir.no/laring-og-trivsel/tilpasset-opplaring/hva-er-tilpasset-opplaring/

Utdanningsdirektoratet. (2018b). Regler for muntlig eksamen. Retrieved 26 July 2018, from https://www.udir.no/eksamen-og-prover/eksamen/muntlig-eksamen/

Utdanningsdirektoratet. (2018c). Trekkordning ved eksamen for grunnskole og videregående opplæring Udir-2-2018. Retrieved 26 July 2018, from https://www.udir.no/regelverk-og-tilsyn/finn-regelverk/etter-tema/eksamen/trekkordning-ved-eksamen-for-grunnskole-og-videregaende-opplaring-udir-2-2018/

Utdanningsdirektoratet. (n.d.). National Curriculum for Knowledge Promotion in Primary and Secondary Education and Training. Retrieved from https://www.udir.no/globalassets/upload/larerplaner/fastsatte_lareplaner_for_kunnskapsloeftet/5/prinsipper_lk06_eng.pdf

Appendix 1: Information on UK NARIC

UK NARIC is the designated national agency in the United Kingdom for the recognition of international qualifications and professional skills. Since 1997, it has performed this official function on behalf of the UK Government.

UK NARIC provides informed advice and guidance on vocational, academic and professional qualifications from over 190 countries worldwide. The information provided enables international and UK organisations, institutions and government agencies to develop informed opinions when considering qualifications or training systems from overseas.

With the expertise and experience developed through running the National Agency, together with a number of other programmes on behalf of the UK Government and European Union, UK NARIC has been uniquely well placed to manage and support delivery of an extensive global research portfolio for:

- Ministries of Education and other government agencies
- Universities and other higher education institutions
- Secondary exam boards and awarding bodies
- Professional bodies.

Specific areas of expertise include:

- International education systems and qualifications
- Comparative studies on curriculum and assessment
- Qualification benchmarking
- Grade comparisons
- Best practice in recognition
- Qualification framework development and/or referencing;
- Supporting the development and implementation of mutual recognition agreements.