Diploma Programme

Environmental systems and societies teacher support material

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Environmental systems and societies teacher support material

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

Diploma Programme
Environmental systems and societies teacher support material

Published February 2024
Updated July 2024

Published on behalf of the International Baccalaureate Organization, a not-for-profit educational foundation of 15 Route des Morillons, 1218 Le Grand-Saconnex, Geneva, Switzerland by the

International Baccalaureate Organization (UK) Ltd
Peterson House, Malthouse Avenue, Cardiff Gate
Cardiff, Wales CF23 8GL
United Kingdom
Website: ibo.org

The International Baccalaureate Organization (known as the IB) offers four high-quality and challenging educational programmes for a worldwide community of schools, aiming to create a better, more peaceful world. This publication is one of a range of materials produced to support these programmes.

IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

As IB learners we strive to be:

INQUIRERS
We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life.

KNOWLEDGEABLE
We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance.

THINKERS
We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions.

COMMUNICATORS
We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups.

PRINCIPLED
We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences.

OPEN-MINDED
We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.

CARING
We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.

RISK-TAKERS
We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change.

BALANCED
We understand the importance of balancing different aspects of our lives—intellectual, physical, and emotional—to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live.

REFLECTIVE
We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.

The IB learner profile represents 10 attributes valued by IB World Schools. We believe these attributes, and others like them, can help individuals and groups become responsible members of local, national and global communities.

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Overview

Welcome to the Diploma Programme (DP) environmental systems and societies teacher support material (TSM). This TSM should be read in conjunction with the *Environmental systems and societies guide* (first assessment 2026), the specimen examination papers and markschemes, and the examples of assessed work submitted for assessment.

The TSM provides teachers with further guidance on approaches to learning and approaches to teaching in environmental systems and societies (ESS). International Baccalaureate (IB) educators who are experienced in supporting students and teachers in the learning and teaching of ESS have written this TSM.

The TSM is designed to provide teachers with:

- further guidance on ways of organizing the course
- advice on how to approach each assessment component
- example student activities
- skills and tools to support teaching
- suggestions for possible resources.

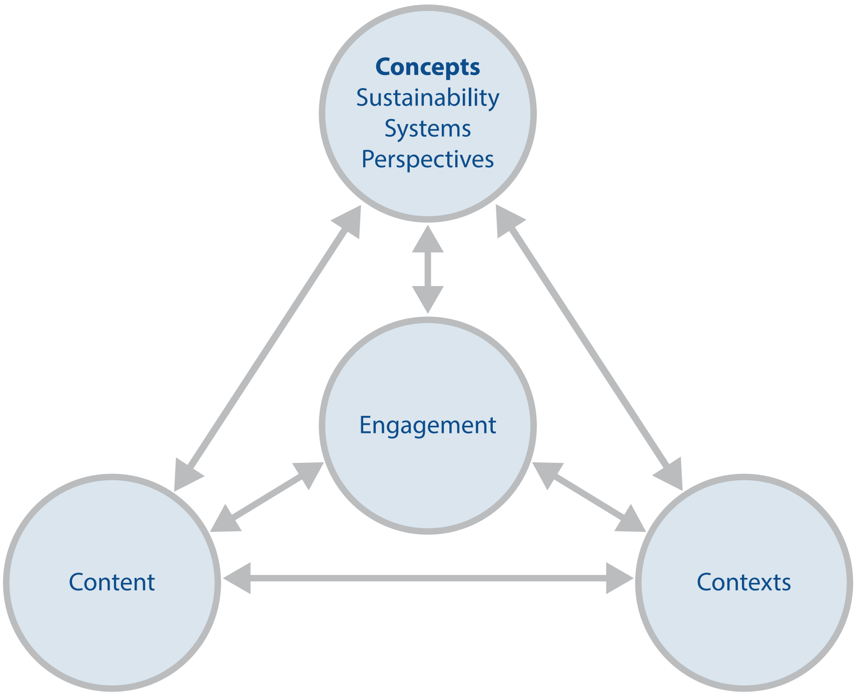
Please note that any suggestions for useful resources and teaching ideas are intended as examples and helpful guidance only; they are not intended to be in any way prescriptive or restrictive. Teachers are encouraged to exercise creativity and flexibility when putting together their ESS course and to choose examples that meet the needs and interests of their students. The ESS course for first assessment in 2026 is ambitious. It attempts to look ahead to an uncertain future—environmentally, sociopolitically, economically and culturally.

The aims of ESS are to empower and equip students by giving them the tools, skills and knowledge they will need to negotiate the world in which they live. It is worth reviewing the aims with students as they are intended to foster engagement with the ESS course, ESS and the world around them. It is a broad and challenging course for both student and teacher. The course is available at standard level (SL) and higher level (HL). HL is covered within the HL lenses.

Figure 1 demonstrates the relationships within the course.

Figure 1

Environmental systems and societies relationships (concepts–contexts–content) inspire students to engage with environmental issues



The ESS course

Topic 1: Foundation

The aims of environmental systems and societies (ESS) are brought into focus in Topic 1: Foundation through the three key concepts of perspectives, systems and sustainability. Starting the course with Topic 1: Foundation is strongly recommended. By introducing the key concepts up front and returning to them frequently (examples of connections are shown in the guide), the course aims to build a coherent understanding of the impact of humans on the Earth’s biosphere.

1.1 Perspectives

How we treat the environment depends on how we view it.

Subtopic 1.1 Perspectives is the intended starting point of the course so that students can consider how their perspectives are developed, influenced and changed, and how others may see the world differently.

It is essential that students understand that the concept of perspectives is fundamental in determining how we act, and why we act as we do. Traditionally, humans might see the environment in one of four ways.

- Stewardship—humans have responsibilities towards the environment on a local and global scale, and with that comes certain privileges. We can manage the environment and we can exploit it; therefore, it is our duty to look after it and treat it respectfully.
- Romantic—its value to humans is seen aesthetically, as a beautiful and unadulterated thing.
- Imperialist—science can be used to control nature.
- Utilitarian—utilitarianism holds that the greatest good is happiness and freedom from pain and suffering. Actions with outcomes that promote the greatest good for the greatest number of humans (those that have the greatest utility) are morally right. Nature is seen from a utilitarian viewpoint in terms of what it can do for humans.

In the ESS course, perspectives and worldviews can be classified broadly as technocentric, anthropocentric and ecocentric. Although controversial, this classification is adopted and returned to throughout the topics as it gives students a model to use in considering why people act in certain ways.

For example, these environmental value systems are discussed in the following subtopics.

- Choice of conservation strategies (3.3.9)
- Perspectives on waste management (7.3.9)
- Legal personhood granted to natural entities (HL.a.11)
- Environmental economics (HL.b.2)
- Ecological ecomonics (HL.b.9)

1.2 Systems

Subtopic 1.2 Systems trains students to think using a systems approach. Whether an ecological, economic or societal system, there are inputs, stores, flows and outputs. Feedback mechanisms either enhance or restrain the processes involved, and energy or materials move through systems.

By being introduced to a systems approach early in the course, students learn to model the concept and apply it to other topics. They develop an understanding of interdependencies and interrelationships. Tipping points, emergent properties and resilience are introduced; these are returned to again in various topics.

Students are asked to create system diagrams in many areas, for example:

- ecological system diagrams (2.2.3)
- the atmospheric system (6.1.2)
- urban systems (8.2.3).

1.3 Sustainability

What is meant by the term "sustainability" is complex, and it is used differently by different groups; this will be explored in subtopic 1.3. Each human produces waste and uses resources; by studying sustainability, students develop an understanding of their impact on the Earth, how the term sustainability is used, and how to live and act in a more sustainable way. Students also learn how to spot greenwashing in its many guises.

The long-term viability of environmental and, therefore, human systems on Earth is now a central topic to most conversations about the future. It is essential that students of ESS should not feel hopeless in the face of all the environmental issues, from climate change and pollution, food production and waste to loss of habitats and biodiversity losses, whether locally or globally. They need to know what has been lost, gained and achieved, as well as what can be done to repair and regenerate environmental systems.

An understanding of how sustainability can be measured and modelled is a theme throughout the course, for example, in the following understandings.

- Natural ecosystems and sustainability (2.1.21–2.1.23)
- Sustainable practices by indigenous peoples (3.2.11)
- Short-term economic interests and sustainability (7.1.18)

In subtopic 1.3, the course introduces the sustainable development goals (SDGs) of the United Nations (UN), and models for the circular economy, doughnut economics and planetary boundaries, for example, in the following understandings.

- 2.1.24 on biosphere integrity
- 2.3.24 and 2.3.25 (HL) on the nitrogen cycle
- 3.3.8 on conservation measures
- 4.2.9 (HL) on freshwater use
- 6.2.8 on climate change
- 8.1.9 (HL) on human population projections

Topics 2–8

The order in which topics 2–8 are developed is at the discretion of the teacher and school context. Teachers may wish to follow the foundation topic with one that is at the forefront of student concerns—for example, climate change or food production or natural resources and energy—or cover the topics in the order of the guide.

Studying ecological concepts and examples followed by biodiversity and conservation lays a foundation of ecological understanding; however, looking at their own urban system through an environmental lens, and then carrying out practical work may be more suitable for some students or locations.

All topics must be covered so that students gain an overview of the effects of human activity on the natural world.

Guiding questions

One or two guiding questions frame the content at the start of each subtopic; these could be used to introduce the subtopic, then be revisited later to review understanding of concepts and context. Teachers and students could develop more guiding questions of their own to reflect on what has been studied. The examples shown include command terms.

1.3 What is sustainability and how can it be measured?

- Explain why sustainability is so important.
- List five sustainability indicators.
- Explain the concept of ecological footprint.
- To what extent are the challenges of sustainable development also ones of environmental justice?
- Define sustainable development.
- Define environmental justice and injustice.
- List and evaluate the SDGs that involve environmental and social justice.

6.3 How can human societies address the causes and consequences of climate change?

SL and HL

- Explain why action on climate change needs to be global and national.
- Evaluate three mitigation strategies to address climate change.
- Evaluate three adaptation strategies to address climate change.

HL only

- List three examples of individual, non-governmental and government measures in limiting climate change.
- To what extent is geoengineering feasible today?
- Comment on why perspectives on climate change actions vary.

Skills

Inquiry-based learning encourages curiosity, critical thinking, problem-solving skills and active engagement in learners, and aims to shift the lead to students rather than the teacher. The skills required in the teaching of ESS can be found in the guide in the section "Skills in the study of environmental systems and societies". Tools and the development of the inquiry process are also covered in the same section of the guide.

The **application of skills** within each understanding provides opportunities to address these skills. The content statement may often be covered through applying the skills.

The internal assessment individual investigation is designed to be part of classroom activities that use the tools and inquiry skills developed throughout the course. It is essential that students undertake practical work to cover the skills required for ESS. How this is managed can be determined by the teacher and resources available, but repeat visits to a local ecosystem or urban system illustrate many concepts and provides context.

The course combines a mixture of methodologies and techniques associated with the subject groups of individuals and societies, and sciences.

Methodologies and models

- Values and attitude surveys or questionnaires
- Interviews
- Issues-based inquiries to inform decision-making
- Observational fieldwork (natural experiments)
- Field manipulation experiments
- Ecosystem modelling (including mesocosms or bottle experiments)
- Laboratory work
- Models of sustainability
- Use of systems diagrams or other valid holistic modelling approaches
- Elements of environmental impact assessments
- Secondary demographic, development and environmental data
- Collection of both qualitative and quantitative data

Analytical techniques

- Estimations of net primary productivity (NPP)/Gross primary productivity (GPP) or net secondary productivity (NSP)/gross secondary productivity (GSP)
- Application of descriptive statistics (measures of spread and average)
- Application of inferential statistics (testing of null hypotheses)
- Other complex calculations
- Cartographic analysis
- Use of spreadsheets or databases
- Detailed calculations of footprints (including ecological, carbon, water footprints)

Investigations may consist of appropriate qualitative work or quantitative work. In some cases, these are descriptive approaches and may involve the collection of considerable qualitative data. In others, establishing cause and effect through inferential statistical analysis (a scientific approach) may be used.

Engagement

"Possible engagement opportunities" sections at the end of each subtopic in the guide are intended to provide suggestions for students to engage with the syllabus in an active and meaningful way. They provide students with strategies to take action and connect with the creativity, activity, service (CAS) programme and engage at the local or global level.

Students may wish to do more to deepen their understanding or take actions; this can be part of the CAS programme for Diploma Programme (DP) students or other school service activities.

The course includes unsettling content—for example, loss of soil fertility, pollution levels, greenhouse gas (GHG) emissions, loss of species on a massive scale—but it is never too late to act, and any action in the right direction is never too small. It is vital that students do not leave the course thinking that there is no hope for the world. By looking at past and present environmental movements, students will see that they can make a positive impact on the world around them.

Engagement ideas are not mandatory, but they may be a prompt to do something either within the class or outside—at home, in school or in the wider community; hopefully, this will continue beyond the ESS course.

Engagement suggestions for incorporation into class time include the following.

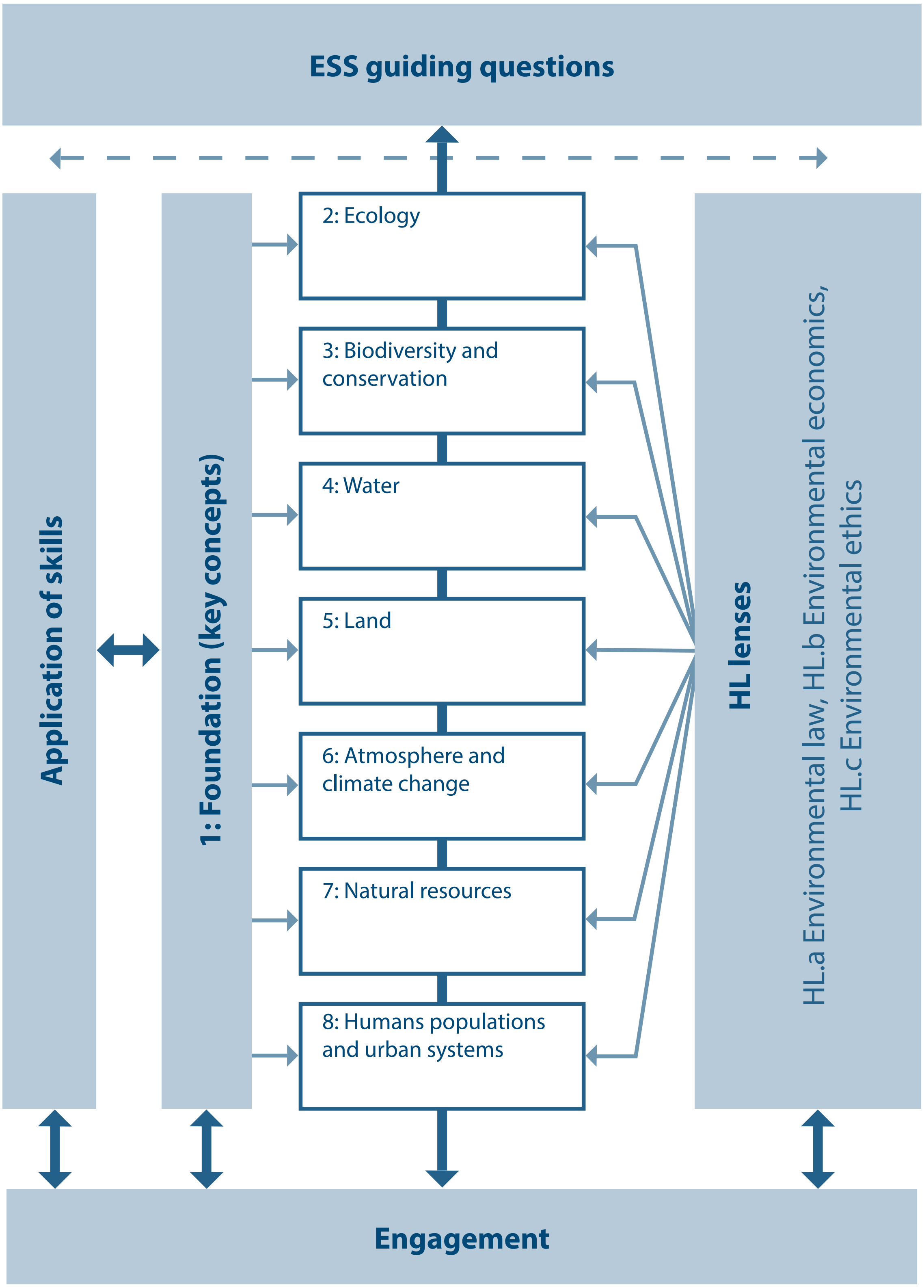
- Class debates and discussions
- Designing questionnaires and surveys
- Building and maintaining an ecosystem
- Further research into case studies of local or global interest

Examples of engagement beyond the classroom include the following.

- Advocacy on an environmental issue for the whole school community
- Joining a Model United Nations (MUN) team
- Citizen science projects
- Joining environmental movements
- Volunteering on local community environmental improvement projects

Figure 2

Overview of the ESS course



Overview

The environmental systems and societies (ESS) course allows teachers to construct the course in a way that suits their context and meets the needs and interests of their students. Topic 1: Foundation includes subtopics that explore the three key concepts and should be taught at the start of the course. Topics 2–8 are not intended to be in teaching order. They provide details of the content to be covered by the end of the course.

Teachers should develop course outlines that work best for their students. Regardless of how the course is constructed, teachers should give students ample opportunity to develop the skills needed to succeed. Teachers have the flexibility to order the topics, design the experimental programme, and provide opportunities to develop and practise skills and techniques through an exploration of case studies.

The higher level (HL) lenses should be integrated with the teaching of the topics across the whole course. This allows for the development of critical evaluation and analysis of problems at greater breadth and depth at HL.

Students enter the course from a variety of backgrounds and may need support to acclimatize to the interdisciplinary nature of the course, which may be unlike other courses they have encountered in their prior learning. Where possible, students should also be engaged in decisions involving the design and examples of their course. The more student ownership there is of the work, the more likely it is that they will be fully engaged with it.

A course outline should be a practical, useful and dynamic document that provides a high-level overview of the ESS course. It should outline how the course will be designed to meet the requirements set out in the subject guide, and how it will reflect the logistics of your school calendar and context. Examples of planning considerations are as follows.

- The timing of holidays, large school events and examination sessions
- The school internal assessment calendar (avoid scheduling of submissions in different subjects at the same time)
- Weather and seasonal suitability for field trips or fieldwork
- The logistical challenges of many students undertaking data collection at the same time
- The accessibility of local examples and speakers
- The incorporation of the skills and techniques into suitable topics
- The integration of the HL lenses into the topics
- The interests of the students

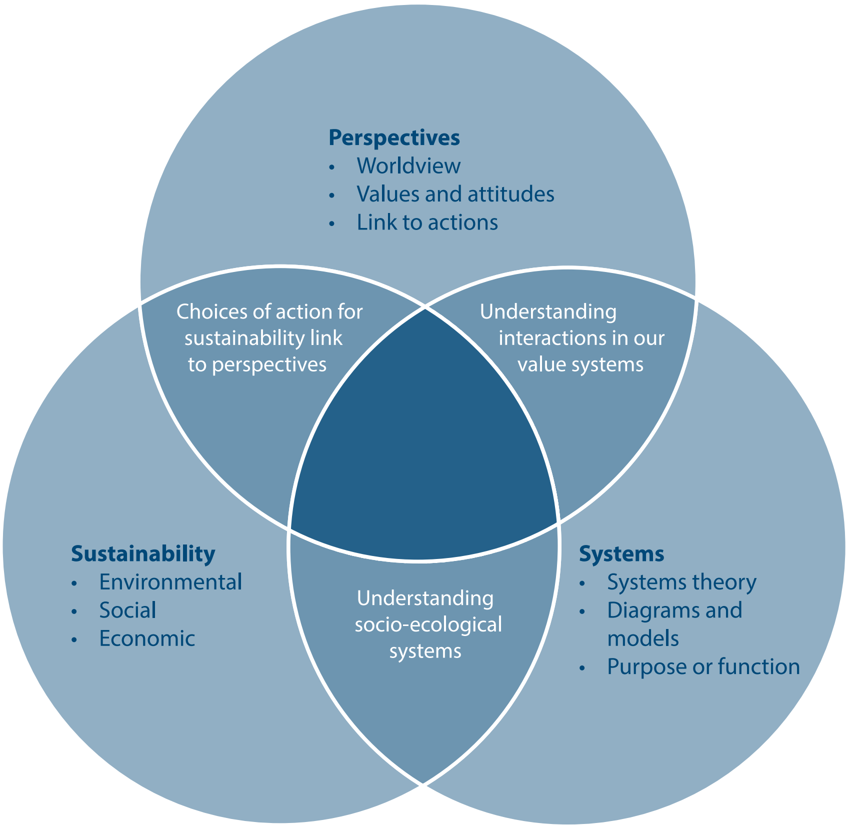
For example, a course outline should include details of how many lessons will be scheduled for ESS to ensure that the requirements for 150 teaching hours at standard level (SL) and 240 hours at HL are met. It should also include details of the timing for the completion of the internal assessment task and the collaborative sciences project.

Planning with the key concepts of the course

Understanding the key concepts (perspectives, systems and sustainability) and the relationships between them allows for a deeper appreciation of environmental systems and societies; this is mapped out in figure 3.

Figure 3

Interactions between the three key concepts



The key concepts (and other concepts) can be mapped to different sections of the curriculum (see table 1 for an example). However, teachers are recommended to consider how they might map differently when planning their own teaching sequences. Three examples of planning in practice are included.

An example of how the key concepts can be mapped across the course (PDF)

Table 1

An example of how the key concepts can be mapped across the course

Foundations	Perspectives:	Systems:	Sustainability:
Ecology	relate to how we understand and explain ecosystems	explain the structure and function of ecosystem energy flow and biogeochemical cycles	through sustainable resource management and carbon sequestering that

Foundations	Perspectives:	Systems:	Sustainability:
			link to understanding ecosystem productivity
Biodiversity and conservation	demonstrate how we value species, communities and ecosystems	show how complex interactions in socio-ecological systems can be better understood and leverage points identified	and biodiversity loss with the current mass extinction event represent a major planetary boundary
Water	inform our understanding of the rights to own, pollute and to exploit water resources	provide our understanding of the hydrological cycle	is essential for food production, playing a key role in climate regulation and productivity of ecosystems
Land	inform our understanding of land ownership and rights to access land, and influence how we value landscapes	allow for clear explanation and understanding of soil ecosystems and factors influencing their degradation	of food production is affected by the degradation of soil resources
Atmosphere and climate change	provide a deeper understanding of the types of worldviews connected to different forms of climate scepticism	are used to produce the predictive global circulation models, giving better understanding of the nature of climate change	targets are impacted by the climate crisis, which represents an existential threat to humanity
Natural resources	relate to our varied ethical positions on natural resource management and exploitation	and especially agricultural and ecological systems underpin production of natural resources	is attained through sustainable resource management in socio-ecological systems
Human populations and urban systems	and especially our political perspectives affect how we manage cities and societies.	allow for an understanding of agricultural and ecological systems and how they underpin production and extraction of natural resources.	models can be used to consider all aspects that underpin the concept of sustainable cities and societies. Models such as **circles of sustainability** can be used to investigate the concept.

Planning in practice 1: A move towards more sustainable cities

This suggested approach to planning a lesson or lessons applies two foundational subtopics—1.1 Perspectives and 1.3 Sustainability—to the context of subtopic 8.2 Urban systems and planning. It could be used as an early introduction to the broad concept of sustainability or developed into a more detailed analysis.

This approach could provide students with a context with which to cover several understandings from the units and answer all three unit guiding questions.

- How do perspectives affect the decisions we make concerning environmental issues? (1.1)
- What is sustainability and how can it be measured? (1.3)
- How can reimagining urban systems create a more sustainable future? (8.2)

Students should be provided with a suitable input of data comparing the different aspects of sustainability for several cities. They could use the circles of sustainability model developed by Paul James (2015). This model graphically demonstrates the different aspects of cities by using four domains.

Versions of the circles of sustainability model can be found online. While the model is complex, the graphs provide a visual display that can be easily accessed by students, and though the domain criteria are detailed, students will not need the full depth to appreciate the point of the criteria. The domain criteria for a city are rated on a scale from vibrant through to critical, and the breakdown of the domain categories can be seen in table 2.

Table 2

Domain criteria from the circles of sustainability model (James, 2015)

Ecology	Economics	Politics	Culture
Materials and energy	Production and resourcing	Organization and governance	Engagement and identity
Water and air	Exchange and transfer	Law and justice	Recreation and creativity
Flora and fauna	Accounting and regulation	Communication and movement	Memory and projection
Habitat and food	Consumption and use	Representation and negotiation	Belief and meaning
Place and space	Labour and welfare	Security and accord	Gender and generations
Constructions and settlements	Technology and infrastructure	Dialogue and reconciliation	Inquiry and learning
Emissions and wastes	Wealth and distribution	Ethics and accountability	Health and well-being

Students can then be asked to interpret the diagrams and discuss which city they would consider to be more sustainable, to rank a number of cities, or to suggest strategies to improve sustainability in one or more of the cities. This approach allows the class to engage in discussions about what sustainability means and why we are likely to have different perspectives on which city is more sustainable from the same data set.

Planning in practice 2: Assessing sustainability for a traditional society

This approach connects statements from 1.2 Systems and 1.3 Sustainability and applies them to 7.1 Natural resources—uses and management.

A skill, an understanding and the guiding question are used together.

- 1.2.3, 1.2.8 and 1.2.10 skill: students should be able to construct from data and interpret systems diagrams including flows and storages. Students should be able to represent examples of positive and negative feedback in diagrams.
- 1.3.1 Sustainability is a measure of the extent to which practices allow for the long-term viability of a system. It is generally used to refer to the responsible maintenance of socio-ecological systems such that there is no diminishment of conditions for future generations.
- 7.1 guiding question: how does the renewability of natural capital have implications for its sustainable use?

Students need to be provided with some raw data on a suitable socio-ecological example. Suitable data could use energy flows ($kJ/m^2/yr$) to include the following data categories for socio-ecological systems.

- Insolation to crops or wildland
- Crops consumed

- Gross primary productivity (GPP)
- Wild species consumption and respiration
- Livestock consumption and respiration
- Wild and farmed livestock products consumed by humans
- Energy expenditure on different hunting or farming activities by humans.

Students can then construct a quantitative systems diagram to analyse the socioeconomic system. Suitable examples can be found published online or in a course text. More isolated indigenous societies that continue traditional practice and have a contained energy flow are suitable, such as East African nomadic pastoralists, Inuit hunter-gatherers or Australian Aboriginals. Historical data may be more suitable where societies are changing practice. Students can use the diagrams to comment on the sustainability of the society and to consider choices or changes they could make in response to changing conditions. For example, external conditions that may impact a society could include climate, and internal conditions could include the impact of modernization. Students could identify tipping points that might change the system and leverage points that the society could work on to improve sustainability. It is informative to consider why this is much harder to do for a larger, modern industrial society and why ecological footprints are often used as a model for analysis of sustainability instead.

These techniques can be further supported by using qualitative modelling through the use of flow charts. Suitable examples can be found published as socio-ecological systems (SES) or coupled human-environment systems (CHES). CHES models can also be converted into predictive graphs to consider future changes to the society (Farahbakhsh et al., 2022). Students can also research and explore contrasting stories and explanations of socio-environmental system collapse, for example, contrasting the survival of the Inuit and Norse communities during 14th-century climate change or competing theories on the collapse of the societies of Easter Island. Emphasis should be made on the value of using both quantitative and qualitative data in such modelling and system analysis.

Planning in practice 3: How do our values influence our actions in the face of climate change?

This planning exercise draws together skills from 1.1 Perspectives, a content statement from 1.2 Systems and skills from 6.3 Climate change—mitigation and adaptation.

- 1.1.5 Application of skills: design and carry out questionnaires/surveys/interviews, using online collaborative survey tools, to correlate perspectives with attitudes toward particular environmental or sustainability issues. Select a suitable statistical tool to analyse this data. Students may use and develop behaviour-time graphs to show lifestyle changes.
- 1.2.12 Tipping points can exist within a system where a small alteration in one component can produce large overall changes, resulting in a shift in equilibrium.
- 6.3.4 Application of skills: create surveys to investigate attitudes to a proposed solution in the school or community to mitigate climate change.

This activity is suggested as a follow-up to a series of lessons on climate change; this would allow students to develop some transferable skills to use within their internal assessment.

1. Start by presenting students with a collection of known climate tipping points (Lenton et al., 2019) and ask them to consider which of these might be leverage points for action. What kind of actions could be taken and what actions are being taken?
2. Ask the students to consider how certain they are about the effectiveness of different proposed actions.
3. Discuss forms of scepticism to help students consider if there are clear values behind them. Consider, for example, trend, attribution, consequence and management scepticism (Rahmstorf, 2004) and how they might link this to a broad categorization of perspectives or worldviews. This could follow the traditional ecocentric, anthropocentric and technocentric categories, though teachers should carefully evaluate these as they will not always provide a useful analysis. Some questions may suit a different

approach, for example, consider political perspectives such as individualist-communitarian or hierarchical-egalitarian approaches (Kahan, 2012). Alternatively, dig deeper into the foundational aspects of human values using the common cause approach that is popular with non-governmental organizations (Crompton, 2011) or allow students to suggest their own values classifications that relate better to their context.

4. Following this introduction, ask students to discuss and suggest questions and hypotheses on what the interactions are between human values and actions.
5. Students choose their own questions to develop further and write their own survey questions. They can decide on a suitable sample group and size, as well as the platform in which they will ask the questions. In order to generate meaningful data, this could be done as a combined class activity and students could test separate questions and hypotheses.
6. Show students how to generate meaningful data with conversions of qualitative values data to numerical format for two or more variables that relate to their research question. If this is produced on a rankable scale, then scatter plots and a correlation coefficient can be generated to test a null hypothesis. If one of the scales remains categorical, then students should be reminded that comparing two categories of such data would usually be the application of a Mann-Whitney U-test, rather than a t-test, as it is nonparametric. Note that this cannot be applied to multiple categories (due to the increased probability of a type-1 error). To compare multiple categories, students should be encouraged to use error bars to clearly show ranges or standard deviations. This allows for a fast analysis on whether the differences are statistically significant. It is better to review the proposed statistical analysis with students and discuss how this would fit with their own questions and samples.
7. Having completed the survey, encourage follow-up discussions to facilitate a critical analysis of the conclusions that can be drawn from their work. Students discuss and evaluate the relative benefits of personal actions, and the role of private enterprise and government policies. The broader understandings and merits of approaches such as mitigation, adaptation and geoengineering can be brought in. Teachers should be aware that such discussions may compound the eco-anxiety already being experienced by some students and how they may respond. Published literature provides guidance on appropriate methodologies for discussing socio-environmental collapse with students. Teachers may consider bringing some of the ideas of deep adaptation to the classroom (Bendell and Read, 2021).

Conclusion

The list of possible connections is endless; everything in this course is interconnected. Conceptual connections can also help with a deeper understanding of the interdisciplinary nature of the course, drawing on some of the broader concepts such as economic growth. Connecting this with concepts such as sustainable yield and net primary productivity (NPP) can help to develop these connections further. Teachers can develop student appreciation of the interconnected nature of the course by encouraging students to make and share their own connections. A powerful pedagogical tool is to get the students to discuss the conceptual connections they have spotted and to co-construct new pathways through the curriculum material.

Routes through the course

These example course routes include an explanatory rationale for the journey followed. "SL only" refers to a class with only standard level (SL) students; "HL only" refers to a class with only higher level (HL) students. This section includes topic sequences that illustrate how to teach a combined SL and HL course over two years, and examples for separate SL and HL courses.

It is anticipated that a combined class would need to follow the same order as that of the HL only course, releasing the SL students when HL course content is covered. It would be challenging to teach the additional HL content in one or two additional lessons per week or timetable cycle owing to the integrated and holistic nature of the course.

SL and HL combined 1

The 100 hours for SL and 190 hours for HL are only for the teaching of the topic content. The environmental systems and societies (ESS) course is designed to start with Topic 1: Foundation. This provides core content and vocabulary for the remaining topics of the course, for both SL and HL students. Links are made to the foundation topic throughout the course. During the teaching of Topic 1: Foundation, the HL lenses should be introduced; environmental ethics will flow from subtopic 1.1 Perspectives; environmental economics and environmental law are taught after subtopic 1.3 Sustainability. The HL lenses will become a focus during the other topics; some suggested places for the focus are included in the course route. Teachers may decide where to incorporate the HL lenses across the topics, allowing the students an opportunity to evaluate and analyse environmental issues critically.

The first semester focuses on ecology, with some content on human population, and atmosphere, which helps to make links to the holistic nature of the course. The second semester continues with Topic 2: Ecology and Topic 8: Human populations and urban systems and also includes Topic 3: Biodiversity and conservation. The first year of the course is interdisciplinary, having both a science and an individuals and societies focus. The collaborative project can be a culminating activity at the end of the year.

In the second year, the HL lenses should become more integrated into the topics, with the possibility of the students choosing where they would like to focus these HL lenses: individually or as a class. Time within class, or homework, can be allocated after each subtopic to build on the HL lenses, depending on how the extra HL hours are set up. SL students could use the time to reinforce SL content.

Topic 7: Natural resources, Topic 4 Water and Topic 5: Land are covered before HL students start their individual investigations, allowing enough content and skills to be taught. SL students can start the individual investigations earlier, while HL content is being covered; this can allow a greater sharing of any limited resources at school.

The course culminates with Topic 6: Atmosphere and climate change, where all the HL lenses can be applied to a topic and a complex situation. This topic links back to all the other topics and can be used as a revision device immediately prior to the examination session.

Year 1 [Semester 1]

Topic 1: Foundation

- 1.1 Perspectives
- HL.c Environmental ethics
- 1.2 Systems
- 1.3 Sustainability
- HL.b Environmental economics

- HL.a Environmental law

Topic 2: Ecology

- 2.1 Individuals and populations, communities, and ecosystems

Topic 8: Human populations and urban systems

- 8.1 Human populations (focus: HL.b Environmental economics)

Topic 2: Ecology

- 2.2 Energy and biomass in ecosystems
- 2.3 Biogeochemical cycles

Topic 6: Atmosphere and climate change

- 6.1 Introduction to the atmosphere

Year 1 [Semester 2]

Topic 2: Ecology

- 2.4 Climate and biomes
- 2.5 Zonation, succession and change in ecosystems

Topic 8: Human populations and urban systems

- 8.2 Urban systems and urban planning (focus: HL.c Environmental ethics; HL.b Environmental economics)
- 8.3 Urban air pollution

Topic 3: Biodiversity and conservation

- 3.1 Biodiversity and evolution
- 3.2 Human impact on biodiversity (focus: HL.b Environmental economics)
- 3.3 Conservation and regeneration (focus: HL.c Environmental ethics; HL.b Environmental economics)

Collaborative sciences project

Year 2 [Semester 1]

Topic 7: Natural resources

- 7.1 Natural resources—uses and management (focus: HL.c Environmental ethics; HL.b Environmental economics)
- 7.2 Energy sources—uses and management (focus: HL.b Environmental economics)
- 7.3 Solid waste

Topic 4: Water

- 4.1 Water systems
- 4.2 Water access, use and security (focus: HL.b Environmental economics)
- 4.3 Aquatic food production systems (focus: HL.b Environmental economics; HL.c Environmental ethics HL.a Environmental law)
- 4.4 Water pollution (focus: HL.a Environmental law)

Topic 5: Land

- 5.1 Soil

Individual investigation SL

Year 2 [Semester 2]

Topic 5: Land

- 5.2 Agriculture and food (focus: HL.b Environmental economics; HL.c Environmental ethics)

Individual investigation HL

Topic 6 Atmosphere and climate change (focus: all HL lenses)

- 6.2 Climate change—causes and impacts
- 6.3 Climate change—mitigation and adaptation
- 6.4 Stratospheric ozone

SL and HL combined 2

The 100 hours for SL and 190 hours for HL are only for the teaching of the topic content. The ESS course starts with Topic 1: Foundation; for HL, this also includes an introduction to the HL lenses. The content and terminology used in the HL lenses can be used with the content from the foundation subtopics. The HL lenses are then assigned for a focus on at least one other topic; for some topics, all the lenses are covered. Although the content of the lenses has been integrated into the teaching order, it is anticipated that they will be used throughout as lenses to explore each topic.

Seasonal factors such as the monsoon, extreme temperatures (both hot and cold) and other considerations, such as Weeks Without Walls or planned combined SL and HL field trips, can impact when topics are taught. This order of teaching assumes that fieldwork is done at the end or start of a year, as weather extremes may make the rest of the year unsuitable. Topic 8: Human populations and urban systems is taught, then Topic 7: Natural resources. Topic 2: Ecology is taught at the end of the first year, along with Topic 5: Land and Topic 4: Water at the start of the second year. These topics use the outdoors for the development of skills.

The collaborative sciences project can be completed at the end of semester 1 in the first year.

Starting year 2 with the individual investigation allows the students to complete investigations outside while the weather is suitable. The final two topics, Topic 6: Atmosphere and climate change and Topic 3: Biodiversity and conservation, can be switched around depending upon the teacher or student preference.

Year 1 [Semester 1]

Topic 1: Foundation

- 1.1 Perspectives
- HL.c Environmental ethics
- 1.2 Systems
- 1.3 Sustainability
- HL.a Environmental law
- HL.b Environmental economics

Topic 8: Human populations and urban systems

- HL.c Environmental ethics
- 8.1 Human populations
- 8.2 Urban systems and urban planning
- 8.3 Urban air pollution

Topic 7: Natural resources

- HL. b Environmental economics
- 7.1 Natural resources—uses and management

Collaborative science project

Year 1 [Semester 2]

Topic 7: Natural resources

- HL.b Environmental economics
- 7.2 Energy sources—use and management
- 7.3 Solid waste

Topic 2: Ecology

- 2.1 Individuals and populations, communities, and ecosystems
- 2.2 Energy and biomass in ecosystems
- 2.3 Biogeochemical cycles
- 2.4 Climate and biomes
- 2.5 Zonation, succession and change in ecosystems

Topic 5: Land

- 5.1 Soil

Year 2 [Semester 1]

Individual investigation

Topic 5: Land

- 5.2 Agriculture and food

Topic 4: Water

- HL.a Environmental law
- 4.1 Water systems
- 4.2 Water access, use and security
- 4.3 Aquatic food production systems
- 4.4 Water pollution

Topic 6: Atmosphere and climate change

- All HL lenses
- 6.1 Introduction to the atmosphere
- 6.4 Stratospheric ozone

Year 2 [Semester 2]

Topic 6: Atmosphere and climate change

- All HL lenses
- 6.2 Climate change—causes and impacts
- 6.3 Climate change—mitigation and adaptation

Topic 3: Biodiversity and conservation

- All HL lenses
- 3.1 Biodiversity and evolution
- 3.2 Human impact on biodiversity
- 3.3 Conservation and regeneration

SL only

In year 1, start with Topic 1: Foundations, and introduce students to the new vocabulary that will be used throughout the course. Build an appreciation that ESS is a holistic course and that students will be making links throughout the course using these foundations. After completing subtopic 1.3 Sustainability, students may be able to complete the collaborative sciences project. Continue with most of Topic 2: Ecology, leaving the last subtopic, 2.5 Zonation, succession and change in ecosystems, to link with soil and agriculture (Topic 5: Land) and to maximize the opportunities of completing fieldwork. Subtopic 2.4 looks at the relationship between climate and biomes, which can be linked to Topic 6: Atmosphere and climate change enabling exploration of the impacts on ecosystems. Complete year 1 with Topic 3: Biodiversity and conservation. The individual investigation could be integrated into year 1 at this point.

Year 1 [Semester 1] SL only

Topic 1: Foundation

- 1.1 Perspectives
- 1.2 Systems
- 1.3 Sustainability

Collaborative sciences project

Topic 2: Ecology

- 2.1 Individuals and populations, communities, and ecosystems
- 2.2 Energy and biomass in ecosystems
- 2.3 Biogeochemical cycles
- 2.4 Climate and biomes

Year 1 [Semester 2] SL only

Topic 6: Atmosphere and climate change

- 6.1 Introduction to the atmosphere
- 6.2 Climate change—causes and impacts
- 6.3 Climate change—mitigation and adaptation
- 6.4 Stratospheric ozone

Topic 5: Land

- 5.1 Soil
- 5.2 Agriculture and food

Topic 2: Ecology

- 2.5 Zonation, succession and change in ecosystems

Topic 3: Biodiversity and conservation

- 3.1 Biodiversity and evolution
- 3.2 Human impact on biodiversity
- 3.3 Conservation and regeneration

Year 2 [Semester 1] SL only

In year 2, starting with Topic 8: Human populations and urban systems will allow students to explore the implications of population growth on society. 8.2 Urban systems and planning connects well with the learning in Topic 3: Biodiversity and conservation at the end of year 1, reminding students that this is a holistic course. Topic 4: Water further explores the impact of changing population densities and growth on water resources. This would be an alternative point at which to include the individual investigation, having covered more of the course. Completing the course with Topic 7: Natural resources means that students will be looking at the consequences of the content already studied throughout the course and will enable them to draw together links between all the topics.

Topic 8: Human populations and urban systems

- 8.1 Human populations
- 8.2 Urban systems and planning
- 8.3 Urban air pollution

Topic 4: Water

- 4.1 Water systems
- 4.2 Water access, use and security
- 4.3 Aquatic food production systems
- 4.4 Water pollution

Individual investigation

Year 2 [Semester 2] SL only

Topic 7: Natural resources

- 7.1 Natural resources—uses and management
- 7.2 Energy sources—uses and management
- 7.3 Solid waste

HL only

Following a similar flow to the SL course, the HL course weaves in the HL lenses, starting with an introduction to each lens with Topic 1: Foundation. It is recommended to spend about two hours per lens with the related Foundation subtopic: so HL.c Environmental ethics will flow well from subtopic 1.1: Perspectives, and HL.b Environmental economics and HL.a Environmental law from subtopic 1.3 Sustainability. Teachers can return to the environmental law and environmental economics lenses with Topic 6: Atmosphere and climate change. This would be a good time to discuss international agreements, degrowth and the opportunities available through a circular economy or doughnut economic model. Completing year 1 with a return to environmental ethics will allow a review of the year through this lens.

Year 1 [Semester 1] HL only

Topic 1: Foundation, and an introduction to the HL lens

- 1.1 Perspectives
- HL.c Environmental ethics (introduction)
- 1.2 Systems
- 1.3 Sustainability
- HL.a Environmental law
- HL. b Environmental economics

Topic 2: Ecology

- 2.1 Individuals and populations, communities, and ecosystems
- 2.2 Energy and biomass in ecosystems
- 2.3 Biogeochemical cycles
- 2.4 Climate and biomes

Year 1 [Semester 2] HL only

Topic 6: Atmosphere and climate change

- 6.1 Introduction to the atmosphere
- 6.2 Climate change—causes and impacts
- 6.3 Climate change—mitigation and adaptation
- HL.a Environmental law
- HL.b Environmental economics
- 6.4 Stratospheric ozone

Topic 5: Land

- 5.1 Soil
- 5.2 Agriculture and food

Topic 2: Ecology

- 2.5 Zonation, succession and change in ecosystems

Individual investigation

HL.c Environmental ethics

Year 2 [Semester 1] HL only

In year 2, HL.a Environmental law and HL.c Environmental ethics can be integrated into the topic of biodiversity and conservation, looking at laws and sustainable development, and the environmental and social justice movements. HL.b Environmental economics integrates into Topic 4: Water with the ideas of the "tragedy of the commons", the value placed on resources and the externalization of pollution in traditional economic systems.

Although the content of the lenses has been integrated into the teaching order, it is anticipated that they will be used throughout as lenses to explore each topic.

Topic 3: Biodiversity and conservation

- 3.1 Biodiversity and evolution
- 3.2 Human impact on biodiversity
- 3.3 Conservation and regeneration
- HL.a Environmental law
- HL.c Environmental ethics

Topic 8: Human populations and urban systems

- 8.1 Human populations
- 8.2 Urban systems and urban planning
- 8.3 Urban air pollution

Topic 4: Water

- 4.1 Water systems
- HL.b Environmental economics
- 4.2 Water access, use and security
- 4.3 Aquatic food production systems

Year 2 [Semester 2] HL only

- 4.4 Water pollution
- HL.b Environmental economics

Topic 7: Natural resources

- 7.1 Natural resources, uses and management
- 7.2 Energy resources, uses and management
- 7.3 Solid waste

Integrating the HL lenses

Environmental systems and societies (ESS) is a challenging course at standard level (SL) as it weaves together multiple aspects and perspectives exploring the ongoing tensions across environmental and societal issues. At higher level (HL), additional content provides opportunities for HL students to widen and deepen their comprehension of issues and network their knowledge to develop a critical and complex understanding of the world around them.

The HL lenses—environmental law, environmental economics, and environmental ethics—are new to the course. The lenses provide additional content for an overview of the legal, economic and ethical issues related to the environment. The lenses attempt to introduce key ideas relevant to ESS; suggested connections to relevant lenses are identified in the guide.

Teachers can choose how to teach the lenses. Assuming HL students have time in extra classes, teachers may wish to teach the lenses at the beginning of the course and then refer to them at relevant points. Alternatively, teachers may choose to map the lenses content to content statements. This allows for the contextualization of the lenses while addressing syllabus content; this option may reduce repetition.

For HL students, the HL lenses apply to both SL and HL content. Students' capacity to provide the added dimensions of the HL lenses when addressing all content statements and examples will be assessed in the external assessment.

SL students are not expected or required to look at content statements through the HL lenses.

Involving colleagues with expertise in these areas in classes may help to show students that disciplines are a construct with much overlap, and that systems thinking across areas is a valuable skill.

Note

This section of the teacher support material (TSM) is mainly intended to support teaching of the HL lenses. However, the resources and some teaching ideas will also be useful for SL teaching of models.

HL.a Environmental law

Definition of environmental law

Environmental law refers to the body of law that regulates the interactions between human activities and the natural environment. It covers a wide range of topics, including pollution management, conservation of natural capital, and conservation of biodiversity.

Environmental law is intended to **prevent and mitigate** the negative impacts of human activities on the environment. It sets out the rules and regulations that individuals, businesses and governments must follow to minimize harm to the environment and promote sustainable development.

Environmental law can be divided into two main categories.

1. International environmental law governs the actions of countries, regions (territories) and organizations on a global scale.
2. Domestic environmental law focuses on specific national or regional issues.

Some of the key areas of environmental law include air and water quality, hazardous waste management, and biodiversity protection (especially regarding conservation status).

The lens enables an evaluation of the strengths and weaknesses of particular laws that students may study throughout the duration of the course, and provides opportunities to debate the issues. The general strengths and weaknesses are outlined in table 3.

Table 3

Strengths and limitations of environmental law

Strengths	Limitations
Setting limits on pollution: environmental law can establish limits on emissions of pollutants, such as greenhouse gases, which contribute to climate change. By regulating industrial and agricultural activities, environmental law can help reduce pollution and limit damage to the Earth's systems.	**Enforcement challenges:** environmental law can be difficult to enforce, especially in cases where violations are difficult to detect or where the responsible parties are hard to identify. This can limit the effectiveness of environmental law in addressing environmental problems.
Protecting natural resources: environmental law can establish protections for natural resources, such as forests, wetlands and oceans, which are essential for maintaining biodiversity and ecological balance. By protecting these resources, environmental law can help ensure the long-term sustainability of the Earth's systems.	**Limited scope:** environmental law often focuses on specific environmental issues, such as air or water pollution, but may not address broader issues, such as climate change or loss of biodiversity. This can limit the ability of environmental law to address the interconnected nature of environmental problems.
Encouraging sustainable practices: environmental law can encourage sustainable practices, such as renewable energy development, sustainable agriculture, and conservation of water resources. By incentivizing these practices, environmental law can promote the sustainable use of natural resources and reduce the impact of human activities on the environment.	**Conflicting interests:** environmental law can conflict with other interests, such as economic development or property rights. This can make it difficult to implement environmental regulations or to obtain support for environmental initiatives.
Holding polluters accountable: environmental law can establish penalties and fines for individuals and companies that violate environmental regulations (the polluter-pays principle). By holding polluters accountable, environmental law can deter harmful activities and promote responsible behaviour.	**Jurisdictional challenges:** environmental law is often implemented at the national or local level, but many environmental problems are global in nature. This can limit the ability of environmental law to address issues, such as climate change, that require international cooperation.
	Lack of political will: environmental law is often driven by political will, and changes in political leadership can result in shifts in environmental policy. This can lead to inconsistent implementation of environmental regulations or a lack of commitment to addressing environmental problems.

Overall, while environmental law can play an important role in promoting sustainability, it is subject to several limitations that can affect its effectiveness. Addressing these limitations may require a combination of legal, technological and social solutions. Environmental law is a rapidly evolving field, as new technologies and scientific discoveries continue to shape our understanding of the environment and its importance to human health and well-being.

ESS and environmental law

Environmental law plays a crucial role in promoting environmental sustainability by establishing regulations, protecting natural resources, encouraging sustainable practices, and holding polluters accountable for their actions.

Links with environmental law, environmental economics and environmental ethics

Environmental laws can set standards for pollution reduction, ethical considerations can motivate businesses to go beyond these minimum standards, and sustainable economics can help identify cost-effective strategies for achieving these goals.

Understanding the environmental law lens	Questions, general activities and resources
HL.a.1 Laws are rules that govern human behaviour and are enforced by social or governmental authority.	What happens without law? Activities could be used to introduce the key concepts underpinning the rule of law, including equality, fairness, liberty and justice.
HL.a.2 Environmental law refers specifically to the rules about how human beings use and impact natural resources, with the aim of improving social and ecological sustainability.	Consider environmental impact assessments (EIAs), natural resource management, and conservation areas. Some examples of EIAs that lead to good discussion because of their controversial elements include the following. • Keystone XL pipeline • Three Gorges dam • The Dakota access pipeline (impact on sacred sites and water sources of the Standing Rock Sioux tribe) • Palm oil plantations • Fracking The understanding of environmental law and how it can support sustainability relies on an understanding not only of ecological sustainability but also social sustainability, for example, the survival of societies and their cultures. It may include consideration of the continued use of language, belief or spiritual practices in a society.
HL.a.3 Environmental laws can have an important role in addressing and supporting environmental justice, but they can be difficult to approve due to lobbying.	Prevention of overexploitation of resources is limited by powerful lobbying from some stakeholders. An example of a possible real-world example: the National Rifle Association (NRA) is a powerful lobbying group representing gun owners in the United States. It has been accused of lobbying against laws that would protect endangered species, such as wolves, and for laws that would allow hunting in protected areas. Malo, S. (2021, July 27). *Utah asks to join U.S., NRA in gray wolf delisting case.* Reuters. Retrieved June 6, 2023, from https://www.reuters.com/legal/litigation/utah-asks-join-us-nra-gray-wolf-delisting-case-2021-07-27/
HL.a.4 Environmental law is built into existing legal frameworks, but its success can vary from country to country.	Environmental law needs strong enforcement; it may be limited by political will or other needs.

Understanding the environmental law lens	Questions, general activities and resources
HL.a.5 Environmental constitutionalism refers to the introduction of environmental rights and obligations into the constitution.	Include an example of a national constitution that successfully addresses environmental issues (see example 2).
HL.a.6 Environmental laws can be drafted at the local, national or international level.	Consider differences between laws at local, national and international level; include strengths and weaknesses of each type (see example 1).
HL.a.7 International law provides an essential framework for addressing transboundary issues of pollution and resource management.	One real-world example that could be used is the Association of Southeast Asian Nations (ASEAN) Agreement on Transboundary Haze Pollution. Its key objective is to "prevent and monitor transboundary haze pollution as a result of land and/or forest fires which should be mitigated, through concerted national efforts and intensified regional and international co-operation". **Key questions** 1. Why would international agreement be needed? 2. What are the limitations of involving international parties at the co-operation meetings of the association?
HL.a.8 UN conferences produce international conventions (agreements) that are legally binding, and protocols that may become legally binding, to all signatories.	Consider the relative success of the Montreal and Kyoto Protocols and Paris Agreement along with their subsequent amendments and developments.
HL.a.9 International agreements can generate institutions or organizations to aid their implementation.	The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the International Union for Conservation of Nature (IUCN) are two well-known examples of international agreements. See example 3.
HL.a.10 The application of international environmental law has been examined within international courts and tribunals.	Example bodies include the International Court of Justice, the International Tribunal for the Law of the Sea, and the European Court of Justice.
HL.a.11 There are an increasing number of laws granting legal personhood to natural entities in order to strengthen environmental protection.	The granting of biorights to natural entities can result in stronger environmental protection. See example 4.
HL.a.12 Both legal and economic strategies can play a role in maintaining sustainable use of the environment.	An example of how these strategies can be combined includes laws imposing fines for illegal dumping or oil spills.

Example 1
4.2.10 Local and global governance is needed to maintain freshwater use at sustainable levels. Include one example of local regulations on water use, such as banning watering of gardens in droughts. Include one example of where international agreements over water sources have become necessary.
HL.a.6 Environmental laws can be drafted at the local, national or international level. A real-world example of international and national agreements on water sources: the Nile River. International law can play an important role in resolving conflicts among countries and regions (territories) with shared water sources. A well-known example of this is the Nile River and the ongoing dispute

Example 1
between the Nile Basin countries. Amid ongoing disputes and the concerns raised by Egypt over Ethiopia's building of the Grand Ethiopian Renaissance Dam (GERD), the latest agreement on the Nile River Basin is the Declaration of Principles signed by Egypt, Ethiopia and Sudan in 2015. This declaration was signed to establish the principles for cooperation on the dam, which Ethiopia has been constructing on the Nile River since 2011. However, Egypt is also facing additional water security issues exacerbated by population growth and climate change, so has implemented its own laws to manage its water sustainably. For example, the Egyptian parliament passed the Egyptian Water Resources and Irrigation Law (Law No. 147 of 2021). The aim is to govern the sustainable and equitable management of Egypt's water resources. It includes aspects of surface water, groundwater and Nile water, and reduces inefficient water use, including a framework of practices to ensure better irrigation. One example of a rule that applies to domestic water use is the requirement for water conservation measures in households. The law mandates that all new buildings and residential complexes must incorporate water-saving devices such as low-flow faucets, showerheads and toilets to reduce water consumption.

Suggested teaching activities

1. Use Google Earth to locate all the countries that stake a claim on the Nile River.
2. Ensure that students understand the concern over the building of the GERD. Resources are available on YouTube.
   - Al Jazeera English. (2020, January 26). *What's behind the Egypt–Ethiopia Nile dispute?* [Video]. YouTube. https://www.youtube.com/watch?v=JdizU0arrJ0
   - France 24. (2023, September 11). *Ethiopia announces filling of Nile Renaissance mega-dam complete* [Video]. France24. Retrieved November, 6, 2023 from, https://www.france24.com/en/africa/20230910-ethiopia-announces-it-has-completed-filling-of-disputed-dam-project-s-reservoir
   - Wendover Productions. (2020, November 9). *Egypt's dam problem: The geopolitics of the Nile* [Video]. YouTube. https://www.youtube.com/watch?v=_BCY0SPOFpE
   - Tvedt, T (2019, June 24). *The Nile agreement* [Video]. YouTube. https://www.youtube.com/watch?v=rZxW5SChTnI
3. Use the real-world example to help students understand others' perspectives: organize a debate with students voicing perspectives from Egyptian, Sudanese and Ethiopian citizens.
4. Ask students to think about how climate change may exacerbate the tensions between the countries.
5. Discussion about the limitations of international law—even with the rules in place, arguments can still happen. Ask students to read articles about the ongoing dispute. For example: BBC News. (2021, July 6) *Egypt accuses Ethiopia of violating law over controversial dam*. BBC. Retrieved June 6, 2023, from https://www.bbc.com/news/world-africa-57734885
6. Moving on from international agreements, some of the biggest threats to Egyptian water scarcity seem to be different to construction of the GERD. What are some of these other threats?
7. Ebrahim, N. (2022, November 8). *Egypt faces an acute water crisis, but it's still building a 'Green River' in the desert*. CNN. Retrieved June 6, 2023, from https://edition.cnn.com/2022/11/08/middleeast/egypt-water-scarcity-climate-cop27-intl-cmd/index.html
8. What are some of the actions Egypt is implementing to conserve its access to freshwater? Students can discuss the strengths and limitations of the Sustainable Development Strategy: Egypt Vision 2030. Ask students to read articles on the topic. For example: Supreme Standing Committee for Human Rights (SSCHR). (2022, March 22). *Report on national efforts to ensure access to water on the occasion of World Water Day on March 22, 2022*. [Report]. SSCHR. https://sschr.gov.eg/media/ysalpy5h/english742022.pdf

Example 2

HL.a.5 Environmental constitutionalism refers to the introduction of environmental rights and obligations into the constitution.

Internationally, there is a growth of environmental constitutionalism as more and more cases are effectively addressed by nations' constitutions. Climate change issues are increasingly being addressed in this manner. Include an example of a national constitution successfully involved in addressing environmental issues.

One example of a national constitution that has successfully addressed environmental issues is the Constitution of the Republic of South Africa, adopted in 1996. The South African constitution recognizes the right to a healthy environment as a basic human right and provides for the protection and preservation of the environment as a fundamental duty of the state.

Article 24 of the constitution enshrines the right to an environment that is not harmful to health or well-being, and requires the state to take reasonable legislative and other measures to protect and improve the environment. This provision has been used to support numerous environmental laws, regulations and policies in South Africa, including those related to air quality, water resource management, biodiversity, conservation and waste management. It plays a crucial role in shaping the country's environmental policies and promoting sustainable development.

While the South African constitution includes a right of access to sufficient water, there are limitations to its effectiveness. One of the main limitations is the lack of clarity in the definition of "sufficient water". This has led to some uncertainty in the application of the right and has made it difficult to establish clear standards for water allocation.

Another limitation is the lack of effective enforcement mechanisms. The right to water is often violated, especially in rural and marginalized communities, but there are few effective remedies for those whose rights have been violated. This is due in part to the complex legal and bureaucratic structures that govern water management and allocation in the country.

Finally, there are issues of implementation and resource allocation. The provision of water and sanitation services requires significant financial and administrative resources, and the government has struggled to provide these services to all citizens, especially in rural and underserved areas.

Overall, while the South African constitution includes a right of access to sufficient water, there are significant challenges in ensuring that this right is effectively realized for all citizens.

South African Government. (1996). *Section 24 Constitution of South Africa 1996*. LawGlobal Hub. www.lawglobalhub.com/section-24-constitution-of-south-africa-1996/

Suggested teaching activities

1. Brainstorming session: ask students to brainstorm ways in which the environment affects their daily lives, and how a healthy environment can improve their overall well-being. Then explain that the South African constitution recognizes the right to a healthy environment as a basic human right and provides for the protection and preservation of the environment as a fundamental duty of the state.
2. Real-world example analysis: provide students with a real-world example of an environmental issue in South Africa, such as deforestation. Ask them to analyse the issue and discuss how it relates to the right to a healthy environment as recognized by the South African constitution. Then ask students to propose solutions for the issue that align with the constitution's fundamental duty of protecting and preserving the environment.
3. Role-playing exercise: divide students into groups and assign them different roles, such as government officials, environmental activists and local residents. Provide them with a hypothetical scenario, such as a proposed development project that could have negative environmental impacts. Ask them to engage in a role-playing exercise where they discuss and negotiate the issue based on their assigned roles and the principles outlined in the South African constitution. Afterwards, ask students to reflect on the exercise and discuss how the constitution can guide decision-making on environmental issues in real life.

Example 3
HL.a.9 International agreements can generate institutions or organizations to aid their implementation. There are a range of conventions and organizations covered in the course, for example, CITES and IUCN.
3.3.2 Species-based conservation tends to involve *ex situ* strategies, and habitat-based conservation tends to involve *in situ* strategies.
Ex situ measures include botanic gardens, zoos, CITES and seed banks; *in situ* measures include the use of national parks, reserves and sanctuaries. Consider two examples of *ex situ* measures and two examples of *in situ* measures. African elephants: in 1989, CITES listed African elephants in Appendix I, which banned the international trade of ivory. Since then, elephant populations have increased in several African countries, indicating that the ban has been effective in reducing poaching and illegal trade. An example of how CITES supports the conservation of African Elephants is the CITES National Ivory Action Plan (NIAP)—the tool of the convention that is being used by a number of parties to strengthen their controls of the trade in ivory and ivory markets and to help combat the illegal trade in ivory. Other examples of species whose conservation status may be improving as a result of interventions facilitated by CITES: students could also be challenged to think about the positive impact of the wildlife trade on certain species. According to CITES, vicuñas (*Lama vicugna*) are an example of the positive impact of legal trade on species conservation. This species was downgraded from Appendix I to Appendix 2, and has seen a population increase and an associated conservation status change by the IUCN to “least concern” following the CITES intervention.
Suggested teaching activities Divide the class into small groups, and provide each group with a chart listing the pros and cons of downgrading the conservation status of the vicuña. **Pros:** increased legal trade in vicuña wool, which could provide economic benefits to local communities and incentivize conservation efforts. **Cons:** the risk of overexploitation and poaching if trade is not well regulated, as well as the potential negative impacts on vicuña populations if protections are weakened. Give students a few minutes to discuss and debate the pros and cons within their groups, and then ask them to share their ideas with the class. This activity will help students to think critically about the potential trade-offs involved in balancing conservation goals with economic interests and human development needs.

Example 4
HL.a.11 There are an increasing number of laws granting legal personhood to natural entities in order to strengthen environmental protection.
Whanganui River Claims Settlement Act • The Whanganui River Claims Settlement Act was passed by the New Zealand parliament in 2017. • The Act grants legal personhood to the Whanganui River, which is sacred to the Maori people. • The river is recognized as a legal entity with its own rights and interests. • *Te Pou Tupua* is a single role, held by two people who are appointed to represent and act on behalf of the river, and protect its health and well-being. • *Te Pou Tupua* has the authority to bring legal actions on behalf of the river. • The Act establishes a fund for the restoration and protection of the river. • The Act also provides for the establishment of a river strategy group to develop and implement a strategy for the long-term management of the river.

Example 4
• The Act is a significant development in the recognition of biorights and the granting of legal personhood to natural entities.
Suggested teaching activities Mapping exercise: provide students with a map of the Whanganui River and its surrounding areas. Ask them to identify key environmental and cultural features of the river, including sites of historical and spiritual significance to the Maori people. Then ask students to mark the areas that are protected under the Whanganui River Claims Settlement Act and explain why they were designated as such. This activity will help students to understand both the importance of the river to the Maori people, and how the settlement act aims to protect and preserve the river's cultural and natural heritage for future generations.

Resources

The following are general resources to help in the teaching of environmental law.

- BBC Newshour. (2023, March 6). *What is the High Seas Treaty and why is it needed?* BBC News World Service. Retrieved June 6, 2023, from https://www.bbc.co.uk/programmes/p0f70r2w#:~:text=The%20High%20Seas%20Treaty%20aims,the%20Law%20of%20the%20Sea
- Monbiot, G. (2023, February 27). *Silence in court*. Retrieved June 6, 2023, from https://www.monbiot.com/2023/02/27/silence-in-court/
- Siemen, P. (2013, December 11). *TEDxJacksonville*: *The rights of nature* [Video]. YouTube. https://www.youtube.com/watch?v=4EPnSw0j5Go
- Widjekop, F. (2015, June 1). *TEDxHaarlem*: *How law can save the Earth* [Video]. YouTube. https://www.youtube.com/watch?v=fKt2DlZWH7k

Use the closed caption button (CC) to turn on the subtitles, then use the settings button to change the subtitles via the "Auto-translate" option to the language required.

HL.b Environmental economics

Definition of economics

The study of economics is defined as a social science of how individuals and groups of human beings make decisions to meet their needs and wants by managing and exploiting limited natural, human and financial resources (land, labour, capital and entrepreneurship).

ESS and economics

Economic systems involve the provision of markets, households, firms, the state and "the commons", which connect humans to the natural world. Thus, the study of economics is linked and is critical to the understanding of ESS, but is also used to meet and assess our social and ecological goals. It is therefore through the study of ESS that an assessment of the human impacts on the environment can be made. This can be understood in both the microeconomic (small/individual) and macroeconomic (large/national/international) scales to meet human needs and wants.

Relevance of economics to the ESS course

This section of the TSM looks at economics and socio-ecological economics through the ESS environmental economics HL lens to help students understand the relationship between human beings and nature. The lens also helps to explain what solutions various groups of economists propose, and attempts to address the problems or issues of human overconsumption, mismanagement and the degradation of Earth's systems.

This lens presents areas of economics to help students distinguish between different schools of thought. These include concepts such as **doughnut economics** and the **circular economy**.

How economists view the world (and the environment)

Students studying the Diploma Programme (DP) economics course are mainly exposed to a school of thought that can be broadly classified as **free market economics**; this is what is presented in most standard textbooks. This system is dominated by concepts such as analysis centred on competitive markets, price-based valuation, assumptions of rationality and equilibrium analysis.

Pose these questions to students to help them to assess how economists view human behaviour and the environment around them.

- What problem is central to the economy?
- What should our economic goals be?
- How and where should we acquire knowledge and information about the economy?
- What is the fundamental nature of human beings?
- How do individuals make decisions?
- What actions are appropriate to reach our social and ecological goals?

Examples of how the environmental economics HL lens can be applied to the course content

Environmental economics, ecological economics and socio-ecological economics are closely related fields that explore the intersection of economics and the environment; while there are overlapping concepts and principles, each field approaches the topic from a slightly different perspective.

Environmental economics

Environmental economics studies the relationship between the economy and the environment. It addresses market failures, promotes sustainable development by valuing natural resources and ecosystem services, and analyses the costs and benefits of environmental policies.

Ecological economics

Ecological economics looks to integrate both ecological and economic principles. It emphasizes the importance of well-being, sustainability and equity. It looks to achieve a harmonious and resilient relationship between humans and the natural environment by exploring interdependencies between ecosystems and the economy.

Socio-ecological economics

Socio-ecological economics describes an emerging synthesis between schools of economic thought, including insights from ecological, feminist, complexity, institutional and behavioural economics. It is a multidisciplinary area of study that shares many ideas and approaches with the ESS course. The strand of socio-ecological economics that deals mainly with the natural world is called **ecological economics**.

Note

Though environmental economics and ecological economics sound similar, they are two different schools of thought. They both look at similar end effects on the environment and the planet; however, ecological economics is more inclusive and cross-disciplinary and adopts a more holistic approach.

DP economics students have some exposure to other schools of thought in economics, but are not exposed to socio-ecological economics. It is, therefore, important for teachers to know that some of the ideas presented in the ESS syllabus on socio-ecological economics will be new to students who are studying DP economics and students may try to associate these socio-ecological ideas with environmental economics.

The aim of the guidance in the TSM for the ESS environmental economics HL lens is to provide written help to ESS teachers who are non-specialists in economics. Where possible, the TSM aims to help with the delivery of teaching without using overwhelming economics language, mathematics or complex diagrams, and to enable those students who are not taking DP economics to engage with the ideas.

Refer to Ecological Economics for All (n.d.), Chen (2022) and Venkatachalam (2007) in the bibliography.

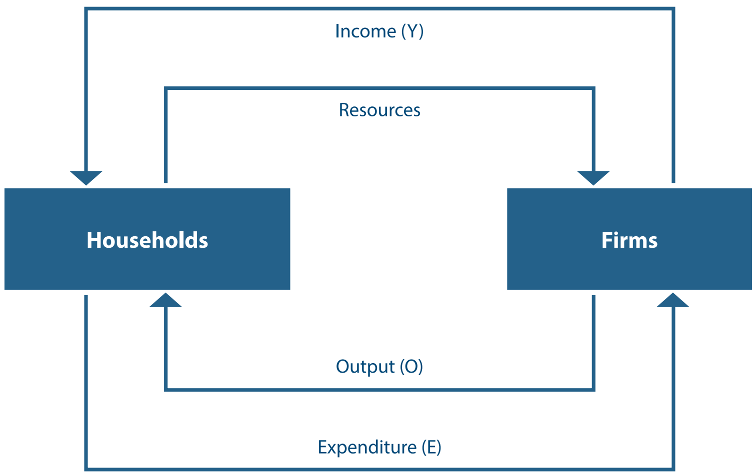
Understanding the economics of the environment

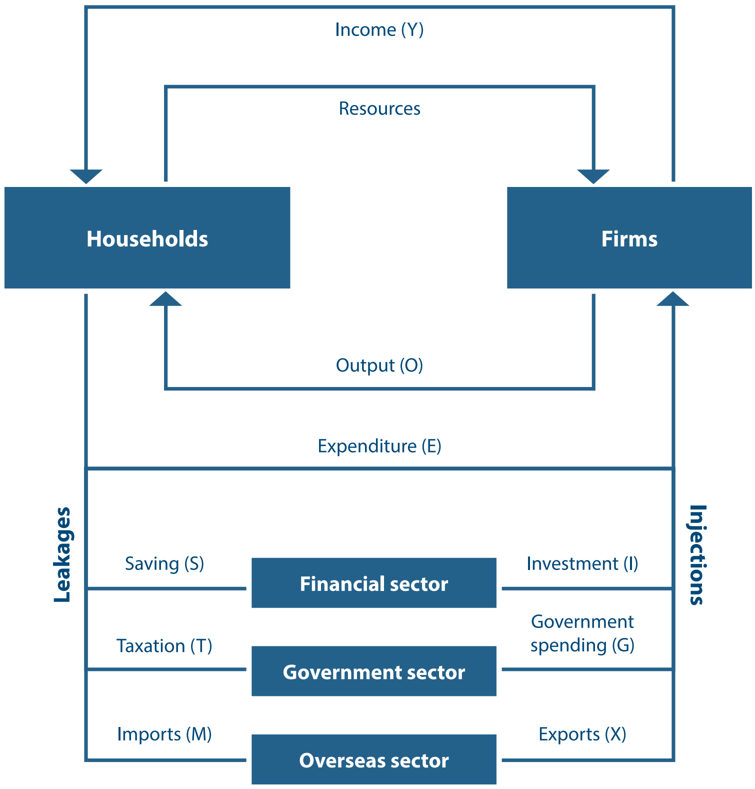
The following is a summary of the main concepts that will help with the delivery of the ESS environmental economics HL lens.

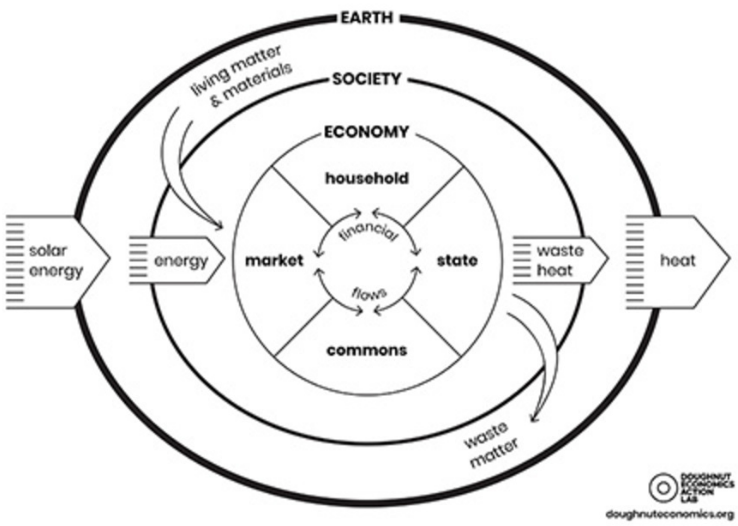
Understanding the environmental economics lens	Questions, general activities and resources
HL.b.1 Economics studies how humans produce, distribute and consume goods and services, both individually and collectively.	Understanding the basic concepts: economics is generally classified as a social science, which is the study of how individuals and groups make decisions about the allocation of scarce natural resources (the economic problem). There are three fundamental issues. • What to produce • How to produce • For whom to produce The current system of resource and product creation, and of monetary exchanges between households and businesses (also known as a "market"), requires significant focus on the "allocating (or provisioning) system" (using land, labour, capital and entrepreneurship to meet human needs and wants). Entrepreneurship creates a space for both environmental and ecological economic activity. In **economics**, **decision-making** also looks at the fundamental concept of **opportunity cost**, which is "choice theory" for economists. "Opportunity cost" is defined as the benefit forgone from making a decision. Any decision requires a choice between two or more competing alternatives. When the decision is made, economists analyse the **benefit foregone**—which means economists look at the benefit that the unsuccessful choice would have given. For example, a country (government) has an investment decision, and chooses to offer subsidies to open a new gas (or coal-fired) power station instead of subsiding a firm to develop a wind (or solar) farm. Therefore, the benefit that is not received is renewable energy.
HL.b.2 Environmental economics is economics applied to the environment and environmental issues.	The notes for HL.b.2 state that "Technocentrics have the perspective that science and technology will enable environmental economics to work within the current economic framework." The existing system reinforces the belief that humans will develop new science (often, for example, in engineering, chemistry, genetics, microbiology) and technology to solve the current environmental and ecological problems or issues. The following article explains the HL.b.2 content statement. ChemEurope. (2023, May 23). *An electric vehicle battery for all seasons*. ChemEurope. Retrieved November 6, 2023, from https://www.chemeurope.com/en/news/1180548/an-electric-vehicle-battery-for-all-seasons.html Supporters of ecological economics believe that there is an emerging movement that believes solutions to the current environment problems can be achieved through a fundamental change in human behaviour towards living with the environment in a sustainable and responsible manner.

Understanding the environmental economics lens	Questions, general activities and resources
HL.b.3 Market failure occurs when the allocation of goods and services by the free market imposes negative impacts on the environment.	An example is the impact of vaping on the environment. Paul, K. (2019, August 27). *Vaping's other problem: are e-cigarettes creating a recycling disaster?* The Guardian. Retrieved June 21, 2023, from https://www.theguardian.com/society/2019/aug/26/vapings-other-problem-are-e-cigarettes-creating-a-recycling-disaster
HL.b.4 When the market fails to prevent negative impacts, the polluter-pays principle may be applied.	Government intervention strategies and policies are designed to prevent externalities and try to impact the polluter. Hughes, R. A. (2023, January 4). *Tobacco companies must pay for clean up of discarded cigarettes in Spain*. Euronews. Retrieved June 21, 2023, from https://www.euronews.com/green/2023/01/04/tobacco-companies-must-pay-for-clean-up-of-discarded-cigarettes-in-spain Other international policies are aimed directly at protection. United Nations. (2023, June 19). *Beyond borders: Why new 'high seas' treaty is critical for the world*. United Nations. Retrieved November 7, 2023, from https://news.un.org/en/story/2023/06/1137857
HL.b.5 "Greenwashing" or "green sheen" is where companies use marketing spin to give themselves a more environmentally friendly image.	The environmental, social and governance (ESG) movement considers the impact that a company has on its employees, customers and the communities where it operates. Bhagat, S. (2022, March 31). *An inconvenient truth about ESG investing*. Harvard Business Review. Retrieved June 21, 2023, from https://hbr.org/2022/03/an-inconvenient-truth-about-esg-investing Newman, G. (2022). *Top 6 ESG issues for companies to tackle*. Ethics & Compliance Initiative. Retrieved June 21, 2023, from https://www.ethics.org/top-6-esg-issues-for-companies-to-tackle/ Critics of the ESG movement use the terms "greenwashing" and/or "green sheen". Icarus Complex Magazine. (2019, September 3.) *How brands are 'greenwashing' you into a false sense of sustainability*. Icarus Complex. Retrieved June 21, 2023, from https://icaruscomplexmagazine.com/how-brands-are-greenwashing-you-into-a-false-sense-of-sustainability/
HL.b.6 The tragedy of the commons highlights the problem where property rights are not clearly delineated and no market price is attached to a common good, resulting in overexploitation.	An example of the commons is international waters. Overexploitation of the commons has led to the term and occurrence of the tragedy of the commons. Related issues are property rights—or a lack of them. World Wide Fund for Nature. (2023, March 4). *WWF: Landmark high seas treaty agreed, ushering in new rules for two-thirds of the ocean*. World Wide Fund for Nature. Retrieved June 21, 2023, from https://wwf.panda.org/wwf_news/?7913966/landmark-high-seas-treaty-agreed
HL.b.7 Environmental accounting is the attempt to attach economic value to natural resources and their depletion.	Environmental accounts are a statistical system bringing together economic and environmental information in a common framework to measure the contribution of the environment to the economy and the impact of the economy on the environment. Mattison, R. (2016, April 4). *Can a new way of accounting save our planet?* [Video]. YouTube. https://www.youtube.com/watch?v=GsM3kYAtYaI

Understanding the environmental economics lens	Questions, general activities and resources
	Fang, E-L. (2021, May 27). *How accountants can help fight climate change?* [Video]. YouTube. https://www.youtube.com/watch?v=LBy2hB-cAtY Boersma, D. (2015, January 27). *Accounting for externalities* [Video]. YouTube. https://www.youtube.com/watch?v=UPSHi35fX_4
HL.b.8 In some cases, economic value can be established by use, but this is not the case for non-use values.	The following resource gives an explanation of an environmental accounting approach. EU Environment. (2017, December 6). *How to value and account for ecosystems* [Video]. YouTube. https://www.youtube.com/watch?v=4U9nbhzvOYI
HL.b.9 Ecological economics is different from environmental economics in that it views the economy as a subsystem of Earth's larger biosphere and the social system as being a subcomponent of ecology.	The following resource gives an explanation of how to account for natural capital: how natural resources are doing—recording and reporting status and trends—and how people are using natural resources. Hein, L. (2019, April 15). *Natural capital accounting* [Video]. YouTube. https://www.youtube.com/watch?v=RdOZmR-geek
HL.b.10 While the economic valuation of ecosystem services is addressed by environmental economics, there is an even greater emphasis in ecological economics.	The following resources give explanations of ecological economics. Constanza, R. (2010, May 11). *What is ecological economics?* Yale Insights. Retrieved June 23, 2023, from https://insights.som.yale.edu/insights/what-is-ecological-economics Steinenburger, J. & Kallis, G. (2020, October 3). *Episode 2: Ecological economics explained* [Video]. YouTube. https://www.youtube.com/watch?v=AW8DRbTF5CM
HL.b.11 Economic growth is the change in the total market value of goods and services in a country over a period, and is usually measured as the annual percentage change in GDP.	Economic growth refers to increasing the size of a country's gross domestic product (GDP). Economic growth is traditionally measured and internationally recognized by GDP. Terms that are also used include: rates of GDP growth (year on year) and GDP per capita (per person). CNBC International. (2018, September 26). *What does GDP mean?* [Video]. https://www.youtube.com/watch?v=iLom1WlqwS0
HL.b.12 Economic growth is influenced by supply and demand, and may be perceived as a measure of prosperity.	Economic growth has impacts on parts of the circular flow model for society and the environment. Typically, these impacts are negative (but can be positive) and are called **externalities**; for example, a negative externality is pollution. Externalities are also called **third-party effects** or **spillover effects**. These effects are a result of a failure of markets (a market misallocation of resources) or a market failure. Sprouts Schools. (2022, November 24). *Negative externalities: The hidden social costs* [Video]. YouTube. https://www.youtube.com/watch?v=8VvqK1JRTuA
HL.b.13 Economic growth has impacts on environmental welfare.	Current economic growth does not measure impact on the environment. NV at CEPImperial. (2014, January 28). *Economy and the environment*. [Video]. YouTube. https://www.youtube.com/watch?v=IF9YsVpZnSE

Understanding the environmental economics lens	**Questions, general activities and resources**
HL.b.14 Eco-economic decoupling is the notion of separating economic growth from environmental degradation.	A different economic model is needed. NV at CEPImperial. (2017, December 1). *Decoupling economic growth from environmental resources* [Video]. YouTube. https://www.youtube.com/watch?v=n7w9j7eciwo
HL.b.15 Ecological economics supports the need for degrowth, zero growth or slow growth, and advocates planned reduction in consumption and production, particularly in high-income countries.	The following resources support the need for change. Ekins, P. (2016, February 1). *Can our economies grow forever?* [Video] YouTube. https://www.youtube.com/watch?v=MLas-o8Er8M Smith, D. (2016, October 7). *Is capitalism saving or destroying us?* [Video]. YouTube. https://www.youtube.com/watch?v=GUP4DVSb0rk
HL.b.16 Ecological economists support a slow/no/zero growth model.	How can we live better while producing less? CNBC International. (2021, May 20). *Degrowth: Is it time to live better with less?* [Video]. https://www.youtube.com/watch?v=Ia8u5P0KbPQ
HL.b.17 The circular economy and doughnut economics models can be seen as applications of ecological economics for sustainability.	A model of an economy is an overview of the current system of resource/product creation and monetary exchanges between households and businesses (a market) with a significant focus on markets as an allocating (or provisioning) system (for example, for land, labour, capital and entrepreneurship) to meet human needs and wants. This circular flow model is either studied using the two-sector or five-sector models. This model should not be confused with circular economy. Economics assesses the impacts of parts of the circular flow model on society and the environment. *Figure 4* *The two-sector model of an economy (isolated model)*  Image source: *Two-sector circular flow diagram* [Diagram], by Ari89, 2006. Wikipedia (https://en.wikipedia.org/wiki/File:Two_sector_circular_flow_diagram.jpg), Creative Commons CC0 1.0 Universal Public Domain Dedication.

Understanding the environmental economics lens	Questions, general activities and resources
	• Income (Y)—wages, rent, dividends and profit • Resources—factors of production • Output (O)—goods and services • Expenditure (E)—consumer spending Figure 4 shows a simple two-sector isolated model of the economy where there are only two economic agents/actors, namely "households" and "firms". In this model, the system boundary is drawn very tightly around the main agents/actors—households and firms only. Households provide "resources" (factors of production) to firms, most notably labour. In return, households receive "income" from firms. Firms use the resources to create goods and services (output). Households spend money ("expenditure") to buy these goods and services. *Figure 5* *The five-sector model of an economy (open model)*  Image source: *Five-sector circular flow of income model* [Diagram], by Ari89, 2006, Wikipedia (https://en.wikipedia.org/wiki/File:Five_Sector_Circular_Flow_of_Income_Model.jpg), Creative Commons CC0 1.0 Universal Public Domain Dedication. Figure 5 shows a more complex version of the circular flow model, where the system of the model is expanded. Three additional economic agents/actors are included: "financial sector" (firms such as banks), "government sector" and the "overseas sector" (international trade or foreign firms).

Understanding the environmental economics lens	Questions, general activities and resources
	Each of these three additional sectors either provide money to ("injections") or receive money from ("leakages") the core exchange between households and firms. For example, both households and firms pay taxes to the government (leakage), but the government also spends money in the core economy (injection). **Notes:** ESS students do not need to draw these diagram models for their examinations. However, they do need to know what these circular flow of income models include and what they exclude, and the significance of these choices. An important point to note about these circular flow of income models is that they portray economic activity as separate from the natural world (and society); nature is invisible in these models. This human–nature dualism has historically played a large role in the overexploitation and degradation of the natural environment. **Socio-ecological economics: The embedded economy** In contrast to the isolated model (figure 4), socio-ecological economics uses an open model of the economy (figure 5), first introduced by the ecological economist Herman Daly in the 1970s. The model shows the input of solar energy and material resources, and heat loss and waste into Earth's sinks. The economy is "embedded"—or "contained"—within society and within the natural environment. *Figure 6* *The embedded economy*  Image source: *The embedded economy* [Diagram], DEAL, 2020. Doughnut Economics Action Lab (https://doughnuteconomics.org/tools/65). DEAL. This model recognizes the dependency and integration of both society and the economy with the natural environment. Thus, any economic analysis that uses this model is more likely to have a holistic and complex understanding of the interplay between the economy and society and the natural environment.

Understanding the environmental economics lens	Questions, general activities and resources
	Note that the embedded model includes more provisioning systems than the economics circular flow models. In the embedded economy model, markets and the state are joined by the household and the commons. The household in this model includes all the unpaid care work undertaken in the home (primarily by women). The way the term “household” is used in this model is different from households in the circular flow diagram, which focused only on the role of providing labour to firms and consuming goods and services. Economist Kate Raworth explains the embedded economy in the following short video. Doughnut Economics Action Lab. (2022, September 27). *Meet the economy* [Video]. YouTube. https://www.youtube.com/watch?v=ZLnAXNbtcZQ

Teaching approaches

Initial approach (introduction to students)

The contrasting models of the economy are a way to embed international-mindedness and theory of knowledge (TOK) into the ESS course. You can highlight:

- the uses and limitations of models
- the significance of where we draw system boundaries
- how the way we draw models influences the knowledge we gain from studying them.

Developing insight and extending understanding (stretch and challenge)

The following activities could be useful if you have students taking DP economics who have completed the unit on macroeconomics.

- You could pair them up with students who are **not** taking economics and ask the economics students to explain the circular flow diagrams to their partners. This would reinforce learning for the economics students and would also help ESS students to understand the diagrams.
- You could break students into groups and ask each group to focus on one of the content statements in the ESS environmental economics HL lens.
- The group could explain the perspectives of the two models of economics (open and isolated), using engaging imagery to support ideas, and discuss the implications of the ideas for:
    - providing insight on how we got into the environmental crisis and what we should be doing about it from the two economics perspectives.
    - key disagreements between mainstream and socio-ecological economics, having students do some research on the contrasting positions and then run structured discussions or debates. See the following examples.
        - Should we pursue green growth or degrowth to bring our societies/economies back within planetary boundaries?
        - Should we put a price on nature?
        - The commons: tragedy or triumph?

Online resources

The following resource, which provides the basics on doughnut economics, is also suitable for standard level (SL) students.

- Doughnut Economics Action Lab. (2023). *About doughnut economics*. Doughnut Economics Action Lab. Retrieved July 13, 2023, from https://doughnuteconomics.org/about-doughnut-economics

Potential class activities

Method: Dual coding

You could print the doughnut economics diagram as a large poster for your classroom, so that it is visually available for you and your students to identify connections between planetary boundaries and the social foundation. Highlighting these connections regularly should help students start to dismantle the human–nature dualism they have likely already internalized.	Doughnut Economics Action Lab. (2020). *Doughnut diagrams in 25+ languages*. Doughnut Economics Action Lab. Retrieved July 13, 2023, from https://doughnuteconomics.org/tools/65
You could also create this doughnut spinner, which will enable students to generate combinations of ecological systems and human needs to explore connections.	Doughnut Economics Action Lab. (2021). *Doughnut spinner*. Doughnut Economics Action Lab. Retrieved July 13, 2023, from https://doughnuteconomics.org/tools/87
This activity has students focus on one dimension of the doughnut and mingle with other students to find connections between the social foundation elements and planetary boundaries.	Doughnut Economics Action Lab. (2023). *Joining the doughnut dots*. Doughnut Economics Action Lab. Retrieved July 13, 2023, from https://doughnuteconomics.org/tools/10
You can use this website to see trends and do comparisons on how well countries are meeting human needs within planetary boundaries.	University of Leeds. (2023). *A good life for all within planetary boundaries*. University of Leeds. Retrieved July 13, 2023, from https://goodlife.leeds.ac.uk/
This article explains data about the planet's limits.	O'Neill, D. (2018, February 7). *Is it possible for everyone to live a good life within our planet's limits?* The Conversation. Retrieved July 13, 2023, from https://theconversation.com/is-it-possible-for-everyone-to-live-a-good-life-within-our-planets-limits-91421
Theme for a research activity: Behavioural nudges. Ask students to create a report or make a presentation.	Increasingly, government and business solutions for tackling human nature and environmental degradation use behavioural nudges. BVA. (2015, November 26). *A brief history of nudge Learn the power of nudge to win at behavioral change* [Video]. YouTube. https://www.youtube.com/watch?v=jVTg3ZsNTTY

Examples of links between the HL.b Environmental economics HL lens for ESS and the main syllabus

Throughout the course, teachers and students can use the HL.b Environmental economics lens to frame discussions around two broad and recurring questions.

1. What insights does the HL.b Environmental economics lense provide on how and why human beings degrade environmental systems?
2. What insights does the HL.b Environmental economics lens provide on what we can do about environmental degradation?

Students can revisit the economics HL understandings whenever they consider human impacts on the environment and strategies to rectify environmental problems.

Teachers may also choose to teach or reinforce understandings from the HL.b Environmental economics lens through individual understandings from the syllabus. Below are several examples; these are not exhaustive.

Example 1

1.2.5 Systems can be open or closed. (SL and HL)

The HL.b Environmental economics lens highlights the differing views of mainstream and socio-ecological economics on how to model the economy. Mainstream economists use the circular flow model, which is a closed system that only includes monetary and resource/product exchanges between households and firms (two-sector model) and the state, financial sector, and overseas sector (five-sector model). Ecological economists use an open system model that includes inputs of solar energy and matter, and shows waste and heat outputs.

Example 2

1.3.8 Common indicators of economic development, such as gross domestic product (GDP), neglect the value of natural systems and may lead to unsustainable development. (SL and HL)

GDP measures the monetary value of all goods and services produced in an economy in a year. It has been the most important internationally recognized indicator of economic progress for many decades. However, it only measures output that is paid for with money and is recorded; it thus reflects the **limited scope** of the circular flow of income model in mainstream economics. In other words, the full cost of energy, material inputs or loss of ecosystem services caused by economic activity are not recorded in the GDP indicator. This means that economic actors (or agents—consumers, firms, government) are not making decisions based on a complete cost–benefit analysis. Also, some areas of the economy, such as care work in the household and unpaid work in the commons, are often ignored by businesses and policymakers, to the detriment of social well-being.

Example 3

2.1.22 Human activity can lead to tipping points in ecosystem stability. (SL and HL)

GDP growth—and the materials extracted from the Earth, and the emissions and waste produced to achieve it—leads to tipping points in ecosystem stability. Free market economics may be **myopic** to these risks because economic models generally assume linear and stable relationships between economic factors that can be quantified. Socio-ecological economics is more attuned to the risks of tipping points. This is because it assumes that the economy is a complex, adaptive system whose stocks and flows, feedback loops and delays are likely to produce unpredictable tipping points (from financial crashes to climate breakdown). In addition to being a complex system itself, the economy is likewise embedded in complex, adaptive social and ecological systems. Complex systems are more difficult to measure, predict and influence, so socio-ecological economics is more likely to propose **stronger** measures to limit ecological harm (the precautionary principle).

Example 4

3.2.2 Most ecosystems are subject to multiple human impacts. (SL and HL)

Whenever human impacts are addressed in the ESS syllabus, it is important for students to recognize and discuss human provisioning systems. Human impacts on the environment come through decisions that we all make:

- as consumers
- as businesses—what, how and for whom to produce products
- as governments—about what kinds of economic activities to incentivize (for example, through subsidies) or disincentivize (for example, through taxes, regulations).

Example 4
Thus, for HL students, wherever possible, it is important not to just state or describe (usually negative, but also positive) human impacts on ecosystems, but to consider the economic reasons why those impacts are happening as well. The HL.b Environmental economic lens can support those discussions.

Example 5
4.2.19 Inequitable access to drinkable water and sanitation negatively impacts human health and sustainable development. (HL only) The goal of economic growth has often resulted in regions overexploiting water resources for certain kinds of economic activities (for example, agriculture, industrialization) at the expense of equitable, sufficient and sustainable water access for the general population. **Note:** the guidance for this understanding asks students to learn about a concrete example of inequitable access to drinkable water. Teachers may want to explore one or more cases where this inequitable access has occurred as a result of the prioritization of economic growth of a sector or business over the general health and well-being of a population.

Example 6
6.2.2 Anthropogenic carbon dioxide emissions have caused atmospheric concentrations to rise significantly. The global rate of emission has accelerated, particularly since 1950. (SL and HL) This understanding is a good point to emphasize the changing relationship between CO_2 emissions and GDP growth. Likewise, it is important for students to understand the impact of increases in GDP and CO_2 emissions on human well-being. Up to a certain income level, these might be well correlated, but above a certain income level, they are less so. Question: what implications does that have for our economic goals?

Example 7
Topic 7: Natural resources There are many points in topic 7 where the HL.b Environmental economic lens is useful for understanding both our overexploitation of natural resources and the strategies that the two broad schools of thought might propose to reach a more sustainable use of resources.

Resources

- A collection of articles on the environmental crisis and what people around the world are doing about it: BBC Future Planet. (2023, various dates). *Future Planet*. BBC. Retrieved June 30, 2023, from https://www.bbc.com/future/future-planet/
- Comparative illustrations and videos about the understandings of the HL.b Environmental economics lens: Doughnut Economics Action Lab. (2020). *Get animated! Introducing the seven ways*. Doughnut Economics Action Lab. Retrieved June 30, 2023, from https://doughnuteconomics.org/tools/2
- This video explains the embedded economy model from the socio-ecological economics perspective: Doughnut Economics Action Lab. (2022, September 27). *Meet the economy* [Video]. YouTube. https://www.youtube.com/watch?v=ZLnAXNbtcZQ
- The mission of Earth Charter International is to contribute to the transition to sustainable ways of living on the planet: Earth Charter. (2000–2023). *Want to learn and grow as a sustainability leader?* The Earth Charter International. Retrieved June 30, 2023, from https://earthcharter.org/education-sustainable-development
- A book that explains the concept of degrowth and how it might be achieved: Hickel, J. (2021). *Less is more: How degrowth will save the world*. Windmill Books.

- An important report on the economics of biodiversity, which stresses that the economy is embedded in nature and urges governments and societies to reconsider how we think, act and measure economic success. There are multiple versions of the report: long, abridged and headline messages: HM Treasury. (2021, August 2). *Final report—The economics of biodiversity: The Dasgupta review*. GOV.UK. Retrieved June 30, 2023, from https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review
- The following video captures the key messages of the previously listed report: Cambridge University. (2021, October 13). *Nature: Our most precious asset* [Video]. YouTube. https://www.youtube.com/watch?v=JvPJALCZOeo
- A good summary of the benefits and drawbacks of pricing nature: Oakes, K. (2021, October 22). BBC Carbon Cost: *The great experiment to put a price on nature*. BBC. Retrieved June 30, 2023, from https://www.bbc.com/future/article/20211018-scotlands-great-experiment-to-calculate-the-value-of-nature
- An article that explores the origin of the tragedy of the commons story and explains why the story undermines our attempts to collaborate to solve environmental problems: Nijhuis, M. (2021, May 4). *The miracle of the commons*. Aeon. Retrieved June 30, 2023, from https://aeon.co/essays/the-tragedy-of-the-commons-is-a-false-and-dangerous-myth
- This book fully explains the contrasting economic lenses from the HL ESS syllabus. It is a relatively quick and entertaining read: Raworth, K. (2017). *Doughnut economics: Seven ways to think like a 21st-century economist*. Penguin Random House.
- A TED Talk with Kate Raworth explaining doughnut economics: Raworth, K. (2018). *A healthy economy should be designed to thrive, not grow* [Video]. YouTube. https://www.ted.com/talks/kate_raworth_a_healthy_economy_should_be_designed_to_thrive_not_grow?language=en
- A website with country data organized by social foundation and ecological ceiling. It supports the doughnut comparisons and trends by country: University of Leeds. (2023). *A good life for all within planetary boundaries*. University of Leeds. Retrieved June 30, 2023, https://goodlife.leeds.ac.uk/

Circular economy

- This website has many resources useful for teachers: Ellen MacArthur Foundation. [n.d.] Ellen MacArthur Foundation [Website]. https://ellenmacarthurfoundation.org/
- Good video: Ellen MacArthur Foundation. (2011, August 28). *Explaining the circular economy and how society can rethink progress* [Video]. https://youtu.be/zCRKvDyyHmI. YouTube.
- This animated video explains the circular economy butterfly diagram for biological and technical cycles of the circular economy: Ellen MacArthur Foundation. (2020, February 12). *Ellen MacArthur on the basics of the circular economy* [Video interview]. https://youtu.be/NBEvJwTxs4w. YouTube.
- This is the teacher resource page from the Ellen MacArthur Foundation website. It provides general resources about the circular economy, activities and workshops, as well as resources for the 12–19 age group: Ellen MacArthur Foundation. [n.d.]. *Teaching resources*. Ellen MacArthur Foundation https://ellenmacarthurfoundation.org/resources/education-and-learning/teaching-resources/.

Planetary boundaries

- A documentary that explains planetary boundaries theory: Netflix. (2021). *Breaking boundaries: The science of our planet* [Film]. Netflix. https://www.netflix.com/de-en/title/81336476
- A video explaining the state of the Earth and the urgent need to take action to stay within planetary boundaries: Rockström, J. (2020, October 15). *10 years to transform the future of humanity—or destabilize the planet* [Video]. YouTube. https://www.youtube.com/watch?v=8Sl28fkrozE
- A free online course to support learning about planetary boundaries theory: SDG Academy and EdX. (2023). *Planetary boundaries: Can our planet continue to support the current scope of human activity*. https://www.edx.org/course/planetary-boundaries?utm_medium=partner-marketing&utm_source=webpage&utm_campaign=sdgacademyx&utm_content=enroll_in_planetary_boundaries. SDG Academy and EdX.

- A description of the planetary boundaries model, along with links to research papers updating the theory with data: Stockholm Resilience Centre. [n.d]. *The nine planetary boundaries*. Stockholm University. https://www.stockholmresilience.org/research/planetary-boundaries/the-nine-planetary-boundaries.html

HL.c Environmental ethics

Definition of ethics

Ethics is the branch of philosophy that focuses on moral principles and what behaviours are deemed right and wrong. Different cultures, traditions and individuals often have ethical codes that they have developed or adopted from influences that surround them. These influences can range from formal ethical systems to religion, to family values, traditions, books, education, media and technology, one's own thinking and reflections, and more. Students and teachers should consider the influences on their ethical system, what value they attribute to the world, non-human organisms, humans and the ecosystems in it. They should also consider how to decide what is morally right or wrong when the value that they attribute to the world, non-human organisms, humans and ecosystems conflict.

For example, if starting a conservation project to protect an endangered species of plant will stop human activity in the area, is it ethically correct to implement the conservation project? It could be argued that the answer that teachers and students generate will be determined, at least in part, by whether they think the value of sustaining the endangered species of plant is greater, equal to or less than the value of the human activity.

Relevance of ethics to the ESS course

All ESS students are encouraged to think critically about how what they learn in the ESS course engages them and may affect their agency in the world. ESS students studying at HL will also think explicitly about the HL.c Environmental ethics lens and how ethical conclusions might be reached about content statements from the courese. These conclusions may form a student's own position on any particular statement or issue, but students should explore how a range of ethical conclusions could be arrived at by different individuals and by using different ethical approaches.

Students should also explore the relationship between humans and nature. To do this, they may want to think about what kind of value they think nature has.

Instrumental value	Intrinsic value
If something has instrumental value, then it has value for some reason other than what it is. This value tends to come, for example, from the use that something has for humans, or individual humans, or from its aesthetic beauty or the pleasure it gives to humans. When applied to the world (and everything in it), some people think that the world is valuable only because it is valuable **to** humans or non-human animals that exist in the world. It therefore tends to follow that if the world has instrumental value, then it can be used. Many who believe that the world has instrumental value may still think the world should be protected or sustained because it has value for something. For example, if the world has value because it is good **for** humans, then it should be preserved **for** humans. Others, though, might think that if the world is valuable only **for** humans, then	If something is thought to have intrinsic value, it means that it has value simply for what it is. The value of something does not come from any use, any aesthetic appeal or anything else. We can apply this to the world (and everything in it) because some believe the planet has intrinsic value: it is valuable in itself. It generally follows from this assumption that the world (and everything in it) should be protected and maintained for no other reason than that it is valuable.

Instrumental value	Intrinsic value
humans can use the world and the resources in it as they wish.	

While the inclusion of ethics as a lens allows students to reach and justify their ethical conclusions, there are some ethical conclusions that are more closely aligned to the current body of scientific knowledge than other ethical conclusions. As our scientific knowledge develops, different ethical conclusions may become more justifiable.

How to apply ethics to the ESS course

The guide and this TSM outline three general ethical approaches—virtue ethics, consequentialist ethics and rights-based ethics. However, there are many more formal systems of ethics that students and teachers could use. The aim of the HL ethics lens is to encourage students to think about, and reflect on, the range of ethical positions that might exist, and what reasons underpin the ethical conclusions. Opportunities throughout the course enable students and teachers to apply ethical approaches to ESS issues. Students do not need to be taught what their ethical stance should be; instead, they need to explore how ethical approaches can lead to conclusions about the issues. Examples provided in this TSM will identify how this can be achieved.

How can ethical approaches lead to understanding the world?

Students and teachers may find that their ethical principles and decision-making will fall into one or more of the three ethical approaches relating to the natural world.

The three ethical approaches are not mutually exclusive, and they are not necessarily contradictory. Students and teachers may find that their ethical conclusions on topics from the course are informed by elements of one, two or all the approaches.

Virtue ethics

Virtue ethics focuses on the character of the person doing the action. It assumes that good people will do good actions and bad people will do bad actions. A key debate within the virtue ethics approach is what virtues should be valued. If respect, compassion and responsibility are key virtues that are exhibited by ethical humans, then any environmental action that displays the virtues may be judged to be ethically correct.

Consequentialist ethics

Consequentialist ethics is the view that the consequences of an action determine the morality of the action.

In consequentialist ethics, actions with good consequences are good actions, and actions with bad consequences are bad actions. Morally good actions are those that result in the greatest common good. The intention of the action does not affect the morality of the action; it is simply a matter of the outcome.

The main area of debate within consequentialist ethics is how we decide what good or bad consequences are. Some ethicists argue that human happiness is the way to measure how good or bad consequences are. Therefore, they would conclude that behaviours that affect the natural world and increase human happiness are ethically good, and behaviours that affect the natural world and decrease human happiness are ethically bad.

Making ethical conclusions about the environment and determining whether the consequences are positive or negative is challenging. Our scientific understanding of nature changes over time. This may reveal initially “good” consequences to be “bad”, as our understanding of the impact of the consequences develops.

Rights-based (deontological) ethics

Rights-based ethics considers the rights that humans, non-human organisms and/or ecosystems could be said to have. Where those rights are protected or maintained, then an action could be said to be morally correct. If the rights are violated, then an action could be said to be morally incorrect or morally wrong.

There is disagreement about what the rights should be, and who or what has rights. For example, if only humans have rights, then actions that damage the ecosystem while maintaining human rights may be deemed to be ethically correct. In the same way, actions that damage the ecosystem and violate human rights may be deemed ethically incorrect. For others who believe that humans, non-human organisms and the ecosystem all have rights, it would follow that any kind of actions that violate the rights of humans, non-human organisms and/or the ecosystem would be morally wrong.

Conclusions

Conclusions reached by the different approaches might be the same, but they might be reached for different reasons. For example, the rights-based approach might lead to the conclusion that air pollution should not be increased because it is ethically wrong to pollute the atmosphere, because the atmosphere should be respected and maintained.

Students should reflect on why they hold the ethical views that they do; they should also know and understand why other people may reach alternative ethical conclusions. Students should also reflect on how the ethical conclusions that they reach should translate into behaviour regarding the natural world. They may discover that there is a discrepancy between their ethical conclusions and their behaviour; for example, many students may think increasing air pollution is ethically wrong, while at the same time contributing to it by using fossil-fuel transport methods. In these cases, students can explore why there might be discrepancies between their ethical conclusions and their behaviour, and whether ethical conclusions should lead to particular behaviours. These behaviours could be personal, individual behaviours or behaviours that engage in collective, community, political or international actions.

The “appeal to nature” fallacy

Often, people assume that what is natural is ethically good. The same people might also assume that what is unnatural or against nature is ethically bad. This might be a reasonable assumption to make, but students should consider and evaluate whether or not this is the case.

This assumption is relevant in that it could be an apparently good way to resolve ethical issues, because it seems to give clear criteria about how ethical conclusions are reached. For example, if deforesting destroys parts of nature and is unnatural, then it is ethically bad.

There are two considerations on which students and teachers should reflect.

1. What is considered natural is debatable. To extend the deforesting example, is it natural that humans deforest to create houses to live in? Or is this unnatural?
2. Humans might question the assumption that “what is natural is good” on the grounds that some things that seem natural do not seem good: disease, predation, drought or low food yields.

Environmental and social justice movements

There are some who compare the abuse of nature to social injustices against people from particular racial groups, genders and sexual orientations or people with disabilities. These parallels are drawn on the grounds that those who wield the most power in a society might perceive themselves, and people “like” them, as being superior to others who are different in some way. This mindset, it is argued, can be extended to nature and aspects of it. In this mindset, humans are considered superior to nature, or things in nature, and this attitude is used to justify all kinds of treatment of nature and things within it. Students might consider the extent to which these parallels are accurate.

Mohai et al. (2009), among others, also argue that environmental injustices may sometimes be based on economic inequality, socio-political exclusion and racial discrimination.

One avenue for further exploration is the notion of speciesism. This is the idea that humans discriminate against particular species. Some proponents of speciesism posit that it is morally wrong to discriminate on the grounds of species that an organism belongs to; others argue that speciesism itself is either a problematic concept or that such discrimination is justified.

Examples of how the ethics HL lens can be applied to the course content

Example 1
1.1 Perspectives Ethical perspectives vary across cultures and individuals. Students and teachers might want to explore what has influenced their ethical stance, and the degrees to which those influences have shaped their ethics. They might then consider why people have different ethical perspectives, and whether there are any particular ethics that they consider to be "more correct" than any other.

Example 2
2.1.13 Limiting factors on the growth of human populations have increasingly been eliminated, resulting in consequences for sustainability of ecosystems. The fact that human populations do not tend to be limited by environmental factors, and human activity can adversely affect ecosystems and the planet, might give rise to the ethical question about whether humans have an obligation to think about controlling or limiting the human population as a way to increase sustainability. Some rights-based (deontological) ethical approaches might hold the view that human life is more valuable than any other form of life and so human population growth should not be limited. Other rights-based ethical approaches might hold the opposing view because they value the ecosystem more than human life, hence reducing the human population to sustain the ecosystem could be ethically justifiable.

Example 3
2.1.23 Keystone species have a role in the sustainability of ecosystems. This raises the question about whether humans have an ethical responsibility to manage ecosystems or whether humans should leave ecosystems to manage themselves. For example, the Lebanese cedar has been subject to an IUCN programme, which has increased the number of trees in existence and also sustains the species that rely on them. Some may hold the ethical perspective that humans have no obligation to species other than the human species. Other ethical perspectives hold the view that humans do have an ethical responsibility to sustain and preserve other species. An alternative ethical perspective might be that humans have a responsibility to conserve species that are declining only as a result of human activity.

Example 4
2.2.19 Non-biodegradable pollutants are absorbed within microplastics, which increases their transmission in the food chain. One ethical view might be that humans have a responsibility to reduce the number of non-biodegradable pollutants that are released into the ecosystem and absorbed by other organisms. Advocates for rights-based ethics (deontologists), who believe that we have a duty to protect ecosystems, might hold this view simply because human pollution is bad and should be reduced; some might hold the view because they believe it is wrong to harm other organisms, and pollutants can harm other non-human organisms; some might hold the view because they believe it is always wrong to harm humans, and pollutants can re-enter humans through the food chain and cause harm. Consequentialists, who judge the ethical value of an action based on the consequences, might also think that non-biodegradable pollutants should be reduced because their absorption has negative consequences on the ecosystem, other organisms or humans.

Example 5
3.2.3 Invasive alien species can reduce local biodiversity by competing for limited resources, predation and introduction of diseases or parasites.

Example 5
Humans have introduced many alien species to local ecosystems (for example, the Asian tiger mosquito in Europe) (European Environment Agency, 2013). Some people may hold the ethical view that we have a duty to leave these alien species in their new environment because their lives have value. Other people might argue that humans have a duty to protect the local ecosystem and must therefore attempt to return it to the state it was in before the alien species was introduced. This can lead to attempts to kill or remove members of the alien species. Others might argue that only when the alien species has a detrimental effect on human health should humans attempt to kill or remove the alien species.

Example 6
5.2.7 The Green Revolution (also known as the Third Agricultural Revolution in the 1950s and 1960s) used breeding of high-yielding crop plants—combined with increased and improved irrigation systems, synthetic fertilizer and application of pesticides—to increase food security. It has been criticized for its sociocultural, economic and environmental consequences. While it might seem that greater food production and food security that results from the Green Revolution is ethically sound, some might hold the view that the harm caused to the ecosystems and organisms within them makes the Green Revolution ethically wrong.

Links to TOK

There are many links that can be made to TOK by teachers and students. The following list of questions is taken from the knowledge framework of the "The natural sciences" and "The human sciences" sections of the *Theory of knowledge guide.*

- Is science, or should it be, value-free?
- Should scientific research be subject to ethical constraints or is the pursuit of all scientific knowledge intrinsically worthwhile?
- Do we tend to exaggerate the objectivity of scientific facts and the subjectivity of moral values?
- In what ways have developments in science challenged long-held ethical values? Can moral disagreements be resolved with reference to empirical evidence?
- Do human rights exist in the same way that the laws of gravity exist?
- Do scientists or the societies in which scientists operate exert a greater influence on what is ethically acceptable in this area of knowledge?
- To what extent are the methods used in the human sciences limited by the ethical considerations involved in studying human beings?
- Do researchers have different ethical responsibilities when they are working with human subjects compared to when they are working with animals?
- What are the moral implications of possessing knowledge about human behaviour?
- Should key events in the historical development of the human sciences always be judged by the standards of their time?
- What values determine what counts as legitimate inquiry in the human sciences? Can knowledge be divorced from the values embedded in the process of creating it?
- Is the role of the human scientist only to describe what the case is or also to make judgements about what should be the case?

Resources

European Environment Agency. (2013, February 23). *Invasive alien species: a growing problem for environment and health*. European Environment Agency. Retrieved May 22, 2023, from https://www.eea.europa.eu/highlights/invasive-alien-species-a-growing

Folger, T. (2014). *The next green revolution*. National Geographic Magazine. Retrieved May 22, 2023, from https://www.nationalgeographic.com/foodfeatures/green-revolution/

Holley, D. M. (1993). Is God a utilitarian? *Religious studies*, *29*(1), 27–45. JSTOR.

Mohai, P., Pellow, D., Timmons Roberts, J. (2009). Environmental justice. *Annual Review of Environment and Resources, 34*, 405–430. https://doi.org/10.1146/annurev-environ-082508-094348

Pojman, L. P., Pojman, P., McShane, K. (Eds.). (2017). *Environmental ethics: Readings in theory and application* (7th ed.). Cengage Learning.

Real-world examples

A **real-world example** illustrates a more limited example of information tied to a specific time and place. These can be used within the classroom for learning and teaching.

Case studies seek to illustrate broader, overarching principles or theses. They are set out in the *Resource booklet*, which contains a spectrum of facts and figures about a specific geographical location. Students process and synthesize the information to aid their responses to the paper 1 examination questions.

There is, and always will be, a dynamic tension between curriculum depth and breadth for environmental systems and societies (ESS) teachers; each topic can become its own “rabbit hole”, providing endless and tempting opportunities to dig deeper into issues accessible through both scientific and social lenses. How much detail is enough? If we take more class time to dig deeper, what disservice does that do to other topics through the loss of those precious minutes? Real-world examples can help provide a good balance between each ESS topic’s guiding questions and the contextual details. The compelling examples will engage and focus students, and the limited events will connect with specific parts of the syllabus. Teachers can select examples, through the teaching of the course, that will embody most of the important learning and skills from each of the eight topics and, for higher level (HL) students, the three HL lenses.

Three categories of resources may be used to incorporate real-world examples into lessons.

1. Resources: the real-world examples are plentiful for both social and environmental science classes.
2. Teacher planning template: this helps teachers to select appropriate real-world examples and tie them into specific parts of the standard level (SL) and HL ESS syllabus.
3. Real-world example: Student summary template: this can be used to facilitate research, discussions, debates and projects based on these real-world examples.

Real-world example resources

This list is not exhaustive; more real-world examples can be found online.

Resource title and URL	Description
The EcoTipping Points Project *Models for success in a time of crisis* https://ecotippingpoints.com	A collection of 100+ new and older stories from all over the world. The site illustrates true and inspiring examples of local environmental crises that were turned around by the cooperative efforts of experts and local citizens to produce systems that are both environmentally and socially sustainable.
McGraw-Hill environmental science case studies library https://mheducation.com/highered/category.11360.environmental-science.html?page=1&sortby=relevance&order=desc&bu=he	A collection of examples written by university professors from all over the world, sorted (and cross-referenced) into “International” and “Regional (largely the USA)” categories. The stories can also be filtered by topic to connect quickly to a specific ESS lesson plan.
National Science Teaching Association (NSTA) *Case studies: Environmental science*	This is a subscription service (USD 25), but it has at least 100 stories. It is a valuable resource and some materials can be accessed without joining. Most stories are likely to focus on environmental science concepts rather than environmental justice concepts.

Resource title and URL	Description
https://nsta.org/case-studies/environmental-science	

Templates and examples

Templates and completed examples are provided to help teachers and students to move through the ESS course.

Real-world example: Teacher planning template

Real-world example: Teacher planning—Completed example

Real-world example: Student summary template

Real-world example: Student summary—Completed example

Technology and ESS

Overview

This section is intended to help teachers to develop their technological literacy in areas that will support the teaching of environmental systems and societies (ESS). The nature of technology dictates that there will be significant evolution in resources over time. Therefore, the teacher support material (TSM) has been structured to provide an overview of the different types of technology that may assist an ESS teacher. Discussions with other teachers in forums, and exploring online and in other formats for concrete examples are encouraged. The relevance of some of these materials may change or be lost over time. Use these sources and examples as a starting point for an ongoing evolution of support materials for the course.

Searching for rich multimedia resources

Twenty-first century teaching is multimedia-rich as a range of resources is utilized to engage multiple learning styles in the classroom. A variety of resource types, along with exemplars for content coverage, are available online that promote the acquisition of knowledge and understanding within the ESS course.

Searching for resources may not be as straightforward as it seems. Search engines have advanced search functions that allow for a more focused approach. For example, combining an ESS term, such as "sustainability", with the technology tool you are looking for, such as "online game", will yield more specific results.

Using key terms from the ESS course—such as "systems", "perspectives", "ethics", "biogeochemical cycles", "water access", "climate change"—will aid you in locating suitable technology-related resources. Teachers are encouraged to search for and use resources that best suit their needs and styles of teaching. The IB programme communities for ESS in My IB and IB Exchange may be useful platforms for sharing newly sourced or created technology-related resources.

While the types of technology are listed separately, different technologies can be used synergistically to enrich the learning experience. Some of the most frequently utilized technology-related resources used in the learning and teaching of ESS are documentaries and video clips containing animations, simulations and online games.

Table 4

ESS search terms

ESS terms	ESS tools terms	Technological process terms
Environment	Fieldwork	Animation
Sustainability	Case study	Simulation
Ecology	Survey	News aggregator
Biodiversity	Questionnaire	Graphic organizer
Climate change	Agency	App
Pollution	Assessment	QR code
Energy sources	Natural experiment	Online game
Food production	Observation	Crowdsourcing/crowd science
Freshwater	Demonstration	Interactive
Waste management	Laboratory	Database

By selecting a term or, for a more focused search, two or more terms from different columns in the table, search engines will present a range of current and relevant sites. For example, “pollution + animation”, “waste management + case study” or “environment + news aggregator” will lead to a wealth of valuable sites.

Teachers are encouraged to use the ideas in this section as a starting point for the ongoing evolution of teaching resources for the course.

An important feature of most technology resources is that they facilitate collaboration between teachers, students and the wider ESS community. Teachers should seek or develop resources that facilitate collaboration, or engage in building resource-sharing communities such as wikis, blogs or social media sites themselves.

Note that free online translation resources have improved over time, allowing for resources produced online in one language to be translated to other languages with much greater ease and accuracy. Google Translate and DeepL Translate, for more technical language translation, may also be useful also be useful to get an initial basic translation.

Teaching strategies

Finding a balance between virtual and in-class teaching strategies will ensure the diverse needs of learners are met. In-class teaching strategies for developing knowledge and skills in environmental values systems, while allowing for face-to-face discussion, dialogue and debate, may include the three-card strategy, role-play, the four corner debate and the fishbowl debate.

Governmental and non-governmental agencies connected to ESS

Familiarity with some key governmental and non-governmental agencies connected to ESS is required learning for the course. The websites in table 5 often have a wealth of information related to conservation efforts and may facilitate students’ holistic understanding of the various stakeholders involved in ESS-related issues.

Table 5

Governmental and non-governmental agencies connected to ESS

Governmental organizations	Non-governmental organizations
United Nations Educational, Scientific and Cultural Organization (UNESCO) https://en.unesco.org/	World Wide Fund for Nature (WWF) http://wwf.panda.org/
United Nations Environment Programme (UNEP) www.unep.org/	International Union for Conservation of Nature (IUCN) http://iucn.org/
World Meteorological Organization (WMO) https://public.wmo.int/en	Greenpeace http://greenpeace.org/international/en/
StatPlanet World Bank—Open Data https://data.worldbank.org/	Sea Shepherd Conservation Society http://seashepherd.org/

General resources

Documentaries and video clips

The ESS subject area has inspired a collection of rich resources, from feature-length award-winning documentaries, to TED Talks and online video resources. The purpose of these media should encourage the development of critical-thinking skills and provide opportunities for dialogue after utilizing the media. Consider learning and teaching strategies, such as a **fishbowl**, or a **four corner debate** for particularly controversial topic areas, to provide opportunities for students to develop skills in communication and collaboration.

Games and simulations

Numerous ESS-related games and simulations are available to assist in reinforcing certain topics within the course. Online games and simulations allow for the manipulation of variables, and act as useful learning tools when principles are applied authentically.

Simulations are particularly useful in science learning and teaching. They increase both the interactivity in the classroom and student enjoyment. Simulations allow for the:

- illustration of situations that would be difficult or impossible to create in reality because of cost, risk or location
- illustration of situations that would be impossible to visualize otherwise owing to the size of the objects or nature of the forces involved
- illustration of situations in a manageable time frame for classroom teaching
- students to interact directly with the data; simulations give students the opportunity to alter a variable and instantaneously determine the result
- acquisition of knowledge and understanding in lesson content, and serve as a building block to inspire internal assessment questions for further research.

Maps and models of the planet

An intrinsic aspect of the ESS course is that issues are examined locally and connected globally. The use of models of the planet and maps facilitate the acquisition of knowledge and understanding for these issues. The globe is an excellent example of a model that has evolved through time.

Massive open online courses (MOOCs)

In terms of providing differentiated instruction, it may be helpful to students to ensure that resources are available for the extension of learning. There is a rapidly growing list of university courses available online and that are free of charge for the curious to explore.

News media outlets

Many media outlets contain publication segments specifically dedicated to environment-related news. These are updated regularly and will often contain connections to the ESS syllabus content; making these real-world connections to current events assists in engaging students in the ESS course. Utilizing news articles and videos may also enrich students' development of international-mindedness as it relates to the subject. Consider exploring local media resources as well, then encourage students to use their critical-analysis skills to connect their local knowledge to events of global importance.

Utilizing different media outlets to compare the same issue may allow students to explore the variety of environmental values systems that exist as a fundamental part of the course structure.

Online activities with downloadable notes

A range of online resources is available that educators have prepared and shared. Take some time to research relevant resources and select the ones most appropriate for learning and teaching in ESS; this may save valuable time.

Online footprint calculators

Provide opportunities for students to engage directly with, and manipulate, resources to reinforce their learning. Footprint calculators (ecological, water or carbon) are powerful tools to support learning around the concepts of resource use, sustainability, water access and climate change. Note that footprint calculators are also potential tools for methodologies for internal assessment data collection. These often vary in quality and appropriateness, depending upon the region of the world in which the course takes place.

Presentation and collaborative communication tools

The ESS course provides numerous opportunities for the development of presentation skills, independently or collaboratively as a group. Empower students to select the platform for their presentation.

QR codes

Quick response (QR) codes can be used for a variety of reasons.

- They can turn an everyday object into a "smart" object. QR codes can be created, printed and placed on everyday objects, providing access to potentially large amounts of data or multimedia information in the form of videos or podcasts.
- They can guide students through a field trip or scavenger hunt virtually, by using periodic QR code placements.
- They can be placed in or on printed material, such as textbooks or study notes, to incorporate a virtual link to a media resource or revision source for study and reinforcement.

Satellite and photographic imagery

Through the ESS course, the IB encourages students to develop a global perspective and to see the connections between societies and their environment. Modern technology, such as satellite imagery, may assist in this endeavour.

Resources for internal assessment

The internal assessment component of ESS requires that an environmental issue be investigated and considered with respect to its connection to society. A wide variety of methodologies may be employed for this investigation, including surveys or questionnaires, interviews, fieldwork, field manipulation experiments, ecosystem modelling, laboratory work, secondary demographics, development or environmental data and the use of qualitative and quantitative observations. Along with these methodologies, analytical techniques may also be employed.

Primary data collection

Databases

ESS teachers and students are encouraged to access the extensive websites and databases of international organizations and bodies to enhance their appreciation of the international dimension of ESS issues.

Data loggers, probes, sensors and test kits

Data loggers and sensors can be used to collect and process quantitative data for environmental variables such as temperature, pH, dissolved oxygen or light intensity. They augment traditional laboratory or fieldwork studies because they can:

- collect large amounts of data
- collect data out in the field remotely
- collect data over long periods of time.

The software provided will allow rapid processing of collected raw data. While data loggers can expand the possibilities for scientific investigations, note that there is no requirement from the IB for schools to purchase data-logging solutions for the completion of practical work.

Smartphone applications

The smartphone is now a ubiquitous tool. It can host a wealth of free and easily downloadable applications (apps) that turn a communication tool into a tool for investigation, research and reporting, both in and out of the classroom. Examples of such apps include light and noise meters, apps for identifying plants and apps that measure the percentage cover of a quadrat or canopy.

Survey work

The interdisciplinary nature of the course requires that students explore the societal connections to environmental issues. The internal assessment provides further opportunity for these connections to be made. Surveys, questionnaires, interviews and crowdsourced data provide some of the most likely methodologies for these types of study. Websites are available that can assist teachers and students with the construction and use of online surveys, as well as provide advice about good practice when conducting survey work.

Students should seek out information on how to design a survey. Using a five- to seven-point Likert scale within a question is considered to be a reliable form of data collection within a survey. If using an open-ended question, a cluster analysis or a bucketing technique may be used for the data generated. Google Forms, or a similar system, could be used to create a survey.

Overview

Practical work is an important aspect of the environmental systems and societies (ESS) course. During the course, 50 hours are allocated for the experimental programme, which comprises 30 hours of practical work, 10 hours for the collaborative sciences project and 10 hours for the individual investigation (internal assessment). Teachers need to complete the *Record of experimental programme* to show where students have spent their time across the three components.

Practical work in the *Environmental systems and societies guide* not only directly requires the use of field techniques, but many components can only be covered effectively through this approach. Practical work in ESS is an opportunity for students to gain and develop skills and techniques beyond the requirements of the assessment model, and should be fully integrated with the teaching of the course. Teachers should plan out a range of practical activities that will reflect the breadth and depth of the content and the interdisciplinary nature of the types of activities available within the school context.

Practical work

Although the requirements for internal assessment are centred on the investigation, students are required to take part in an experimental programme that accounts for 30 hours of lesson time. The 30 hours are in addition to the 10 hours prescribed for the individual investigation (internal assessment task) and 10 hours for the collaborative sciences project.

The different types of practical activities serve a variety of purposes and may include:

- developing an appreciation of:
  - the essential hands-on nature of laboratory and fieldwork
  - the use of secondary data from databases
  - the use of modelling and simulations
  - surveys and questionnaires
  - the benefits and limitations of a range of investigative methodology.
- illustrating and reinforcing theoretical concepts
- selecting and demonstrating the use of appropriate methodologies and skills
- carrying out ethical investigations into environmental issues.

The record of experimental programme

The *Record of experimental programme* is an essential planning and recording document for teachers to ensure that a suitable range of practical activities is carried out and that the appropriate hours are allocated. It encompasses the practical activities, collaborative sciences project and the individual investigation.

It is not necessary to submit this form to the IB. Teachers should continue to maintain this form (or their own version of it, including all the same information) to record the practical activities carried out by the class. The form should be retained in the school and made available to the IB, for example, during the five-year school evaluation process.

Syllabus coverage

The range of practical work carried out should reflect the breadth and depth of the subject syllabus and the skills. It is not necessary to carry out an investigation for every syllabus topic. All students must participate in the individual investigation and collaborative sciences project.

Planning the experimental programme

Teachers design their own experimental programme that supports the learning and teaching of ESS. Their choices should be based on the needs of their students, available resources, and preferred learning and teaching styles.

Each experimental programme must include complex tasks that make conceptual demands on students. Given the aims and objectives of this course, students should be provided with opportunities to carry out investigations that demonstrate the interrelationships between environmental and social systems. An experimental programme that consists only of simple experiments will not provide an adequate range of experience for students.

Teachers are encouraged to use My IB programme communities, IB Exchange and other platforms to share ideas and resources for possible activities and to contribute to discussion forums.

Flexibility

The experimental programme should allow for a wide variety of activities to be carried out. These could include the following.

- Laboratory-based manipulation practical activities/exercises: projects extending over several weeks, done at home or at school.
- A variety of technologies, such as mobile phone apps, digital probes, computer modelling and online calculators, to determine sustainability footprints.
- Secondary data collection using databases, remote sensing and satellite data.
- The development and use of models and simulations, such as mesocosms, modelling cycles (both hands-on and virtually) and online soil sampling.
- Data-gathering exercises, such as questionnaires, opinion polls, interviews and surveys.
- Data-analysis exercises from photos and teacher-presented data.
- Fieldwork, undertaken locally or on a trip—this can include observation or manipulation field studies on the school campus, close to students' homes, or on a school or family trip.

It is vital that the range of tasks undertaken reflects the interdisciplinary nature of this course. Through a balanced and varied experimental programme, students should be able to experience tasks that focus on laboratory or fieldwork, as well as more value-based investigations.

The experimental programme prepared by the teacher should provide students with a range of opportunities to develop skills in a variety of types of practical activities so that they are well prepared for developing and carrying out the individual investigation for the internal assessment.

Practical activities generate both qualitative and quantitative data, and it is important that students are aware of the issues surrounding the collection of meaningful data and the presentation of analysed results. See the "Skills in the study of environmental systems and societies" section within the guide for guidance on the experimental techniques, technology, mathematics, and systems and models that students should be exposed to over the course.

Collaborative sciences project

Full details of the requirements are in the *Collaborative sciences project guide*.

Individual investigation

The internal assessment task involves the design, implementation and completion of an individual investigation of an environmental systems and societies (ESS) research question. The investigation is submitted as a written report.

The individual investigation consists of:

- establishing a local or global environmental issue and developing a research question to investigate from this issue
- understanding how tensions between perspectives can impact the outcomes of a strategy addressing the issue
- developing methodologies to generate data that are analysed to produce and inform knowledge and understanding of the issue.

The study could be carried out at a local, regional or global level. It is possible for the student to identify a global issue, to carry out a related study on a local scale and then consider how their findings relate to the bigger issue. It is also possible to identify a global issue and then to carry out a small-scale study of one aspect of that global problem using secondary data that is available through databases or other secondary sources. A third possibility is that the student uses a local issue as the basis of their focused study, since not all authentic environmental problems are global in nature. Students should be encouraged to ask questions to develop approaches and techniques to formulating questions throughout the course.

The research question

A relevant and focused research question should arise from a local or global area of environmental interest (the issue).

- Least developed countries' (LDCs) governments argue that they cannot be asked to bear the brunt of protecting the environment by limiting the development of their natural resources owing to concerns about the environment; for example, deforestation in Southeast Asia for palm oil or in the Amazon basin for industrial cattle range. These examples illustrate the tension between national economies and global environmental sustainability.
- Reintroduction of locally extinct apex predators to restore ecological balance has an impact on ranchers concerned about livestock losses; for example, wolves in Wyoming, USA. This illustrates the tension between regeneration and rewilding, and maintenance of local livelihoods.
- As human communities expand and encroach on the habitats of animals, different groups need to make use of the same space; for example, tigers entering villages, and villagers—who fear attacks—pre-emptively killing the tigers. This illustrates the tension between the protection of tigers and wild areas versus human community safety.
- Pesticides are used to control herbivorous insects to maximize crop yields. However, this has an adverse impact on non-target organisms; for example, the effect that neonicotinoids—pesticides—have on the learning and memory capacity of honeybees. This illustrates the tension between local livelihoods and environmental pollution.

Strategy

Students describe an existing or developing strategy and then discuss the tensions that different perspectives have with that strategy. It is not appropriate for students to devise their own strategy. The strategy does not have to be in direct relation to their investigation, but it must have a connection to the research question. It is intended that the strategy criterion will allow students to show personal engagement with the issue.

For example, if a student carries out a study on the environmental issue of climate change and looks at the efficiency of wind turbines, the strategy could be building more wind turbines at their school. However, the building of wind turbines locally may create tensions between the different perspectives within the local community. The student will discuss at least one tension that could have been, or has been, created.

Interdisciplinarity and the individual investigation

The investigation produced may draw on methodologies and analytical techniques used in either experimental or human science studies, thereby reflecting the interdisciplinary nature of ESS. The section "Skills in the study of environmental systems and societies" in the *Environmental systems and societies guide* has a range of prescribed experimental techniques, digital technology and mathematical skills that students should be exposed to over the course.

Accompanying these prescribed skills is a range of methodologies and analytical techniques that could be explored. These are listed in "Introduction">"The ESS course">"Skills" section. Other suggestions can be found within the syllabus (application of skills).

Guiding the individual investigation

Supporting the individual investigation requires forethought and planning. The optimal strategy depends on school-based considerations. Key factors to consider include:

- the number of students in the class
- the availability of technical support staff
- access to fieldwork opportunities
- the availability of apparatus and materials
- the access to technology.

School timing

Teachers are free to decide which stage of the course is appropriate for carrying out the individual investigation and whether or not students' individual investigations should be carried out simultaneously or staggered within a class. Considerations for scheduling the individual investigation include the following.

- Introduce the aims of the individual investigation early in the course so that students can identify areas of interest. The teacher can flag up possible productive areas of study as students progress through the course.
- When will the key concepts and prescribed skills be addressed? They should be introduced at appropriate times to provide students with sufficient opportunity to formulate and investigate a diverse range of feasible research questions.
- Are the available materials and human resources sufficient for all students in the class to undertake the individual investigation, either simultaneously or staggered?
- Does the scheduling of other Diploma Programme (DP) assessment tasks within the school enable students to give sufficient attention and time to the individual investigation?
- How much time will be needed for internal moderation between ESS teachers?
- When are the deadlines for the submission of the internal assessment marks and the compiling of the sample?

Student timing

To support students, and to make limited resources available, it is acceptable for students to carry out their individual investigations at different times. This means that some may be doing their individual investigation while the rest of the class is taking part in other learning activities.

Where all students carry out their data collection simultaneously, the following recommendations may help.

- Ensure students submit detailed requirements for materials in good time.
- Encourage students to address a wide range of research topics and approaches.
- Provide sufficient opportunities for students to develop skills in the use of technology and secondary data so that a range of investigations may be carried out.
- Emphasize to students that sophisticated concepts can be meaningfully investigated with simple equipment and methodology.

Teachers need to ensure the authenticity of work submitted for assessment. Sufficient measures should be put in place to ensure the authenticity of the investigation. This includes supervision of the ongoing investigation and requesting drafts of the report at regular intervals. Other strategies may include asking students to provide photographic evidence of fieldwork or screenshots of simulations used.

Initial planning

The initial planning is crucial to the successful outcome of the individual investigation. It is at this stage that the teacher will guide the student as to the appropriateness of the research question. This will include ensuring that the level of complexity is commensurate with the level of the course and compatible with the assessment criteria. Teachers can suggest possible environmental issues, and develop approaches and techniques to formulating questions, but cannot allocate specific research questions to study.

It might, however, be useful to have introduced the aims of the individual investigation early in the course so that students can identify areas of interest. The teacher can identify possible productive areas of study as students progress through the course.

Teachers should positively encourage students to explore a range of options available to them, and pursue an environmental issue, a research question and a strategy that engage their interest. Students should consider which methodology is most appropriate to explore their issue. This may include the use of surveys, case studies, fieldwork, experimental work, secondary sources such as databases and simulations, or possibly a hybrid of all these approaches.

Generating data

ESS investigations use a broad variety of techniques in collecting data, including but not limited to experimental work, fieldwork, secondary data mining, simulations, online calculators, mapping, surveys, questionnaires, interviews, observations, note-taking, audio and visual recordings, and collecting censuses.

The type of data collected should be determined by the research question posed and the environmental issue addressed. The methods and techniques of data collection and data processing need to be explored in relation to the type of data—quantitative and/or qualitative.

The individual investigation may consist of both appropriate quantitative and qualitative data.

Quantitative data and qualitative data

Quantitative data is collected through measurement and may be processed using statistical and other techniques. The focus is on numbers, and the data can be displayed through tables, graphs and maps.

Qualitative data is collected through observation and subjective judgement; it is non-numerical and does not involve measurement. Qualitative data may be processed, coded or quantified, where appropriate, or it may be presented through images or as text. Students are advised to remember the word limit when presenting qualitative information as text only.

Most students try to convert qualitative data into quantitative data to help answer their research question. Some qualitative data can be used to set the scene for the quantitative data collection; for example, the weather on the day of fieldwork data gathering.

The data collected must provide sufficient information to enable adequate interpretation, analysis and conclusions drawn from the data as they connect with the research question.

A range of methodologies may be used when collecting qualitative data.

- Observation (participant or non-participant)
- Interviews (unstructured, semi-structured or structured)
- Questionnaires/surveys
- Visual media (photography, film, multimedia, material culture)

Table 6 summarizes a range of approaches to collecting qualitative data, together with their inherent strengths and weaknesses.

Table 6

Strengths and weaknesses of qualitative data collection methods

Method	Description	Strength	Weakness	Example of use in ESS
Non-participant observation	The student observes but is not participating. The student is physically removed from the activity and is only watching.	Can focus and take notes Can review and add to notes Can be detailed observation Easy to get informed consent if people are involved One person's consistent interpretation Unaltered data Can capture unplanned action/speech Tries to capture reality as it is Can compare observations reasonably objectively	Hard to write everything down Cannot ask questions People often do not like being watched Cannot watch everything at once Does not always know why/what something means and can misinterpret meaning Awareness of own biases Time-consuming People may act differently when they are being observed Takes time to understand and compare	Attending a public inquiry for an environmental impact assessment (EIA) and observing the people attending Watching news reports of a climate march Observing environmental hazards and vulnerability in different parts of a city Observing animal behaviour around an environmental hazard, such as an oil spill or an industrial outflow pipe
Participant observation	The student fully participates in the activity.	Insider perspective; full immersion More in-depth relationships/context Lived experience; better understanding Builds more trust	Introduces personal bias; biased by your particular role participating in the activity Influences the activity by getting involved Cannot objectively gather data People may act differently when they are being observed	Attending a community meeting about the proposed new conservation area in their town Observing their neighbourhood for environmental risks How their family uses water and energy

Method	Description	Strength	Weakness	Example of use in ESS
			Could offend others by doing things wrong	
Interviews	The student asks questions: • to one person or a group of people • either in formally structured, semi-structured, or unstructured ways • that are open or closed • to produce more quantitative or qualitative data.	Able to ask customized questions Allows clarification and follow-up questions Able to have one-to-one conversations Reliable answers from the person asked Able to get qualitative data about how, why, thoughts, feelings, explanations and motivations More detailed answers; in-depth, insider perspective Can bring up new ideas	People lie or do not know Time-consuming Possible language barriers or miscommunication Relies on trust It is very difficult to record everything someone says, and awkward to try, but can use a recording device It is easy to ask leading questions	Asking for people's response to the adoption of the new water conservation laws in their town/ area Interviewing farmers about fertilizer usage and water sports people about algae blooms
Questionnaire/ survey	The student asks a large number of people a set of questions, which may include set answers to choose from.	A lot of responses Able to get quantitative data (from closed questions), as well as qualitative data (from open questions) Questions are standardized and generalizable A wide range of personal opinions Answers in their own words, not the student's interpretation The student does not have to be present The student gets answers to their specific questions The student can compare their perspective with the respondents'.	Questions may be too generic Self-reporting may be inherently flawed; people may not remember or may inaccurately record events Cannot ask for clarification Responses are not detailed Not ideal for controversial or confusing issues Inflexible design The questions could be inappropriate if you do not have enough perspective	Questions on people's opinions and their willingness to make lifestyle changes about climate adaptations or mitigation Asking about people's values and ethics on solid domestic waste

Method	Description	Strength	Weakness	Example of use in ESS
Visual	The student collects visual records through photographs and videos. The student creates visual displays of opinions or perspectives.	Easy task to do Easy to explain what you want Does not miss any details and is accurate Best for material culture and space Enables others to see what you did Ability to see context Visual material can help with your memory of events Interesting to look at (often more interesting than words)	Photographs cannot capture conversation or actions Can forget what you heard in that moment because you cannot write notes (while taking photographs) Only captures one frame/perspective; may lack context Does not give insider knowledge Could lead to mistaken assumptions	Before and after pictures of pollution events Colour changes for test kits, such as tropospheric ozone-detecting strips Heat map of opinions Visual storytelling of an environmental event A Leopold matrix for a local EIA, colour coded for high, medium, low impact

Data visualization techniques for qualitative data are varied and can include: pie chart, bar chart, histogram, Gantt chart, heat map, box and whisker plot, waterfall chart, area chart, scatter plot, pictogram, timeline, highlight table, bullet graph, choropleth map, word cloud, network diagram and correlation matrices.

Designing to collect sufficient data

Data collected for the individual investigation should be commensurate with the 10 hours' work required for the individual investigation. There is no single standard for determining that data collected in an investigation is insufficient: some ESS investigations will generate data more quickly than others. Guidance to students is necessary, especially at the outset of the individual investigation.

The amount of data collected through a methodology will be determined by the nature of the investigation and the time available. The number of repeats should be selected with a clear rationale to collect sufficient data to draw a conclusion that answers the research question.

Qualitative data should be collected as and where appropriate. It can add richness to most types of investigation, provide information where quantitative data is not available or is beyond the scope of an individual investigation, and provide information about the normal variation in the data collected.

For example, a germination investigation will, generally, gather data more quickly than a decomposition investigation. Secondary data from an air quality database will generate data more quickly than fieldwork to collect air quality data, such as a lichen survey or tropospheric ozone variations in urban areas. Surveys done within a school environment will generate data more quickly than surveys undertaken with the general public.

Students should cross-check the minimum data required for data processing as they develop their method. The research question, together with the method chosen to process the collected data, can determine the amount of data required; for example, correlation statistics usually need 30+ samples.

It is strongly recommended that students consider the appropriateness, and the amount of data, as it is being collected. Processing while collecting data may help the student identify possible issues. This allows them to modify the range, interval or frequencies, as well as collect additional data. Science and social science protocols for data collection often involve a pilot study. Here, the procedure, survey questions and other techniques can be tested out to identify problem areas, or missing and extraneous steps.

For example, students could:

- carry out a pilot study that tests the viability of a batch of seeds prior to carrying out a full-scale germination-based investigation
- ask a small group of people to take a survey to check:
  - issues of understanding
  - how to answer the questions
  - whether answers address the topic that is being explored
- test a chosen random strategy for mining databases or for locating a sample site in the field
- test probes, after calibration, with control samples to establish a baseline set of data.

The report should be an account of what happened—which may not turn out as initially planned. The report should include details of the problems encountered when collecting data. It should also describe issues faced during trials and how the student responded to them. One possibility is that a potentially feasible investigation fails to provide enough data, through no fault or inexperience of the student. The data may be rough and possibly inconclusive. A degree of student adaptability is expected, and an adaptation method should be included in the method.

Sufficient data is necessary to carry out adequate processing. Interpreting the results and arriving at a conclusion will require care and attention. For example, standard deviations need to have sample sizes of five or more. For an effective t-test, at least 10 replicates are needed. Meanwhile, for the standard error of the mean, 30 or more replicates is considered sufficient. Nevertheless, it is still possible to have fewer replicates and express variation as a range.

Hybrid investigations combining some primary data with secondary data from a simulation or a database allow for the rapid collection of data. For example, the student could carry out a germination experiment and then access growth data from a database.

How does the amount of data collected impact other criteria?

Insufficient data will impact the type of data processing that can be carried out and may lead to issues when considering the reliability, validity and uncertainties, which may subsequently impact students' marks.

If, through no fault of the student, the data are insufficient, the only viable processing may be to calculate the mean and the range. This is straightforward and can include a test of significance. If the processing carried out is commensurate with the level expected to address the research question, there should be no reason why the work would not achieve the highest marks available.

Insufficient data may impact the analysis, conclusion and the evaluation of the investigation. Here, it is important to look for evidence that the student is aware that the amount of data is limiting the conclusion. Note that if the amount of data is limited, then the processing may also be limited, and the interpretation may be impacted too. It is important that the teacher counsels the student to follow a process that will be productive with the time and materials available. If there is no good reason why more data could not have been collected, the mark for data analysis may be impacted.

If the data are more plentiful, standard deviation or standard error may be included. Investigations with more data or larger data sets may inherently reveal a larger number of flaws in processing. In these cases, carefully consider the student's approach rather than penalizing small errors in the processing. Large errors in processing, however, will influence interpretation and the conclusion. Errors carried forward may be applied.

Students should be guided in how to determine anomalous data and justify how and why it is removed from data processing. This is important when large data sets are produced, as anomalous data is more likely to appear. For example, if some seeds do not germinate then the "zero" data should not be included in the mean. The non-germinated seeds could be non-viable, and a viability test of the expected germination percentage should be considered. If the percentage of zeros in a treatment is higher than the viability test, then this pattern can be commented upon. If the percentage of zeros is lower than the viability test, then the zero data should not be used in the data processing.

Using databases and simulations

The candidate must explain how and why the specific simulation was used, and the methodology for collecting data. The criteria will apply consistently across all methodologies. The source of the data needs to be identified clearly, its reliability and validity needs to be established, and its sufficiency and relevance to answering the research question should be considered. Students using databases and simulations should provide the necessary screenshots, including web addresses or the program name, to clearly demonstrate appropriate data collection and manipulation in support of their methodology. Databases and simulations that are free or behind paywalls are acceptable.

Students using databases and simulations should provide the necessary screenshots, including web addresses or program name, to clearly demonstrate appropriate data collection and manipulation in support of their methodology.

It is expected that data should be collected from more than one database to facilitate sufficient treatment of the research question. If this is not possible, an explanation should be provided. Students will need to explain how the data sampling is controlled, extracted or filtered. They should explain their selection and the decisions taken for extracting data. They should also consider using a series of screenshots to illustrate the methodology.

Investigations based on tables found in published articles are rarely suitable, as the authors have often already made decisions that the students themselves should make.

Students should be discouraged from using simulations that result in obtaining the same value each time. In this case, the student can use additional simulations or databases to gather enough data to answer the research question. Typically, in ESS, data can be extracted that is both historical and geographical in nature.

Investigations based on computational analysis should use tools that calculate properties accurately, rather than those limited to visual representations—unless these can be converted into data that can be processed. For example, colour saturation can be awarded a numerical value.

Databases that show field data can be used for ESS. The method needs to focus on the database use rather than the original field data collection protocols.

Using photos, online images, satellite data and maps

Data can be extracted from images, often allowing a large amount of field data to be collected quickly. Image data can then be processed later, away from the field.

Smartphone cameras, cameras and online streaming stills/screenshots can be used. Referencing of the images should be made clear, including students' own images.

For example, diversity quadrats can be placed and photos taken at a determined height. Individual plants can be photographed for identification (using a book, key or an online plant identification app). This allows more field data to be collected in a short time frame. Processing the quadrat data, from an image on a computer, can be done rapidly in a spreadsheet.

Examples of image data are smartphone photos, camera traps, live-streaming videos, Google Earth/Google Timelapse, drone photos, aerial photos, satellite images and both online and paper maps.

Students need to explain how the data sampling is controlled and how it is extracted or filtered. They should explain their selection and the decisions taken for extracting data from the image.

The amount of data will depend upon the data processing and analysis required to answer the research question.

Using surveys and questionnaires

Surveys and questionnaires need to collect enough data to be considered statistically valid. The survey/questionnaire should be designed in a way that is consistent with the type of data processing that will follow.

Often, general questions address population demographics. One question can relate to the independent variable, and the subsequent questions may act as controlled or possible confounding variables. These can often be asked in the pilot survey to help finalize the final survey parameters.

Survey and questionnaire response rates are varied; typically, a 20–30% response rate is considered good. The student should allow for this type of response rate when considering the minimum data that is required.

Many statistical tools used with survey data indicate 30 data points or more to provide an outcome with a higher confidence interval/level.

The collection of 30 data points should be applied to each variation of the independent variable. For example, when considering age cohorts, each cohort should have 30 data points. This constraint will guide the student in determining how many cohorts should be in the method.

Descriptive data processing includes frequency, percentage, measures of central tendency and dispersion. Inferential statistics includes t-tests, chi-squared tests, analyses of variance (ANOVA), correlation and regression.

Writing the report

On completion of the investigation, students should be briefed on the final requirements of the written report. It is good practice during class to:

- revisit the assessment criteria
- remind students that the report should not exceed 3,000 words in length
- set an interim deadline for submission of the full draft
- set a deadline for providing teacher feedback
- set a final deadline for the final version.

The report should include sufficient detail for the investigation to be replicated independently.

Once the full draft is submitted, the teacher is permitted to make **general** comments and annotations regarding its overall strengths and weaknesses, but these should **not** be corrections. The work can then be handed back so that the student may produce the final version.

The decision on how to structure the internal assessment report is the student's responsibility. The IB offers no guidelines here, except that the report should be clear, concise and focused, and should demonstrate relevant scientific or social science skills. A cover page and a table of contents are not required. A clear and informative title reflecting the research question and inquiry should inform the reader what the investigation is about.

There is no fixed style for presenting the method. Both prose and numbered steps are acceptable. The use of the passive voice or a personal style should not impact the marks given; neither should errors of expression, spelling and grammar, unless these result in ambiguity, contradictions or incomprehensible content. The structure, scientific relevance and conciseness of the report are more important than the language used. This is particularly important considering that many students may not be writing in their preferred language.

Assessment is always based on evidence found in the report, and this evidence needs to be clearly communicated in scientific and/or social science terms. Effective communication is not a criterion on its own; it is an essential part of all six criteria.

Effective communication is:

- necessary for the research question and inquiry criterion; the explanation of the background research for the environmental issue, and how this addresses the research question, needs to be communicated clearly
- explicit in the strategy criterion; the discussion of tension between perspectives needs to be researched and articulated in a balanced way
- explicit in the method criterion; students need to communicate the methodology (the purpose and practice) and the collection of sufficient data for their investigation
- an aspect of the treatment of data criterion; the presenting and processing of data should be clear, precise and accurate, given the research question

- implicit in the analysis and conclusion, and evaluation criteria; an answer to the research question must be discussed and evidence of an evaluation expressed.

The report should not exceed 3,000 words in length. The word count does not include data tables, sketches, graphs, headings, references or bibliographies. Where a large amount of data has been collected, only a sample of the data should be included.

The presentation of scientific names should use the recognized conventions: in italics and with the correct use of case in letters, for example, *Homo sapiens*.

The International System of Units (SI units) should be used for quantitative data, with the units chosen fit for purpose; for example, growth data is recorded in days or weeks rather than seconds. Non-metric units should not be used; conversion tables from cups or imperial measurements can easily be found.

The treatment of data needs to be precise; this includes appropriate annotation/labelling of graphs and tables, and the use of units, decimal places and significant figures.

The data processing should be easy to follow and can be checked by the teacher.

Data tables and graphs need to be large enough to read and interpret. The type of graphs or presentation of the processed data should be appropriate for the data collected.

Citations, bibliographies and academic integrity

If the student is quoting broadly accepted facts or theories, citations are generally not needed. However, if a precise fact is quoted, a citation would be expected. For example, the fact that precipitation has a typical pH of 5.6 can be considered general knowledge, but the fact that acidic precipitation in a stated location can have a specific pH would require a citation.

Citations can be in-text, in footnotes on each page, in endnotes or written as references in a bibliography. The citations should allow sources to be traced, for example, through the URL and retrieval dates for online sources. They should also be limited to sources that have been used in the investigation, either for ideas, content quoted or images copied. The style of citation is up to the student, but they should follow a clear and consistent method of referencing. The bibliography can be used to record the full reference details.

Academic integrity is important to International Baccalaureate (IB) educational philosophy and, indeed, to any academic pursuit. When writing their reports, the students must clearly distinguish between their words or ideas and those of others.

If a teacher believes some of the report's content may have been taken from a source without adequate citations, this may be a case of malpractice. The teacher must discuss this with the student, to clarify how and why the content came to be presented in the report.

All work submitted to the IB for moderation must be authenticated by a teacher and must not include any known instances of suspected or confirmed academic misconduct. Each student must confirm that the work is their authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work, it cannot be retracted. The requirement to confirm the authenticity of the work applies to that of all students, not just the individual investigation to be submitted to the IB for the purpose of moderation. For further details, refer to the IB publications *Academic honesty*, *The Diploma Programme: From principles into practice* and the relevant general regulations (in *Diploma Programme Assessment procedures*).

Authenticity may be checked by discussion with the student on the content of the work, and scrutiny of one or more of the following.

- The student's initial proposal
- The first draft of the written work
- The references cited
- The style of writing compared with work known to be that of the student
- The analysis of the work by a web-based plagiarism detection service, such as www.turnitin.com

The same piece of work cannot be submitted to meet the requirements of both the internal assessment and the extended essay.

If an examiner is not satisfied that the report is the candidate's own work, the IB will instigate an inquiry on academic misconduct.

For further guidance, refer to the IB's *Academic integrity policy* (IBO, 2019, updated 2023) and *Effective citing and referencing* (IBO, 2022).

Appendices

Appendices are not necessary and will not be read by the examiner. All information of relevance to the investigation must be presented within the report.

A blank consent form for student participation in data collection (demonstration of ethical practice) should be included in the appendices. Students should design their own consent form.

Unpacking the internal assessment criteria

Assessing the report

Once the student's report has been finalized, the teacher will assess it using the assessment criteria.

The individual investigation is internally assessed and externally moderated, meaning the teacher's assessment should be made clear to the moderator. To this end, the teacher should make sure that each report contains ample evidence of the assessment decisions made by the teacher, either through comments on a separate marksheet or annotations on the student's report, or both.

Where several teachers are working with the same cohort of students within a single school, assignments should be subject to internal moderation to standardize the school's assessment prior to the submission of marks.

The final total mark is submitted and a sample for moderation will be requested by the International Baccalaureate (IB). At this stage, no further amendment to the marking of the report is permitted.

Calculating the overall criterion marks

Deciding on an overall mark for a criterion can seem challenging, but it is less so when a clear methodology is used.

- When marking a report submitted for assessment, first read the complete report to determine a holistic impression of the work before deciding on the marks to be awarded.
- Evidence for a single criterion will inevitably appear in several places; this could be under a variety of sub-sections—it is not expected that students will respond to each criterion in a linear or standard way. Read the complete report several times, marking against each criterion.
- A **best-fit approach** must be used to decide the appropriate mark for each criterion. The overall mark awarded for a criterion is **not** an arithmetic mean of the different strands. Rather, it is a holistic judgement reflecting the overall standard of work demonstrated for that criterion.
- Read the level descriptors for each criterion (starting with the lowest level) until you arrive at a descriptor that most appropriately describes the level reached by the work submitted for assessment.
- If a piece of work seems to fall between two descriptors, read them both again. Choose the descriptor that more appropriately describes the work submitted for assessment. This approach means that compensation can be made when a piece of work matches aspects from different level descriptors of a criterion.
- When deciding on a mark, it is essential to consider how well the application of command terms has been addressed, as described in the *Environmental systems and societies guide*.
- It is not necessary that level descriptors from each strand are met within a single markband for a mark to be awarded.
- Mark positively. Give credit for what the student **has** done; do not penalize what they could have done or should have done. Instead of questioning whether they have included everything, ask, "Have they said enough to meet the descriptor level?"
- Record only whole numbers when giving marks; partial marks (fractions and decimals) are not acceptable.
- Be open-minded and try to reward independent thinkers and risk-takers. The produced work may fulfil a criterion in a way these guidelines have not foreseen. Let the work define the outcome.
- It is recommended that the assessment criteria be made available to students.

Figure 7

The markbands and level descriptors for criterion A: Research question and inquiry

Criterion A: Research question and inquiry

This criterion assesses the extent to which the student establishes and explores an environmental issue (either local or global) for an investigation, and develops this issue to state a relevant and focused research question. (Maximum 4 marks)

Marks	Level descriptor
0	The report does not reach a standard described by the descriptors below.
1–2	The report: • describes a local or global environmental topic or issue but with errors or omissions showing a limited understanding • states a research question but there is a lack of focus or it is not linked to the chosen environmental topic or issue.
3–4	The report: • explains a local or global environmental topic or issue with sufficient background research to support the research question • states a focused research question that addresses the chosen environmental topic or issue.

First strand

In this "Research question and inquiry" criterion there are three **strands**.

The first strand concerns the research questions. The second and third strands are the next two items in the markband.

Each strand repeats in each markband, incrementally differentiated each time.

In "Research question and inquiry" the three strands appear twice each, in markbands 1–2 and 3–4.

Awarding zero for a criterion

It is rare that a report should be awarded a zero, but there are specific circumstances in which this is appropriate.

- In the case of an incomplete report, where there is no evidence at all for a criterion, a zero is awarded.
- When there is evidence of some effort to address a criterion, the work should only be awarded a zero if it is incomprehensible or totally irrelevant to the criterion.

If one strand of a criterion scores a zero when the other strands do not: if a strand is not addressed at all, or the work does not reach the required standard for scoring in that strand, the appropriate score is zero. However, if the other strands are found to match the higher markbands, the overall mark for the criterion should reflect the student's achievement, that is, by not over-penalizing the zero-scoring strand.

If there is no achievement against one of the aspects within a criterion, or if the work does not reach the standard required and scores zero, the overall criterion score should automatically drop an entire band.

If a report exceeds 3,000 words, material after this word count cannot be awarded a mark. (Count the number of words for 10 lines at random to give a line average, then count the number of lines quickly and then multiply.)

Investigations not entirely focused on ESS

The internal assessment is interdisciplinary; the focus should be on an environmental issue and the tensions that can impact environmental or societal issues.

Some topics or issues may be relevant to other subjects, for example, air pollution and human health have a more biological approach; acid rain is chemistry-focused; population dynamics and societal issues, such as crime, are more geography-based. These investigations can be formulated to focus on an environmental issue. For example, air pollution impacts all biotic parts of an ecosystem. Human health can be used as a model for the rest of the system, or biotic indicator species, such as lichen, or stream indices can show sensitivity/tolerance to pollution.

If a teacher is concerned about the focus of the investigation proposed by a student, it is possible to consult other experienced teachers and examiners for clarification on the IB programme communities in My IB. It remains the teacher's responsibility to make sure each student's internal assessment report is appropriate for assessing environmental systems and societies (ESS).

Independent thinkers and risk-takers

Students should avoid research questions where the answer is known to them beforehand. Where a well-studied topic is used for the environmental issue, the student should show their research and link to the global and/or local context very clearly.

A student may have produced work that fulfils a criterion in a way these guidelines have not foreseen. All students (whether standard level (SL) or higher level (HL)) can explore topics outside the syllabus.

Criterion A: Research question and inquiry

This criterion assesses the extent to which the student establishes and explores an environmental issue (either local or global) for an investigation, and develops this to state a relevant and focused research question. (Maximum 4 marks)

Research question and inquiry

The teacher should look out for the following issues and check that:

- a local or global environmental topic or issue is stated
- the background research is relevant and focused for the environmental topic or issue
- the research question is unique to the student
- the research question contains variables:
  - an independent variable is present, or two variables being correlated are present
  - a dependent variable or derived dependent variable is present
- the context of the variables is relevant and focused for the environmental topic or issue
- the scientific name of the organism is used (where relevant).

Deciding on the environmental topic or issue

The environmental topic or issue can be the same or similar to that of other students. The background research on the environmental topic or issue should contain information on the theory or model that is being explored, or should include a literature review. The background research provided underpins the reasoning for the development of the research question and the identification of variables.

General accounts of the broad area of study will not achieve the highest marks; for example, a general review of carbon dioxide levels in the atmosphere. An investigation that refers to, and examines, the Keeling curve for carbon dioxide levels and the models for predicting future changes will be more successful. Many research questions can stem from this general topic, such as:

- modelling temperature changes in a range of carbon dioxide levels
- measuring germination or the growth of plants in varying carbon dioxide levels
- changes to coral reefs due to increased ocean temperature or changes in ocean acidity
- opinions on banning fossil fuels.

The environmental topic or issue can be a global one, such as climate change, or a local one, such as planting street trees in a city in response to urban heat island concerns. Encouraging the students to choose an environmental topic or issue they feel connected to or concerned about can help to develop the whole investigation.

Students should ensure that the topic or issue and the research question are appropriate for an ESS internal assessment. Investigations that focus on only human health, economics, or elements of biology or geography are often not suitable for an ESS investigation; for example, how photosynthesis is impacted by the colour of light is a biology topic, while the correlation of gross domestic product (GDP) and electricity usage could be economics or geography. If the environmental topic or issue is made clear in the background research, as well as the relationship between areas and how they impact the environmental issue that is being studied, then these focuses could be appropriate. For example, electrical supply and demand related to proposed offshore wind farming and its impact on the environment and coastal communities is an example of a suitable focus.

Deciding on the research question

The research question needs to be unique to the student. In the case of group work, the teacher should verify this. Both the research question and the background research provided need to be considered in the verification. Both need to be unique to ensure the developing internal assessment is unique to the student.

The research question must contain variables. Most research questions will use independent and dependent variables, but derived variables may be stated or two variables compared/correlated. An experiment will have an independent variable that will be used to test the dependent or derived variable. A correlation looks at the relationship between two variables. The student does not change the independent variable in a correlation, but the data that is to be correlated could be an independent variable and a dependent variable or two independent variables.

The link between the dependent variable and the investigation would need to be established in the background research. Similarly, the range of, and justification for, the independent variable may appear in the background information, not in the research question itself. This may not be the case with simulations, which may provide derived values, such as rates, as their outcome. In these cases, the rate would be the raw data; for example, access to safe water and GDP data can be correlated for countries. Students should know that correlation does not imply causation. Attributing causality without evidence will result in a loss of marks.

Teachers should discourage overambitious research questions that cannot be answered within the proposed methodology and word count. Vague terms, for example, “efficient” and “suitable” should not be used.

The range chosen for the independent variable must be realistic and appropriate in terms of the topic or issue being explored. For example, when exploring the relationship between algae growth and temperature in ocean warming, students should consider that one of the hottest ocean surface temperatures is in the Red Sea, where it can reach 32.2 C. Therefore, a range going above 50 C would be excessive and imply a weak understanding of this environmental issue.

The research question does not need to be a question, and it does not need to comply with a standard form. However, when a general research topic is being investigated, it needs to be expressed in a form that makes it clear what the quantities are, and their relationship, thus guiding an appropriate investigation method. For example, when comparing the biodiversity of two areas in a national park, where one area has a higher frequency of visitors than the other, the research question could be expressed as a statement, such as: “A comparison of the impact of visitor numbers on biodiversity in two areas of National Park X.”

If the investigation’s background is too broad and/or lacks detail, the work will not reach the top markband for the second strand.

Students are permitted to present more than one independent variable, but there must be a clear link between them. They should also carefully consider if including more than one variable will allow the investigation to reach the expected depth, considering the word limit.

Students are permitted to formulate a hypothesis for the outcome of the investigation, though this is not required nor will it be assessed. It may, however, help frame the investigation and therefore be of value to the success of the student. A hypothesis may help students relate the variables more formally, and provide an indication of the nature of the relationship.

Note

The hypothesis should not be in the form of the null and alternative hypotheses unless for statistical analysis. If null and alternative hypotheses are included, this must be addressed in “Criterion E: Analysis and conclusion”.

Criterion B: Strategy

This criterion assesses the extent to which students understand how tensions between perspectives can impact the environmental or societal outcomes of a strategy that addresses an issue central to the student's investigation. (Maximum 4 marks)

The teacher should look out for the following issues and check that:

- a strategy is described that addresses an environmental topic or issue linked to the research question
- the strategy exists or is being developed; strategies created by the student are not appropriate
- a tension (or tensions) that arises from the strategy when viewed from different perspectives is discussed
- the discussion includes at least two contrasting worldviews/perspectives on a stated tension
- the discussion includes the arguments used by each perspective regarding its potential outcomes
- a personal perspective on the stated strategy is included.

The environmental issue or topic

The environmental issue or topic needs to be explained as a local or global environmental topic or issue with sufficient background research to support the research question. The stated research question needs to be focused to address the chosen environmental topic or issue.

Strategy

The strategy can be a plan of action, a management option, or any other intervention that is designed to address the environmental issue. The strategy might be based in the local context of the study itself, or be broader, depending on the nature of the environmental topic or issue. Local strategies and issues could include, but not be limited to, references in photographs, local pamphlets, posters or brochures. For example, community-based action to save a local forest might be linked to a research question on deforestation and climate change. The environmental issue or strategy explored can be different to the one explored in the investigation. However, the issue must have a clearly stated and credible connection to the research question.

Tensions

Tensions arise from strain, unrest, imbalance or opposition between individuals, organizations or communities that have different worldviews/perspectives regarding the strategy and actual or potentially conflicting goals, interests and/or needs. The worldview/perspective could be based on, for example, ethics, logic, religion, politics, sociocultural perspectives, economics or pragmatism. For this criterion, the perspectives chosen must illustrate a stance on the strategy so that the tensions can be discussed.

Topics

Subtopics 1.1 Perspectives and 1.3 Sustainability will be useful in framing the factors that can be considered when exploring a tension that exists within a proposed strategy to an environmental issue; for example, environmental philosophies, the cultural filter model, environmental justice and inequalities, the circular economy, the doughnut economic model, and the United Nations (UN) Sustainable Development Goals (SDGs).

Students should discuss the tension between at least two divergent worldviews/perspectives linked to the strategy. Each worldview/perspective should include the following.

- A review of the position/argument of the worldview/perspective on the environmental topic/issue
- An explanation of how the worldview/perspective view the strategy (their position on the strategy)
- A discussion of the potential impacts of the tension on the outcome of the strategy, both positive and negative
- A personal viewpoint

For example, the creation of a national park by a government, in order to protect habitat, may cause tension between the local (indigenous) community, living within the new national park boundaries, and the government. The report should include the following.

- A review of the position of both parties—the government and the local community. Why does the government want a park in that location versus why does the community want to keep living there?
- The reasons for and against the strategy from each worldview/perspective. Each is linked to the outcome on the strategy. For example:
    - the local (indigenous) community may not respect the new rules for entering the national park or for harvesting previously unrestricted produce
    - tourism may lead to encroachment on religious or traditional land and the desecration of religious or traditional artefacts
    - the local (indigenous) community may set up businesses to cater to visitors to the national park
    - the government may try to employ local people to work in the national park
    - the government may fine or jail locals who trespass in the national park.
- The student's personal engagement with this issue. A conclusion should be drawn and/or state their stance, supported by a brief appraisal of the tensions discussed.

Other examples may include:

- farmers using inorganic fertilizers, and the government making a law about when, where and how much fertilizer can be applied to reduce runoff into the local river
- the reef-safe sunscreen strategy in Hawaii, and tourists not being willing to buy reef-safe sunscreen
- the introduction of new waste management strategies by a community, and businesses or some people within the community rejecting these strategies
- the introduction of "meat-free Mondays" in the school canteen by the school, and students resenting the imposition that is put upon them by the removal of choice
- a legal ban on single-use plastics versus shopkeepers' need to bag products
- the UN climate change agreement and the drafting and implementation of laws/legislation by governments.

These examples range from small, local strategies to global ones. Each example could use other worldviews/perspectives with the strategy.

References and data sources

It is critical that the report includes literature references for the environmental topic or issue, and the strategy to address it, which explains the connections and relevance to the research question. Reliable sources in the bibliography, with sufficient detail to be traced (for example, retrieval dates for online sources), should be included. Generalized arguments about the benefits and problems with a strategy that are common knowledge, but with no supporting references, are unlikely to score well.

Data can be used from primary and secondary sources; for example, an ocean plastic clean-up strategy may be linked to a research question on surveying students about their plastic consumption.

Criterion C: Method

This criterion assesses the extent to which the student has developed an appropriate and repeatable method to collect data that is relevant to the research question. The data could be primary or secondary, qualitative or quantitative. (Maximum 4 marks)

The teacher should look out for the following issues and check that:

- the method can generate appropriate data (data that addresses the research question); the type, amount and replicates of the data collected are appropriate; and the protocol for collecting appropriate data is clear

- the method can be repeated. This should include all essential information required to carry out the investigation, including but not limited to:
  - the location chosen for fieldwork
  - inclusion of a survey or questionnaire
  - methods for selecting participants in surveys
  - website details for a database
  - materials, sampling kits, probes, (concentrations of) reagents and solutions, where appropriate
  - the actual method for measuring a variable (such as the length of shoot or number of leaves)
  - the range and interval of independent variables
  - sampling rate/frequency
  - methods for establishing controls
  - the correct use of scientific terms (spelling is not penalized provided there is no ambiguity)
  - the correct conventions for scientific names
  - the sketches, diagrams, charts and photographs used to illustrate the investigation, including scales and labels, as necessary
  - the use of screenshots to explain how the data was captured (in the case of investigations using databases and simulations).

Protocols, methods, procedures

This protocol will be a record of the method used, including an account of any preliminary, pilot or trial investigation. It should not be a proposed plan, but a record of what was done during the investigation. Students should use standard protocols for determining the dependent variable; the protocols should be cited but not copied verbatim; for example, there is no need to describe in detail the Winkler method for determination of dissolved oxygen.

The stated methodology should be appropriate as part of a 10-hour period of investigative work, and the method employed must be able to collect sufficient data to answer the research question. This 10-hour period may include designing and trialling, followed by a redesign of the method. Teachers should ensure the investigation can be completed within the allocated time. The quantity of data collected needs to be realistic. Students must consider time constraints during the design of their investigation. If the investigation requires more time than is allocated, the teacher should provide the necessary scaffolding.

The procedure should be clear and detailed enough so that the investigation could be reproduced.

ESS allows for a broad range of studies that could be science- or social science-based. This criterion has been designed to allow for assessment of a wide range of types of study. Students could be:

- using quadrats to collect data suitable for calculating a diversity index
- undertaking a survey to determine citizen opinions on a particular environmental initiative (for example, solar energy subsidies), or carrying out data mining of an ecological database
- doing a lab-based experiment on the effects of fertilizers on plant growth.

Replicates and samples in ESS

ESS, and especially ecological studies, because of their complexity and inherent variability, require replicate observations and multiple samples. Generally, the lower limit is five measurements of an independent variable, with five repeats for each one. For example, in a study to see how a storm drain affects dissolved oxygen levels in a stream, the student might consider fives sites—one site above the drain and four below the drain. The student should take five samples at each sampling site, thus generating 25 data points (5×5). The 5×5 rule is a good guide for many laboratory-based investigations and some field studies.

When carrying out transect studies, it may prove difficult to collect that much data because of time constraints; however, this should be explained in the report.

Field studies may be more effective if carried out in groups. Teachers must ensure that each research question (and thus the sampling method) is individual. For example, a group may decide to investigate the effect of a city on river water. Each research question can be built around a different dependent variable. It is also possible to use class data to generate sufficient replicates to permit adequate processing of the data in group and non-assessed practical work.

In survey-based research, students must ensure that there are enough participants to generate meaningful data. Generally speaking, 30 candidates per group are required. For example, in a study on the relationship between age and attitudes to recycling, the student should have 30 participants per age group.

Variables

It is not necessary for the variables to be identified explicitly and separately using subheadings or a table. This may be useful for some students, but it is not a requirement.

Sampling

The sampling strategy chosen should be appropriate to the methodology that addresses the research question. Sampling strategies are not directly assessed in the new model. The student must provide enough detail to assess whether the method will gather enough data to answer the research question. If the method will not gather sufficient data to be representative, it will not reach the 3–4 level descriptor for the second strand.

Representative samples are used in many ESS investigations. The report must include sufficient information on how both the samples and sample site were chosen. See the "Skills in the study of environmental systems and societies" section within the guide for suggestions of possible sampling techniques.

For example, looking at plant diversity across a footpath could have transects laid perpendicular to the path with quadrats every 1–2 m or so. How far apart would the different quadrats be placed? How far away from the path would a transect be placed? If a survey is being conducted, how many people will be asked to take the survey? Many statistical calculations require a minimum of 30 data points per variable. For example, if gender is the independent variable, then a minimum of 30 participants per gender should be surveyed.

The method must include sufficient information so as to be repeatable. For example, the amount or type of active ingredient(s) in sunscreen may change with the brand or country of origin. Simply stating that a sample is "factor 50" lacks the required detail to assess the data adequately. Sampling must also be adequately described. For example, when determining the amount of nitrate in a lake, the results obtained will be a function of the location at which samples are taken; therefore, this information must be provided.

In experiments that incorporate digital technology, such as probes, the sampling rate needs to be considered to ensure that meaningful, but not excessive, data are collected. This is often best determined during trialling. For example, collecting the carbon dioxide level every second for 30 minutes is unnecessary; setting the probe to sample every minute, two minutes or five minutes still provides plenty of data.

Even though sampling is the first step in many scientific investigations, a research question cannot be correctly answered if the samples are not representative. Storing samples correctly also deserves careful attention, given that the parameters that are being measured can change during storage and affect the results. For example, when collecting soil samples from the field to analyse in the lab, students should describe the method for collection and storage of the soil samples to ensure consistency.

Illustrations and lists

Students should consider illustrating their investigation using annotations, when they add value. For example, fieldwork should always include some form of site description. This could include maps, diagrams or photographs with appropriate annotations. Diagrams of rulers, stopwatches and photographs of beakers are unnecessary. Illustrations can help to describe the investigation and have minimal impact on the word count. These should be clearly titled and referenced, as appropriate.

A list of materials is useful but not obligatory. Details of the materials can be given in the method.

Risk assessment

Although this is no longer assessed directly, teachers have a responsibility to ensure that their students carry out safe, ethical investigations and that the students also consider their environmental impact. In particular, students must comply with the application of *IB sciences experimentation guidelines* and *Ethical guidelines for extended essays research and fieldwork*.

Examiners who come across experimental set-ups that constitute a severe risk to safety or the environment will refer these to the IB. The school may then be contacted.

Considering uncertainties

Random variation or normal variation

In nearly all ESS laboratory or field investigations, errors can be caused by variation at the location of study (for example, owing to the time of day or season), by differences between sampled locations (for example, the slope or aspect of the locations) or variation in the material used. Living materials are subject to variation, even when controlled laboratory-based experiments are carried out. For example, when the gain in dry mass of seedlings grown in the presence of different types of fertilizers is measured, the seedlings will vary in their growth rate. This can occur even if variables such as light intensity and temperature are controlled. This is due partly to genetic differences between the seeds, and partly because it is impossible to control all the possible factors completely that might impact growth rates. Errors of this nature are described as random errors; they can be kept to a minimum by careful selection of locations and materials, and by careful control of variables, where appropriate, but can never be eliminated entirely.

Human errors

Making mistakes is not an acceptable source of error if these could have been easily avoided with more care and attention. Data loggers can be used if a large number of measurements need to be made, in order to avoid errors arising as a result of loss of concentration by the student. Careful planning can help reduce this risk.

Systematic errors

Systematic errors can be reduced if equipment is regularly checked or calibrated to ensure that it is functioning correctly. For example, a thermometer should be placed in an electronic water bath to check that the thermostat of the water bath is correctly adjusted. A blank control should be used to calibrate a colorimeter to compensate for the drift of the instrument.

Criterion D: Treatment of data

This criterion assesses the extent to which the student has effectively communicated and processed the data in ways that are relevant to the research question. The student should utilize techniques associated with the appropriate experimental or social science method of inquiry. (Maximum 6 marks)

Communication of raw and processed data

The teacher should look out for the following issues and check:

- that qualitative observations (pictures/drawings) are correctly labelled
- for concise presentation (of text, tables, calculations, graphs, other illustrations)
- for use of correct scientific units and their symbols
- for appropriate formatting of data: units and uncertainties are correct; there is a consistent number of decimal places or significant figures
- for clear and precise presentation of raw and processed data that addresses the research question
- for a sample calculation or the use of screenshots, where appropriate
- that graphs are relevant and add value, for example, with lines of best fit or curves. Multiple graphs showing the same data in different formats are not appropriate.

Units and decimal places

International System of Units (SI units) or other metric units (for example, ml or cm^3; L or dm^3 for volumes) are acceptable. Non-decimal system units (for example, °F, cups and inches) are not appropriate and should be converted.

A correct and consistent number of decimal places, based on the degree of precision, is expected. Minor errors in data tables can be accepted if, overall, the student is trying to maintain consistent decimal places between the raw data, any degrees of precision expressed and the processed data. In ESS, students are not expected to use significant figure conventions; if they do, they should be used correctly. For example, when rounding the results of calculations, these must be reported to the same precision.

Presenting data

Correctly tabulated and graphed data should be clearly presented and should include appropriate titles and numbers.

Where relevant, there should be concise column/row headings, and units should be given in the column/row headers with their uncertainties (as appropriate). It is not necessary to provide separate tables for raw data and processed data.

When large amounts of data have been collected, students are permitted to present a representative sample of the raw data, to facilitate comprehension. Students may use appendices to include very large data tables (this is a departure from the previous assessment model). The data shown should allow any worked examples of processing to be checked. For example, the raw survey forms from a questionnaire will not be required, but a tallied data table of survey responses should be included.

Data taken directly from an electronic device is raw data and requires further processing to constitute processed data. For example, if the device determines "rate", this is raw data. If the software automatically constructs a graph, the graph itself is acceptable as raw data. Details about how the results were obtained and information about quantities, units and precision should be mentioned in the text, where appropriate. The gradient of a line or an area under the graph may then be used for further calculations. For example, secondary data as a screenshot from a database or website is raw data. Graphs from a website are raw data. The data from the screenshot or graph can then be processed to address the research question. Lines of best fit on the graph, or correlation of the data from two graphs, may be appropriate processing.

The presentation of the processed data should enable analysis of patterns and trends to address the research question. The type, size, proportions and scaling of the data display/graph not only impact presentation, but also the usefulness of the display/graph in data analysis. Inadequate labelling of graphs (axes, legends, titles) will impact data analysis.

Qualitative observations are expected to accompany the raw data where applicable. Their importance will depend on the nature of the investigation.

The layout of the processed data will depend upon the tools being used. Inserting percentages, means, standard deviations or ranges at the end of the column or row of data they represent will be sufficient without an example of processing. It should be possible to use the presented raw data to review the calculations carried out.

For more complex processing using spreadsheets, for example, screenshots including the formula used are acceptable. For other less orthodox processing, a worked example is necessary.

For many statistical analytical techniques, the student will need to make a statement of null and alternative hypotheses. This is required even if the student is using a graphing display calculator or a statistical program for calculations. There is no need to state a null and alternative hypothesis at the beginning of the investigation.

Providing examples of full calculations is superfluous or irrelevant when using dedicated programs. A program like MS Excel gives only the probability level (p-value) for the t-test. Therefore, students cannot use the t-statistic on a probability table because it is built into the program. The program also calculates the degrees of freedom. Students do not need to present these, though they do need to be aware of the impact of sample size. Students should state the source, for example, MS Excel 2016. The result obtained from the statistical test must be interpreted using the null and alternative hypotheses or statement of significance.

Note

Interpretation of the data as it relates to the research question is assessed in criterion E: Analysis and conclusion.

Statistics

An effective presentation of the data goes a long way to assessing whether or not a trend is emerging. However, this is not the same as using statistics to assess the nature of such a trend and whether it is significant; in other words, whether a trend, judged subjectively from a graph, is actually valid. Students are encouraged to use relevant statistical tests to assess their data, but they should briefly explain their choice of tests, outline the working hypothesis and put the results of the test into the analysis of their investigation. For statistical tests, the correct protocol should be presented, including null and alternative hypotheses (degrees of freedom), critical values and probability levels.

The teacher should look out for the following issues and check for:

- variation in raw or processed data, as shown by standard deviations, standard errors, trend lines, R^2 values, range, error bar showing uncertainty
- significance testing
- an appropriate response to outlier data.

It is not expected that students will necessarily cover all of the above parameters. This is merely a guide to the ways a student may evidence that they have considered the impact of uncertainty/reliability/validity on the analysis.

Uncertainty in measurement

Measurement uncertainties can be obtained from the instrument's graduations or the manufacturer's specifications (for electronic devices). The realistic use of the instrument also needs to be considered. For example, using a handheld calliper to measure the height of a plant will not need a precision of 0.01 mm. Even if the calliper can provide such a read-out, the start- and end-point determination for the measure with each plant will be far greater than 0.01 mm. Students should justify the size of uncertainty based on the nature of the experiment. Repeating the measurement for the same event often reveals an uncertainty larger than the precision of the instrument.

Uncertainties for counts (±1) are not necessary; however, data derived from these counts may possess a degree of precision. For example, the percentage germination of a sample of 25 seeds will have a margin of error of ±4%, as it is ±1 for each set of 25 seeds and there are 4 sets of 25 in 100. The propagation of uncertainties for percentages, and other calculations, is not systematically expected in ESS. Propagating errors during data processing is not expected, but it is accepted, provided it is appropriate and the basis of the experimental error is explained. However, students may be penalized for the incorrect calculation of error propagation.

Where relevant, measurement uncertainties should appear in the column headings along with the units, unless there is reasonable justification for data to have different values of uncertainty within a column. Uncertainties are also expressed graphically using scatter plots with trend lines. These may also include error bars showing uncertainty and R^2 values. Box and whisker plots may also be used. Where the uncertainty is too small to be visible, this should be noted in the report. Uncertainty bars can be different for each datum point, or each point can have the same absolute uncertainty. Error bars showing uncertainty are normally only drawn for the dependent variable.

Statistical tests that generate significance levels are also measurements of uncertainty. For some tests, such as the t-test, chi-squared test or analyses of variance (ANOVA), establishing the p-value is part of their outcome. For correlation coefficients, it is an additional step that needs to be considered. If used, ANOVA (F-test) should also be accompanied by a post-hoc test (for example, a Tukey test) so that the significance of the difference between the treatments can be determined.

When one uncertainty is negligible, identifying this fact and neglecting it with a brief, clear explanatory comment would add value to the analysis. Students must be careful when the uncertainties involve logarithmic values, such as pH.

Outliers

Outliers that have been identified should not be systematically removed from calculations. The impact of an outlier on the results needs to be considered. Removing outliers so that the results fit the general model "better" is not good practice.

Outliers may be identified statistically from the data. A common calculation used is that they are greater than 1.5 times the interquartile range below the first quartile, or more than 1.5 times the interquartile range above the third quartile. **If the student is considering excluding these, a justification is required.** This is especially true of data in ESS scientific investigations as the sample size is usually small ($n \leq 30$) or very small ($n < 15$). However, if observations are made that can explain why an outlier occurred, or if a weakness in the method is identified and corrected, then the student may choose to include the analysis with and without the outliers in order to reveal their impact.

Outliers are most likely to occur as the result of human error, methodological flaws or irregularity in the equipment or environment. The quantity in question can be re-measured. The scientific method requires rigour and integrity in gathering data, while the IB requires academic integrity from students. Both of these are more important than attempts to make data appear consistent. Although there is no single agreed-upon method for rejecting outliers, common sense and careful analysis are always helpful.

Data that produces zero results can sometimes be considered outliers. This depends on the experiments being conducted. Any seed germination/growth experiment should consider a viability test on the seeds to check what percentage will not germinate. This needs to be considered in the data processing. For example, if 10% of the seeds never germinate, then when one-tenth of seeds in a treatment do not germinate, this is expected and the data point can be removed. If half of the seeds did not germinate in a treatment, then one data point can be removed, but the other four should be included. The approach must be consistent across all treatments.

Processing of data

The teacher should look out for the following issues and check that:

- processing is efficiently presented and at the correct level for the topic
- appropriate processing tools/techniques are selected within the context of the research question
- there are realistic trend lines in terms of presented data
- statistical analysis has a justification for the choice of a test, and appropriate display and/or graphing techniques including adequate scale, title and labelled axes
- correct calculations and graphing and/or display are present.

Any processing of the data must be appropriate to the focus of the investigation in an attempt to answer the research question and enable a conclusion to be made. Mathematical skills are important, but this is not a mathematics course.

Any processing will be superficial if there is insufficient data. It is hoped that a student would recognize the potential for such a lack of data within their experiment and review the suitability of the method before they start the data processing. Alternatively, a lack of primary data could be supplemented by the use of secondary data from data banks or simulations to provide sufficient data for analysis.

Graphing raw data is part of processing and can be used to derive values (for example, gradients/slopes for rates).

Graphing raw data when the graphing of processed data would be more appropriate can be considered insufficient or irrelevant, but it is not wrong.

The types of display or graphs produced by the student should be appropriate for the data being analysed. Bar graphs showing nominal data should order results according to some criterion; for example, a bar graph of the number of cars per household in different municipalities should organize the data from least to most, or vice versa, in order to show patterns.

Online survey/questionnaire data often has the generic graphs or charts that the online survey produces; however, these seldom answer the research question fully. Further processing to answer the research question needs to be done.

Dot-to-dot plotting of data may be acceptable. Nevertheless, going further and placing a trend line on the data (especially if error bars showing uncertainty accompany it), a correlation coefficient (r) or the coefficient of determination (R^2 value), can be a useful step in processing and interpretation (for example, comparison with an accepted model).

In order for a trend line to be drawn on a graph, there must be sufficient data. Given the variability in systems, this is very difficult at this level. A trend line may be used to show how the limited data collected fits a given model (for example, the pH optimum for a growth experiment or light saturation of a photosynthetic system). Students should not be penalized for producing a dot-to-dot graph where there are continuous variables.

The correlation coefficient (r) is useful when determining a linear correlation. Any two variables will have an r-value between -1 to 1. The coefficient of determination (R^2) is also useful in providing an evaluation of the goodness of fit/match that a trend line has to the data.

Note

The correlation coefficient is not the same as the coefficient of determination.

An appropriate best-fit line or curve is common practice and should be guided by theoretical considerations, known equations or models. Students should not assume a linear fit unless it is justified. Most graphing software (such as MS Excel, Google Sheets) allow students to apply a non-linear model. A high R^2 value does not necessarily mean that the chosen trend line mirrors the correct underlying process; for example, when looking at the change in an environmental variable over distance or how income can impact demographic data. Students should be discouraged from applying trend lines to data when the value of r is so low as to indicate no correlation. Likewise, drawing a trend line on nominal data (for example, data that has no hierarchy, such as recycling data according to city districts) should also be discouraged. (However, if city districts are graphed in order of ascending or descending median incomes, the data becomes ordinal and has a natural order or ranking.)

The standard deviation is a measure of how spread the data is around the mean. The larger the standard deviation, the wider the spread of data. Standard deviation is used for normally distributed data. For example, when data is collected on the weekly mass of household domestic waste for the families of students in a particular class, the mean can be calculated and compared to the means in other parts of the world. Moreover, it might be interesting and informative to calculate the standard deviation in order to know how representative the mean was. It can be useful for showing the general variation/uncertainty around a measurement; it is less helpful for identifying potential anomalies.

Both standard deviation and standard error of the mean (standard error) can be useful, assuming there is a sufficient number of replicates to be able to calculate one; otherwise, ranges are acceptable for maximum–minimum values. Standard deviations may be calculated on sample sizes as low as five. The standard error of the mean is more influenced by sample size, so it ought to be reserved for samples greater than 30.

Error bars showing uncertainty that plot the highest and the lowest value for a test, joined up through the mean to form the data point plotted on the graph with a vertical line, will allow the variation/uncertainty for each data set to be assessed. If the error bars showing uncertainty are particularly large, it may show that the readings taken are unreliable (although reference to the scale might be needed to determine what "large" actually is). If the error bar showing uncertainty overlaps with the error bar showing uncertainty of a previous or subsequent point, it would show that the spread of data is too wide to allow for effective discrimination. If trend lines are possible, then adding the coefficient of determination (R^2) can be helpful as an indication of how well the trend line fits the data.

If a statistical test is carried out by the students, then it is vital that they appreciate that the sample size is important. As a rule, $n > 30$ is considered a large sample, 15–30 a small sample and 5–14 a very small sample. n <10 is usually considered too small a sample to apply tests like the t-test. Though some tests, such as a Mann-Whitney U-test, can handle very small samples, in general, sample size ought to be at least 10 for the calculation of a statistical test.

Refer to the "Introduction">"The ESS course">"Skills" section for guidance on the types of statistical tests the students could use, and should be familiar with, for the internal assessment.

Criterion E: Analysis and conclusion

This criterion assesses the extent to which the student has interpreted the data in ways that are relevant to the research question. The patterns in the data are highlighted and correctly interpreted to reach a valid conclusion. (Maximum 6 marks)

Analysis of the data

The teacher should look out for the following issues and check that there is:

- a valid discussion of trends, patterns or correlations in or of the results
- interpretation of the data and/or results that will then lead to a conclusion
- interpretation of the significance of statistical tests results, if used
- discussion of the impact of the uncertainties, as appropriate
- discussion of the measures of bias, reliability and validity of the data (which may indicate an appreciation of the strengths or weaknesses of the data).

The analysis needs to discuss all the processed data calculated and presented. Where possible, the variability and reliability of the data should be demonstrated, explained, and their impact on the conclusion fully acknowledged. Reference to scientific literature and/or experimentally acceptable ranges of data to support or refute the student data will help with the discussion.

Within the text of the report, the data should be referenced (for example, "According to figure 1 … ").

The student should be able to identify the trend lines correctly; for example, a negative correlation is not the same as an inverse relationship.

Survey and questionnaire data can contain bias, prejudice and misrepresentation. If this is the case, then it needs to be discussed in the analysis. The identification of conflicts of interest and the positional perspectives should be commented upon in the analysis.

Considering uncertainties in the analysis

There are sources of uncertainty at a number of stages of any investigation. The chosen method should try to address as many as possible but, despite this, many will remain. Students should not be discouraged by this, because experimental results are only "snapshots" or samples of a complex system. Instead, students should be encouraged to take uncertainties into consideration when analysing the data and drawing conclusions. Where appropriate, a thorough evaluation of the sources of uncertainty and error will also help to gain perspective on the scope of the investigation in general, and to suggest potential improvements and recommendations or unresolved questions. This is assessed in the criterion F: Evaluation.

Measures of variation, such as the range or the standard deviation, can give an indication of the reliability of the results.

Students should show an appreciation of the limitations of their sample size in the interpretation of their results. As the sample size gets smaller, the impact of uncertainties becomes greater. Increasing sample size will generally increase the accuracy, this can be judged using the standard error of the mean, and will generate 95% confidence limits as the estimate becomes more accurate.

Other indicators of uncertainty may be used, such as the coefficient of determination (R^2). This will reveal if a trend line, straight or curved, fits the data well.

In ESS, random uncertainties from biotic and abiotic factors will probably be the most significant source of variation, so, the interpretation of statistical tests will be important. For significance tests that generate a *p*-value, 0.05 or 5% is taken as the critical value below which the results can be said to have significance.

Above this level, the results could be due to random chance. The *p*-value is a controversial issue among scientists, but it is still used to judge whether one fails to reject the null hypothesis or accepts the alternative hypothesis.

Relevance of the conclusion

The teacher should look out for the following issues and check that:

- a conclusion that addresses the research question is stated
- reference is made to a hypothesis (if one has been stated), and the student indicates whether it is supported by their data or not.

The conclusions drawn must be based on the evidence from the data rather than on assumptions. Given the scope of the internal assessment and the time allocated, it is more than likely that variability in the data will lead to a tentative conclusion, and may identify patterns or trends rather than establishing causal links. Students must include a statement of whether the data addresses the research question or not. The results may also be inconclusive. Conclusions must be supported by the data and the analysis that the student has performed.

Teachers should be aware that often students mistake their models (from their investigations) with reality and come to conclusions regarding the phenomenon being modelled on the basis of their model's data. For example, when a student simulates the effect of acid rain on germination, by pouring an acid solution on seeds, their conclusion should be limited to their data, and not necessarily expanded to apply to the phenomenon at large.

Criterion F: Evaluation

This criterion assesses the extent to which the student carries out an evaluation of the investigation. (Maximum 6 marks)

Methodological limitations and weaknesses

The teacher should look out for the following issues and check that:

- methodological and procedural limitations or weaknesses are seen
- evaluation is given of the relative impact of specific limitations or weaknesses that affect the conclusion
- evidence is given supporting the identified limitations or weaknesses, including measures of reliability, validity and uncertainty.

The evaluation of the investigation does not need the student to differentiate between weaknesses or limitations. There is no expectation that a student will address all methodological weaknesses or limitations, but when evaluating the results of an investigation, students should explain the relative impact of significant weaknesses or limitations. The student can do this in a qualitative way, identifying major and minor weaknesses by explaining how they would affect the conclusion.

- Methodological weaknesses need to consider both the issues in the methodology and their effect on the quality of the data. The control of variables or the precision of measurements during the data gathering should be explored. Weaknesses should not include errors due to the careless manipulation of apparatus, the taking of samples, or hypothetical events for which there is no evidence.
- Limitations refer to the fact that experiments will only go so far in answering the research question and drawing a conclusion. Even if conditions were perfect, an experiment will still have its shortcomings. The range of the data collected, the confines of the system or the assumptions made can all be limitations. If a simulation is used, there may be few methodological weaknesses, but there will be some limitations in the simulation, such as not including all the natural conditions.
- Systemic uncertainties/errors can often be picked up and fixed in a trial of the method. These include instruments that are faulty or that have not been calibrated correctly. These errors, which affect accuracy, can also be caused by human error. These should not be used for weaknesses or limitations

in the evaluation. Mention can be made of how a systemic error was controlled; for example, all masses used the balance that started at 2 g, so this error is applied (or removed) from all the data.

- Random uncertainties/errors are uncontrollable; they are often fluctuations in the environment or observational bias/judgement.

The reliability and validity of the results need to be judged in the light of the uncertainties that have been established.

Random uncertainties are unpredictable in size and direction. In ESS, random uncertainties from biotic and abiotic factors will probably be the most significant source of variation. Measures of uncertainty in populations (such as range or standard deviation) can be used to judge their impact on the results. The precision (measurement uncertainty) of instruments varies due to random errors. Judging the degree of impact of each measuring instrument on the results is an important task in science. The IB does not expect uncertainties to be propagated, so this judgement will remain qualitative.

The act of measuring environmental or observational errors can also influence the results. For example, when and how a measurement is taken can affect the environment of the experiment significantly. When a cold thermometer is put in a test tube of warm water, the water will be cooled by the presence of the thermometer; when the behaviour of animals is being recorded, the presence of the experimenter may influence them. The wording of questions in a survey may also bias the answers.

The student must clearly address the range and frequency of collected data and explicitly consider whether their controls had been adequately dealt with; for example, the lack of secondary data available may restrict the range used.

Limitations should be consistent with the analysis and interpretation of uncertainties presented in the data analysis. They should be supported by evidence rather than speculations; for example, “the temperature of surroundings that was not controlled or monitored may have changed during the extended period” has limited value.

Limitations, such as small sample size or procedural weaknesses (for example, a pH meter was not calibrated), which should have been solved during the trials, are generic limitations. The use of apparatus and instruments should be considered during design. For example, if the pH meter or colorimeter produces erratic values, this must be established during a pilot. If no other instrument is available, it is in the student’s best interest to consider changing the methodology. The same might apply to issues related to incorrect sampling or storage of the samples.

Students may be familiar with certain methodological weaknesses and limitations; for example, heat losses in calorimetry. These are valid limitations, but they will only add value when the student has tried to minimize their impact during the design. For example, if the student worked with an open container without insulation, referring to heat losses in calorimetry is weak evidence of the understanding of this methodological limitation.

Smartphone apps can be used for identification and as a sensor; these vary in their efficacy and accuracy, and depend on the age and type of phone. Showing an awareness of the limitations of these apps should be included in the evaluation.

Fieldwork site choice and sample site limitations owing to weather, inaccessibility or safety can often mean a well-planned method has to be altered when on site in the field. Inaccessibility could include vegetation, steep slopes or slippery ground.

Surveys/questionnaires/interviews will involve voluntary participation; this means the results may not be a representative sample of the population, and they are dependent on the participant providing honest answers. The type of questions asked can skew the answers. For example, using the Likert scale, which asks for an opinion using a numbered scale, the highest and lowest numbers are often avoided by respondents. The survey, if too long or complex, can lead to survey fatigue. This can result in unfinished surveys or poorly answered questions.

In investigations using databases, the student should not refer to the validity of the sources, because this should have been done in the method. However, there can be issues in the curation of databases, and a reflection adds value. Problems resulting from experimental and theoretical values present the same challenges.

Group work data quality may vary. If the student is using data collected from a group, there may be differences in the way each group member collected the data, despite establishing a commonly agreed method.

Evaluating improvements to the investigation

The teacher should look out for the following issues and check that:

- realistic and relevant improvements for specific weaknesses and limitations are made
- evaluation of the improvements is done.

Suggested improvements should be realistic and relevant to the investigation research question and methodology. The improvements must be related to the weaknesses or limitations that have been identified, and they should be feasible in a school environment or field course.

Generalities like “take more measurements” or “use a more precise measuring method” should be avoided. Only if these generic issues are connected to specific issues can they be seen as improvements to weaknesses. These may be valid when further detail is provided. For example, taking more than 15 samples would have allowed a more robust statistical analysis and increased the significance of any differences; or the use of a well-calibrated colorimeter would have provided more reliable data than the visual colour code method used.

Describing unresolved questions

The teacher should look out for the following issues and check that:

- realistic unresolved questions, as they impact the conclusion, are described
- there is a clear link to the method and environmental topic or issue that extends the investigation beyond the original investigation.

Students should include potential questions that might bring the results closer to what is expected. These could be modifications to the weaknesses, or limitations already mentioned or linked to research seen in the literature.

The questions suggested should follow on from the investigation in a meaningful way and go beyond the original methodology to show how the investigation will enhance understanding of the issue or research question. The questions should be qualitatively different from the method undertaken. For example, collecting more field samples is insufficient, whereas undertaking the field investigation in different seasons would be acceptable; or investigating a controlled variable in a survey to see how that changes the results. If gender was investigated, then looking at age or location is recommended.

Bibliography

Bendell, J., & Read, R. (Eds.) (2021). *Deep adaptation: Navigating the realities of climate chaos*. Polity.

Brundtland, G. (1987). *Report of the World Commission on Environment and Development: Our Common Future*, A/42/427. United Nations General Assembly. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Chen, J. (2022, October 2022, updated 2023, June 26). *Environmental economics: Definition, importance, and example*. Investopedia. Retrieved July 21, 2023 from, https://www.investopedia.com/terms/e/environmental-economics.asp

Crompton, T. (2011). *Common Cause Foundation: Unlocking the potential of human values*. Retrieved April 3, 2023, from https://commoncausefoundation.org/

Ecological Economics For All. (n.d.). *Economics 101—Economics cannot exist without ecology: We need ecological economics for all*. Ecological Economics For All. Retrieved June 19, 2023, from https://www.ecologicaleconomicsforall.org/ee101

Farahbakhsh, I., Bauch, C. T., & Anand, M. (2022). Modelling coupled human–environment complexity for the future of the biosphere: Strengths gaps and promising directions. *Philosophical Transactions of the Royal Society B, 377*: 20210382. https://doi.org/10.1098/rstb.2021.0382

International Baccalaureate. (2019, updated 2023). *Academic integrity policy*. International Baccalaureate Organization.

International Baccalaureate. (2022). *Effective citing and referencing*. International Baccalaureate Organization.

James, P. (2015). *Urban sustainability in theory and practice: Circles of sustainability*. Earthscan, Routledge.

Kahan, D. M. (2012). Cultural cognition as a conception of the cultural theory of risk. In S.Roeser, (Ed.), *Handbook of risk theory* (pp. 725–759). Springer. Retrieved July 20, 2023, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1123807

Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., & Schellnhuber, H. J. (2019). Climate tipping points—too risky to bet against. *Nature, 575*. https://doi.org/10.1038/d41586-019-03595-0

Monneret, C. (2017). What is an endocrine disruptor? *Comptes Rendus Biologies*, *340*(9–10), 403-405. https://doi.org/10.1016/j.crvi.2017.07.004.

Rahmstorf, S. (2004). The climate sceptics. *Munic Re, Weather catastrophes and climate change*, 77–83. Retrieved July 23, 2023, from http://www.pik-potsdam.de/~stefan/Publications/Other/rahmstorf_climate_sceptics_2004.pdf

Venkatachalam, L. (2007). Environmental economics and ecological economics: Where they can converge? *Ecological Economics*, *61*(2–3), 550–558. https://doi.org/10.1016/j.ecolecon.2006.05.012

Glossary of ESS terms

Term	Definition
Abiotic factor	A non-living, physical factor that may influence an organism or ecosystem; for example, temperature, sunlight, pH, salinity, precipitation.
Adaptive strategies	Strategies that can be used to reduce adverse effects and maximize any positive effects of climate change.
Adhesion	An attraction between molecules of different substances (for example, water to xylem inside vascular plants)
Age-sex pyramid	A graphical illustration (usually pyramid-shaped) showing a population. It depicts the distribution of age groups and gender for a country or region.
Anthropocene	A period in which human influence is the dominant source of change to the biosphere.
Anthropocentrism	A viewpoint that argues that humans must sustainably manage the global system, through the use of, for example, taxes, environmental regulation and legislation.
Anti-fouling agents	A coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms.
Aquaculture	The farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants.
Artificial Recharge (AR) and Aquifer Storage and Recovery (ASR)	The methods "Artificial Recharge (AR) and Aquifer Storage and Recovery (ASR)" are used in this context for the purpose of water replenishment, and water storage.
Artificial selection	A process by which humans identify desirable traits in plants and animals and take steps (genetic engineering, selective breeding) to perpetuate those traits in future generations.
Autotrophs	Organisms that make their organic nutrients from inorganic sources.
Background extinction rate	The estimate of the standard rate of extinction through geological time, between mass extinctions and excluding effects due to human interference.
Barrier	A challenge or constraint that can slow or halt progress of mitigation and adaptation strategies, but that can be overcome with concerted effort.
Bioaccumulation	The build-up of persistent or non-biodegradable pollutants within an organism or trophic level because they cannot be broken down.
Biocapacity	The ability of a given biologically productive area to generate an ongoing supply of renewable resources and to absorb its wastes.

Term	Definition
Biodegradable	When something is capable of being broken down by natural biological processes; for example, the activities of decomposer organisms.
Biodiversity	The amount of biological diversity per unit area. It includes the concepts of species diversity, habitat diversity and genetic diversity.
Biodiversity hotspot	An area that contains at least 1,500 species of endemic vascular plants and has lost at least 70% of its primary native vegetation.
Biohazardous (or clinical) waste	Materials that are contaminated with potentially infectious agents or other materials that are considered a threat to public health or the environment. Clinical waste may contain blood, body fluids, human cell lines, drugs and other pharmaceutical products, swabs and dressings, syringes, and needles.
Biomagnification	The increase in the concentration of persistent or non-biodegradable pollutants along a food chain due to the decrease of biomass and energy.
Biome	A collection of ecosystems sharing similar climatic conditions.
Biosphere	The part of the Earth inhabited by organisms that extends from the upper parts of the atmosphere to deep within the Earth's crust.
Biotic factor	A living, biological factor that may influence an organism or ecosystem; for example, predation, parasitism, disease, competition.
Biotic index	A measure of the quality of an ecosystem by the presence and abundance of the species living in it. Using this index and indicator species is an indirect method of measuring pollution.
Bottom trawling	A fishing method where large, weighted nets are dragged across the ocean floor, clear-cutting a swath of habitat in their wake.
Bycatch	A fish or other marine species caught unintentionally while harvesting certain other target species and target sizes of fish, crabs, and so on.
Carbon sequestration	The process of capturing and storing atmospheric carbon dioxide.
Carrying capacity	The maximum population size of a species or "load" that can be sustainably supported by a given environment.
Catalytic converter	An exhaust emission control device designed to reduce toxic gases and pollutants in the exhaust gas of internal combustion engines.
Cataracts	A clouding or loss of transparency of the eye as a result of tissue breakdown.
Chemoautotrophs	Organisms that use chemical oxidative processes to synthesize organic nutrients from inorganic sources.
Citizen science	Science that uses the involvement of the public in scientific research to generate data.
Classification	The organization of organisms into different taxa or groups.
Climate	This describes how the atmosphere behaves over relatively long periods of time. The two main factors determining an area's climate are its average temperature, with its seasonal variations, and the average amount and distribution of precipitation.
Closed system	A system that exchanges only energy, but not matter, with its surroundings (for example, the Earth).

Term	Definition
Cohesion	The attraction of molecules to themselves due to hydrogen bonding or other forces of attraction.
Commons	Cultural and natural resources that are available to all members of a society. These resources are held in common, not owned privately.
Community	A group of populations of different species living and interacting with each other in the same area.
Competition	A common demand by two or more organisms upon a limited supply of a resource; for example, food, water, light, space, mates, nesting sites. It may be intraspecific or interspecific.
Consumers	Organisms that ingest live or recently dead organisms, and are further classified as herbivore, carnivore, or omnivores.
Contexts	This describes when ESS "understandings" are applied in real-life situations.
Crude birth rate (CBR)	The number of live births per 1,000 people in a population per year.
Crude death rate (CDR)	The number of deaths per 1,000 in a population per year.
Dichlorodiphenyltrichloroethane (DDT)	Dichlorodiphenyltrichloroethane (DDT) is an insecticide that was used in agriculture. There is a worldwide ban for agricultural use. However, some countries still use it to control the spread of malaria.
Decarbonization	The reduction or removal of carbon dioxide from energy sources.
Decarbonization of the economy	An economy based on low-carbon power sources that therefore has a minimal output of greenhouse gas (GHG) emissions, specifically carbon dioxide.
Decoupling	The disconnection of economic growth and environmental impact so that one no longer depends on the other.
Demographic Transition Model (DTM)	This model describes the changing levels of fertility and mortality in a human population over time. Birth and death rates shift from high to low levels in a population. The mortality decline precedes fertility decline, resulting in rapid population growth during the transition period.
Denitrification	The conversion of nitrates to nitrogen gas in the atmosphere by bacteria.
Density-dependent factors	These are limiting factors that are related to population density. They are biotic factors (for example, competition for resources) that limit population growth.
Density-independent factors	These are limiting factors that do not depend on the size of a population.
Dependency ratio	This describes the ratio of people in the ages defined as dependent (under 15 years and over 64 years) to people in the ages defined as economically productive (15–64 years) in a population.
Desalination	Processes that remove the excess salt and other minerals from water in order to obtain freshwater that is suitable for consumption or irrigation.
Desertification	Desertification is a type of land degradation in drylands in which biological productivity is lost due to natural processes or induced by human activities whereby fertile areas become increasingly desert-like.

Term	Definition
Detritivores	Organisms that ingest and internally digest detritus.
Dew harvesting	A process that involves using the passive process of condensation to obtain clean and potable water from water vapour.
Doubling time	The number of years it would take a population to double its size at its current growth rate.
Ecocentrism	A viewpoint that puts ecology and nature as central to humanity and emphasizes a less materialistic approach to life with greater self-sufficiency of societies.
(Principles of) ecological design	These principles aim to ensure designed artifacts work in harmony with the environment through sustainable means. Size, shape, wildlife corridors, edge effects, and proximity to human influence are considered.
Ecological footprint	The area of land and water required to support a defined human population at a given standard of living; the measure takes account of the area required to provide all the resources needed by the population and the disposal of waste materials.
Ecological pyramids	Quantitative models showing changes between organisms at different trophic levels in a food chain. They include pyramids of numbers, biomass, and productivity.
Ecosystem	A community and the physical environment with which it interacts.
El Niño Southern Oscillation (ENSO)	A periodic warming of the eastern Pacific, where a reversal of the normal air and ocean circulation patterns for low latitudes occurs.
Emergent properties	Characteristics that are shown by a whole system but not by individual components of the system.
Emigration rate	The number of emigrants departing an area of origin per 1,000 population in that area of origin in a given year.
Endocrine-disrupting chemicals (EDCs)	Chemicals that are found in various materials such as pesticides, metals, additives or contaminants in food, and personal care products. EDCs have been suspected to be associated with altered reproductive function in males and females, increased incidence of breast cancer, abnormal growth patterns and neurodevelopmental delays in children, as well as with changes in immune function. (Monneret, 2017)
Enhanced greenhouse effect	The additional heat retained by the atmosphere, and its impacts on the Earth's climate, due to increased CO_2, methane and nitrous oxide (dinitrogen oxide, N_2O) present in the atmosphere since the Industrial Revolution. It is also referred to as climate change.
Environmental education	An education that teaches children and adults how to learn about and investigate their environment, and to make intelligent, informed decisions about how they can take care of it.
Environmental ethics	The branch of philosophy that studies the moral relationship of human beings to the environment, and the value and moral status of other species.
Environmental impact assessment (EIA)	Environmental impact assessment (EIA): a method of detailed survey required, in many countries, before a major development. Ideally, it should be independent of, but paid for by, the developer. It should

Term	Definition
	include a baseline study, and monitoring should continue after completion of the project.
Environmental justice	The rights of all people to live in an unpolluted environment and have equal access to natural resources.
Environmental Management Systems (EMS)	A set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency.
Environmental Value System (EVS)	A perspective that shapes the way an individual, or group of people, perceives and evaluates environmental issues, and is influenced by cultural, religious, economic and sociopolitical contexts.
Equilibrium	A state of balance among the components of a system.
Equity	The state, quality, or ideal of equality and justice between economic classes, ethnic and cultural groups, and the fair distribution of resources.
Estuary	An area where a freshwater river or stream meets the ocean, resulting in brackish water.
Estuary storage	A barrage built across the mouth of the estuary to prevent direct seawater intrusion.
Eutrophication	The natural or artificial enrichment of a body of water, particularly with respect to nitrates and phosphates, that results in the depletion of the oxygen content of the water. Eutrophication is accelerated by human activities that add detergents, sewage or agricultural fertilizers to bodies of water.
Ex situ conservation	The conservation of a species outside of its natural habitat.
Extensive farming	An agricultural system with relatively low levels of inputs of fertilizers, pesticides, machinery and labour per unit of land.
Extinction rate	The number of species becoming extinct over time.
Feedback	This occurs when part of the output from a system returns as an input, and affects subsequent outputs.
First law of thermodynamics	The principle of conservation of energy, which states that energy can be transformed but cannot be created or destroyed.
Flagship species	A "charismatic" species selected as an "ambassador" to raise support and awareness for the conservation of its habitat where other species are also threatened.
Flow	A movement of matter, energy or information between storages in a system.
Food security	A measure of the availability of food and individuals' ability to access it. Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.
Food webs	Two or more food chains linked together and can show that a single species can occupy multiple trophic levels.
Fundamental niche	This describes the full range of conditions and resources in which a species could theoretically survive and reproduce.
Genetic diversity	The range of genetic material present in the population.

Term	Definition
Ghost fishing	This occurs when fishing gear has been lost, dumped or abandoned and continues to kill aquatic species.
Global warming	An increase in the average temperature of the Earth's atmosphere.
Green architecture	A sustainable method of building, where design and construction are carried out with the environment in mind. Green architects aim to create energy efficient, environmentally friendly buildings.
Green economy	An economy that is low carbon, resource efficient and socially inclusive.
Green GDP	This measures environmental costs and subtracts these from GDP.
Greenhouse effect	A natural process where long-wave, infrared radiation emitted from the earth's surface is absorbed by certain gases in the atmosphere. Some of this absorbed heat is re-emitted towards earth, serving to warm the atmosphere and insulate the planet to the extent that life is possible.
Greenhouse gas	Atmospheric gases which absorb infrared radiation, causing world temperatures to be warmer than they would otherwise be. The natural greenhouse effect is caused mainly by water and carbon dioxide.
Grey water	Any domestic wastewater produced, excluding sewage.
Gross primary productivity (GPP)	The total gain in energy or biomass per unit area per unit time fixed by photosynthesis in green plants.
Gross secondary productivity (GSP)	The total gain by consumers in energy or biomass per unit area per unit time through absorption.
Habitat diversity	The range of different habitats or number of ecological niches per unit area in an ecosystem, community or biome. Conservation of habitat diversity usually leads to the conservation of species and genetic diversity.
Harmful algal blooms (HABs) (also called "red tides")	These blooms occur when colonies of algae grow out of control and produce toxic or harmful effects on people, fish, shellfish, marine mammals and birds.
Heterotrophs	Organisms that obtain their organic nutrients from other organisms.
Immigration rate	The number of immigrants arriving at a destination per 1,000 population at that destination in a given year.
In situ conservation	Conservation of a species within its natural habitat.
Inorganic (substance)	Compounds which do not contain carbon (with the exception of carbon dioxide and carbonates) and are not derived from living matter.
Intensive farming	An agricultural system aiming to maximize productivity from a given unit of land with a relatively high number of inputs (for example, agrochemicals and labour) per unit area of land.
Intrinsic value	A characteristic of a natural system that has an inherent worth, irrespective of economic considerations, such as the belief that all life on Earth has a right to exist.
Invasive species	Introduced species can become invasive if they threaten the ecosystems or societies in which they were introduced.
Issues	These are important topics in ESS; for example, resource management, pollution, globalization and energy security.

Term	Definition
Justice	The idea that people are treated impartially, fairly, properly and reasonably by others, the law and arbiters of the law.
Key biodiversity areas (KBA)	Key sites that contribute significantly to global biodiversity in a range of terrestrial, freshwater and marine ecosystems.
K-strategist	Species that usually concentrate their reproductive investment in a small number of offspring, thus increasing their survival rate and adapting them for living in long-term climax communities.
Land degradation	This occurs when the economic and biological productivity of land is lost, primarily through human activities.
Latitude	The angular distance from the equator (north or south of it) as measured from the centre of the Earth (usually in degrees).
Leverage point	This refers to a place(s) within a complex system (for example, a living body, a society, an ecosystem) where a small alteration in one component can produce large overall changes.
Life expectancy	The average number of years that a person can be expected to live, usually from birth, if demographic factors remain unchanged.
Limiting factor	Factors that can significantly impact population size.
Mass extinction	Events in which 75% of the species on Earth disappear within a geologically short time period, usually between a few hundred thousand to a few million years.
Maximum sustainable yield (MSY)	The largest yield or catch that can theoretically be taken from a species' stock without permanently depleting the stock.
Mitigation	Strategies involve reduction and/or stabilization of GHG emissions and their removal from the atmosphere.
Model	A simplified version of reality that can be used to understand how a system works and to predict how it will respond to change.
Mutualism	A relationship between individuals of two or more species in which all benefit and none suffer. (The term symbiosis will not be used.)
Natural capital	A term that includes all natural resources that can provide a sustainable natural income (carefully managed renewables) and those that are finite and can only produce an unsustainable yield.
Natural capital (nonrenewable)	Natural resources that cannot be replenished within a timescale relative to that in which they are taken from the environment and used; for example, fossil fuels.
Natural capital (renewable)	Natural resources that have a sustainable yield or harvest equal to or less than their natural productivity; for example, food crops, timber.
Natural income	The yield obtained from natural resources.
Natural increase	Fluctuation between the birth rate and death rate.
Natural selection	A process by which individuals with genetic mutations that confer enhanced sexual selection and/or enhanced survival in a changing environment have a greater chance to reproduce and pass on the beneficial genes to offspring.
Negative feedback	Feedback that tends to counteract any deviation from equilibrium and promotes stability.

Term	Definition
Net primary productivity (NPP)	The gain by producers in energy or biomass per unit area per unit time remaining after allowing for respiratory losses (R). This is potentially available to consumers in an ecosystem.
Net secondary productivity (NSP)	The gain by consumers in energy or biomass per unit area per unit time remaining after allowing for respiratory losses (R).
Niche	The ecological role of a species in an ecosystem and the range of conditions necessary for its survival. An organism's ecological niche depends not only on where it lives but also on what it does.
Nitrification	The conversion of ammonia to nitrates by bacteria.
Nitrogen fixation	The conversion of atmospheric nitrogen to ammonia by bacteria and/or lightning.
Ocean acidification	A reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO_2) from the atmosphere.
Open system	A system that exchanges both matter and energy with its surroundings (for example, an ecosystem).
Organic (substance)	Carbon-containing molecules associated with living organisms; for example, carbohydrates, lipids, nucleic acids, proteins, and hydrocarbon fuels.
Organism	An individual plant, animal, fungus, or any living thing.
Parasitism	A relationship between two species in which one species (the parasite) lives in or on another (the host), gaining all or much (in the case of a partial parasite) of its food from it.
Peroxyacyl nitrates (PANs)	A secondary pollutant and component of photochemical smog, produced in the atmosphere when oxidized volatile organic compounds combine with nitrogen oxide.
Perspectives	Particular viewpoints, which may vary between different interest groups, that can exist at a variety of scales.
Photoautotroph	Organisms which use sunlight to synthesize organic nutrients from inorganic sources.
Photosynthesis	carbon dioxide + water → glucose + oxygen
Plagioclimax	Interrupted succession, where disturbance can stop the process of succession so that the climax community is not reached.
Planetary boundaries	Processes that regulate the stability and resilience of the Earth system, within which humanity can continue to develop and live sustainably; crossing these boundaries increases the risk of creating sudden, extensive or irreversible environmental changes.
Planetary health	The health of human civilization and the state of the natural systems upon which it depends.
PM10	A component of air pollution that is made of larger particulate matter with a diameter of 10 micrometres.
PM2.5	A component of air pollution that is made of fine particulate matter with a diameter of 2.5 micrometres or less.
Polychlorinated biphenyl (PCB)	Chemicals that affect innate immune functions in humans.

Term	Definition
Population	A group of organisms of the same species living in the same area at the same time, and which are capable of interbreeding.
Population structure	This is the breakdown of different groups and numbers of people in an area; it is important as it affects the area itself. Population structure includes consideration of age, gender, ethnicity, and density.
Positive feedback	Feedback that increases change; it promotes deviation away from an equilibrium.
Primary productivity	The gain by producers in energy or biomass per unit area per unit time. This term could refer to either gross or net primary productivity.
Primary succession	The process of life that begins on a substrate that does not contain living organisms or soil. Examples are after a glacier retreats or a lava flow, where there is new, lifeless rock exposed. The process goes through a series of intermediate stages leading to a climax community.
Producers	Typically, plants or algae that produce their own food using photosynthesis and form the first trophic level in a food chain.
Product stewardship	An environmental management strategy that means whoever designs, produces, sells, or uses a product takes responsibility for minimizing the product's environmental impact throughout all stages of the product's life.
Radiative forcing	A measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.
Realized niche	The actual conditions and resources in which a species exists due to biotic interactions.
Resilience	The resilience of a system, ecological or social, refers to its tendency to avoid tipping points and maintain stability.
Respiration	glucose + oxygen → carbon dioxide + water.
Reverse osmosis (RO)	The process of purifying water through a semipermeable membrane, used in desalination.
r-strategist	Species that tend to spread their reproductive investment among a large number of offspring so that they are well adapted to colonize new habitats rapidly and make opportunistic use of short-lived resources.
Rural	This describes the state of the relatively low density and dispersed settlement in the countryside.
Rural-urban migration	The migration of people from rural to urban areas due to perceived or real advantages of urban settlements.
Saprotrophs	Heterotrophs that digest and absorb detritus.
Second law of thermodynamics	This law states that the quality of energy changes as it is transferred or transformed, from useful energy (for example, solar radiation) to low-quality energy (for example, heat).
Secondary productivity	The biomass gained by consumers, through feeding and absorption, measured in units of mass or energy per unit area per unit time.

Term	Definition
Secondary succession	The process of life that begins with a biological footprint, such as soil and the organisms within it. It often occurs after a disturbance such as a forest fire or a recently clear-cut forest. The process goes through a series of intermediate stages leading to a climax community.
Seral stage	An intermediate stage found in ecological succession in an ecosystem advancing towards its climax community.
Sere	The set of communities that succeed one another over the course of succession at a given location.
Sewage treatment	The process of removing contaminants from wastewater and household sewage water.
Society	An arbitrary group of individuals who share some common characteristics, such as geographical location, cultural background, historical time frame, religious perspective, value systems and so on.
Soil	A mixture of mineral particles and organic material that covers the land, and in which terrestrial plants grow.
Soil profile	A vertical section through a soil, from the surface down to the parent material, revealing the soil layers or horizons.
Solar distillation	The process of using energy from the sun to separate freshwater from salts and other contaminants. Solar stills can be used for low-capacity and self-reliant water-supplying systems.
Solid domestic waste (SDW)	Household waste such as paper, glass, metal, plastics, organic (kitchen or garden), packaging, construction debris, and clothing.
Speciation	The formation of new species when populations of a species become isolated geographically or behaviourally and evolve differently from other populations.
Species	A group of organisms that share common characteristics and that interbreed to produce fertile offspring.
Species diversity	The variety of species per unit area. This includes both the number of species present (richness) and their relative abundance (evenness).
Specific heat capacity	The quantity of heat needed to raise the temperature of a unit mass by one degree of temperature (°C/K).
Stable equilibrium	The tendency in a system for it to return to a previous equilibrium condition following disturbance.
Steady-state equilibrium	The condition of an open system in which there are no changes over the longer term, but in which there may be oscillations in the very short term.
Stewardship	The responsible management and protection of something that is considered worth caring for and preserving.
Storage	The locations where matter, energy or information is held in a system.
Suburbanization	The movement of people from inner urban areas to the outskirts of urban areas (often leading to urban sprawl).
Succession	The process of change over time in an ecosystem.
Sustainability	Definitions of sustainability begin with the idea that development should meet the needs of the present without compromising the ability

Term	Definition
	of future generations to meet their needs. It refers to limiting the degree to which the current generation's activities create harmful environmental outcomes involving resource depletion or degradation that will negatively affect future generations. Sustainability is increasingly important as planetary boundaries are pushed to their limit. Sustainability today has three integrated aspects: environmental, sociocultural (including political) and economic.
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland, 1987)
System	An assemblage of parts and the relationships between them, which together constitute an entity or whole.
Systems approach	A system is composed of interrelated and interdependent elements that can be collectively regarded as a unitary whole. A systems approach explores connections and interdependencies between the elements and within the system as a whole.
Technocentrism	A viewpoint that argues that technological developments can provide solutions to environmental problems.
Temperature inversion	This occurs due to a lack of air movement when a layer of dense, cool air is trapped beneath a layer of less dense, warm air. This causes concentrations of air pollutants to build up near the ground instead of being dissipated by "normal" air movements.
Thermocline	The transition layer between the warmer mixed water at the surface and the cooler deep water below.
Thermohaline circulation	Large scale, density-driven circulation in the world's oceans, caused by differences in temperature and salinity.
Tipping cascades	Crossing a threshold in one part of the climate system may trigger another tipping element to tip into a new state.
Tipping point	A critical threshold when even a small change can have dramatic effects and cause a disproportionately large response in the overall system.
Total fertility rate	The average number of births per woman of childbearing age.
Tragedy of the Commons	A concept that explains how the short-term interest of the individual can lead to overconsumption of common natural resources at the expense of the broader society.
Transfers	Processes that involve a change in location within the system but no change in the state.
Transformations	Processes that lead to the formation of new products or involve a change in the state.
Trophic level	The position that an organism occupies in a food chain, or the position of a group of organisms in a community that occupy the same position in food chains.
Tropical cyclone	A rapidly circulating storm system with a low-pressure centre that originates in the tropics and is characterized by strong winds.

Term	Definition
Upwelling	The mass, vertical movement of cold, nutrient-rich waters from the depths to the surface in response to the displacement of windblown surface waters.
Urban area	A dense assemblage of buildings and people located close together for residential, cultural, productive, trade and social purposes.
Urban ecology	Urban ecology is the scientific study of the relationship of organisms with each other and their surroundings in an urban environment.
Urbanization	The process of making a landscape more built-up, industrialized and dominated by close human settlements.
UVA	The most harmless and longest wavelength category of ultraviolet radiation (320–400 nm). This type of UV is not blocked or absorbed by stratospheric ozone.
UVB	The medium wavelength category of ultraviolet radiation (290–320 nm). This type of UV is mostly blocked or absorbed by stratospheric ozone.
UVC	The most harmful and shortest wavelength category of ultraviolet radiation (100–290 nm). This type of UV is entirely blocked or absorbed by stratospheric ozone.
Walker circulation	An east-west atmospheric circulation system above the equatorial Pacific. Changes to this circulation system can result in El Niño or La Niña conditions.
Water Quality Index (WQI)	A single weighted average, consisting of the combined results of several individual water-quality test parameters, representing the degree of contamination in a given water sample.
Water transfer	Any (pumped) movement of water from one river catchment to another, using river reversal or pipeline.
Weather	This describes the conditions in the atmosphere (temperature, humidity, air pressure, wind speed, etc.). Over a short period of time.
Zonation	The arrangement or patterning of communities or ecosystems in response to change, over a distance, in some environmental factor.

Updates to the publication

This section outlines the updates made to this publication. The changes are ordered from the most recent to the oldest updates. Minor spelling and typographical corrections are not listed.

Changes for July 2024

Introduction > The ESS course

Engagement

Correction of error in the previous version.

In Figure 2, the phrase “HL extension lenses” has been changed to “HL lenses”.

Planning the course > Integrating the HL lenses

HL.a Environmental law

Correction of error in the previous version.

In HL.a.11, The phrase “The river person” has been replaced with “*Te Pou Tupua*”.

The experimental programme of the ESS course > Individual investigation

Generating data > Using databases and simulations

Introduction of revised content.

In the first paragraph, the sentence “Databases and simulations are freely accessible online.” has been replaced with “Students using databases and simulations should provide the necessary screenshots, including web addresses or the program name, to clearly demonstrate appropriate data collection and manipulation in support of their methodology. Databases and simulations that are free or behind paywalls are acceptable.”