semester 3

Science - II

COURSE GUIDE

Associate Degree in Education/
B.Ed. (Hons) Elementary

2012

Higher Education Commission

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Technical Support: Education Development Center (EDC); Teacher's College, Columbia University

Higher Education Commission

Foreword

Teacher education in Pakistan is leaping into the future. This updated Scheme of Studies is the latest milestone in a journey that began in earnest in 2006 with the development of a National Curriculum, which was later augmented by the 2008 National Professional Standards for Teachers in Pakistan and the 2010 Curriculum of Education Scheme of Studies. With these foundations in place, the Higher Education Commission (HEC) and the USAID Teacher Education Project engaged faculty across the nation to develop detailed syllabi and course guides for the four-year B.Ed. (Hons) Elementary and the two-year Associate Degree in Education (ADE).

The syllabi and course guides have been reviewed by the National Curriculum Review Committee (NCRC) and the syllabi are approved as the updated Scheme of Studies for the ADE and B.Ed. (Hons) Elementary programmes.

As an educator, I am especially inspired by the creativity and engagement of this updated Scheme of Studies. It offers the potential for a seismic change in how we educate our teachers and ultimately our country's youngsters. Colleges and universities that use programmes like these provide their students with the universally valuable tools of critical thinking, hands-on learning, and collaborative study.

I am grateful to all who have contributed to this exciting process; in particular the faculty and staff from universities, colleges, and provincial institutions who gave freely of their time and expertise for the purpose of preparing teachers with the knowledge, skills, and dispositions required for nurturing students in elementary grades. Their contributions to improving the quality of basic education in Pakistan are incalculable. I would also like to thank the distinguished NCRC members, who helped further enrich the curricula by their recommendations. The generous support received from the United States Agency for International Development (USAID) enabled HEC to draw on technical assistance and subject-matter expertise of the scholars at Education Development Center, Inc., and Teachers College, Columbia University. Together, this partnership has produced a vitally important resource for Pakistan.

PROF. DR. SOHAIL NAQVI
Executive Director
Higher Education Commission
Islamabad

How this course guide was developed

As part of nation-wide reforms to improve the quality of teacher education, the Higher Education Commission (HEC) with technical assistance from the USAID Teacher Education Project engaged faculty across the nation to develop detailed syllabi and course guides for the four-year B.Ed. (Hons) Elementary and two-year Associate Degree in Education (ADE).

The process of designing the syllabi and course guides began with a curriculum design workshop (one workshop for each subject) with faculty from universities and colleges and officials from provincial teacher education apex institutions. With guidance from national and international subject experts, they reviewed the HEC scheme of studies, organized course content across the semester, developed detailed unit descriptions and prepared the course syllabi. Although the course syllabi are designed primarily for student teachers, they are useful resource for teacher educators too.

In addition, participants in the workshops developed elements of a course guide. The course guide is designed for faculty teaching the B.Ed. (Hons) Elementary and the ADE. It provides suggestions for how to teach the content of each course and identifies potential resource materials. In designing both the syllabi and the course guides, faculty and subject experts were guided by the National Professional Standards for Teachers in Pakistan 2009 and the National Curriculum 2006. The subject experts for each course completed the initial drafts of syllabi and course guides. Faculty and student teachers started using drafts of syllabi and course guides and they provided their feedback and suggestions for improvement. Final drafts were reviewed and approved by the National Curriculum Review Committee (NCRC).

The following faculty were involved in designing this course guide: Zubaida Kifayat, F.G Elementary College for Women, Skardu; Bilqees Batool, F.G Elementary College for Women, Skardu; Alia Ayub, Sardar Bahadur Khan Women University, Quetta; Kifayat Khan, Hazara University, Haripur; Waheed Akbar, Hazara University, Mansehra; Mohammad Shaban, GCET Rawalakot; Shahida Iqbal Nizami, GCET Muzaffarabad; Anwar ul Haque, GCET Muzaffarabad; Dr. Abdul Ghaffar, GCET Faisalabad; Muhammad Altaf, GCET Lala Musa; Riazalai Gorai, GCE Gilgit; Muhammad Nasir Khan, GCE (M) Gilgit; Muhammad Iqbal, GCE Gilgit; Asghar Ali Khan, GCET Kasur; Khalid Mahmood, GCET Shahpur Sadar; Tahseen Lateef, GECE (M) Lyari; Ali Asghar Khaskheli, GECE (M) Hyderabad; M. Faheem Kausar, GCE Quetta; Rubina Masood, GCE Quetta; Parveen Ashraf, GCET Rawalakot; Shahnaz Bibi, GCET DG Khan; Naeema Rasool, GCET Bahawalpur; Muhammad Siddique Kalwar, GECE (M) Sukkur; Naureen Mumtaz, University of Education, Lahore; Bushra Bano, GCEE Sibi (F); Banafsha Khan, GCEE Pishin; Fouzia Ghias, Fatima Jinnah Women University, Rawalpindi; Liaquat Hussain, Gomal University; Zubair Ahmed, University of Sindh; Mumtaz Hussain, F.G Elementary College for Women, Skardu; Liaqat Ali, F.G Elementary College for Women Skardu; Dr. Rafaqat Ali Akbar, IER University of the Punjab; Muhammad Nadeem, RITE DI Khan; Muhammad Sharif, RITE(M) Kohat; Humaira Abbasi, University of AJK; Safia Khatoon, GECE (W) Hyderabad; Ch. Khalid Mahmood, GCET Shahpur Sadar; Tufail Muhammad.

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Date of NCRC review: 3 March 2012

Reviewers: Dr. Rizwan Akram, University of the Punjab, Lahore; Dr. Parveen Munshi, Sindh University; Dr. Rehana Masroor, Allama Iqbal Open University, Islamabad; Dr. Nabi Bux Jummani, International Islamic University Islamabad.

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Syllabus

SCIENCE II

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Year/semester

Year 2, semester 3

Duration (hours)

48 hours (16 weeks)

Credit value

3 credits

Prerequisites

Matriculation (with a science subject)

Course description

This course will strengthen prospective Student Teachers' subject-matter knowledge. It provides further opportunity to deepen the pedagogical science content knowledge required to effectively teach general science in elementary school. The course covers core concepts in physical science, life science, and earth science. It also covers teaching strategies and instructional approaches that best support the development of a conceptual understanding of science. In contrast to Science I, which dealt with simpler concepts, Science II establishes connections between core concepts, such as matter and energy, and entire systems, such as Earth's systems or systems within the human body.

After taking Science I and Science II, Student Teachers will be well prepared to implement the National Curriculum in elementary grades 1–5.

Science I and Science II integrate science content with science pedagogy and skill building. Both courses are designed to prepare prospective elementary teachers to teach inquiry science in grades 1–5. Their (pedagogical) content knowledge is chosen accordingly. It is recommended that prospective science teachers who want to teach science in lower secondary grades (6–8) deepen their science knowledge further by attending additional science classes offered in year 3 and year 4 of the B.Ed. (Hons) program.

Course outcomes

After completing this course, Student Teachers will be able to:

- Describe forms and interactions of energy and matter, including energy transfer and transformations, as they apply to chemical and physical processes with an emphasis on events/phenomena in everyday life.
- Begin to see that complex interactions among the atmosphere, the hydrosphere, and the lithosphere in Earth's systems undergo constant change. Understand the theory of plate tectonics as it relates to Pakistan's mountain formations and earthquakes. Provide examples of advances in technologies that have made it

possible to more accurately predict natural disasters and provide life-saving warnings (for floods, hurricanes, etc.). Explain how human activities influence air and water quality, ecosystems, and climate across the globe.

- Begin to understand the vastness and age of the universe and be able to discuss the characteristics and differences of objects within our solar system.
- Describe the flow of matter and energy in living systems and apply it to the human body to explain, for instance, the circulatory and digestive systems.
- Be able to understand the purpose of scientific models and tools and use them appropriately. Examples are the periodic table, classification tables, maps, and models of particle theory and the atom. In addition, be able to demonstrate and teach data collection, recording, and graphing to present conclusions of investigations.

Teaching-learning framework

Throughout this course, pedagogy is interwoven with the content development. Faculty will model inquiry teaching to Student Teachers in order for them to experience the learning and teaching of science using inquiry methods. Thoughtful discussions will follow such hands-on experiences to clarify the applied methods and expected learning. These reflections are essential because it is through these discussions that Student Teachers will gain essential transfer and pedagogical content knowledge needed for after graduation, when they enter the field and teach science to children in elementary grades. Therefore, it is critical to give them the opportunity to reflect on what they are experiencing as learners as well as opportunities to practice their role as teachers. They can thus develop meaningful activities around core concepts that will enable children in elementary grades to gain deeper conceptual understanding and allow them to modify these activities to best meet the needs of their individual classrooms.

In addition to content and pedagogical content knowledge, this course is also designed to help Student Teachers develop science thinking and process skills.

After completing this course, Student Teachers will be able to:

- apply inquiry to the teaching of science at the elementary level
- identify, adapt, and modify investigations that lead to conceptual understanding
- design science investigations around core concepts
- understand the need for learning progressions
- recognize common misconceptions and be able to respond with appropriate remedies
- use open-ended questions to assess children's conceptual understanding
- provide children with exciting science experiences that extend their natural fascination with the world and help them learn the science skills and concepts they will need in later schooling and in life
- reflect on their teaching to develop a personal approach to the teaching of science.

Semester outline

UNIT 1:	Course Overview
Week #	Topics/themes
1	Overview of course content (science and teaching) Life of scientists and the role of science in society Nature of science and its application for teaching Introduction to independent course project, possible topics, and criteria

During this unit, Student Teachers will:

- understand that science reflects its history and is an ongoing, changing enterprise
- read about and reflect on the nature of science and apply it to their own learning and teaching
- distinguish between observation and inference
- read about famous scientists and their lives and relate their scientific quest to their own lives
- investigate and present a science topic of their choice, applying their science and teaching of science knowledge and following specific criteria (research component, science explanations, and transfer of conclusions to teaching in elementary school grades).

UNIT 2:	Energy transfer, transformations, and conservation
Week #	Topics/themes
2	Types of energy (heat, light, sound, kinetic, potential, gravitational, etc.) Investigating light
3	Energy transfer and transformation: concepts of conduction, convection, and radiation Law of conservation of mass and energy
4	Teaching 'populations and ecosystems' in elementary grades

During this unit, Student Teachers will:

- distinguish among different forms of energy (kinetic, potential) and demonstrate that energy can be transferred and transformed
- provide examples of kinetic energy being transformed into potential energy and vice versa
- recognize that heat can spread from one place to another in predictable ways
- provide examples of the transfer of energy from hotter to cooler objects by conduction, radiation, or convection
- explain that energy can be transferred (e.g. by collisions and radiation) but never destroyed (conservation of energy)

[1] These objectives will be continued and deepened in unit 3, Energy and matter, where the focus of energy transfers will be on the microscopic level (between and within atoms)—for instance, understanding chemical reactions (exothermic and endothermic) and radioactivity.

- differentiate the states of matter based on their energy state (e.g. the structure of molecules and atoms in these different states varies from rigid in solids to independent motion in a gas)
- view thermal energy (i.e. heat) in terms of atomic and molecular motion (i.e. the higher the temperature, the greater the atomic or molecular motion)[1]
- compare the transmission, reflection, refraction, and absorption of light using different materials
- listen for Student Teachers' misconceptions about properties and particle theory and try to correct them
- identify the underlying core science concepts in this unit for children in elementary grades
- design age-appropriate, inquiry-based activities and identify learning outcomes.

3 UNIT 3:	**Interactions of energy and matter**
Week #	Topics/themes
5	Review of physical and chemical properties and physical change Solutions and solubility Conservation of mass in solutions
6	Introduction to chemical reactions Difference between chemical and physical reactions The role of energy in explaining bonds Applications of electrolysis
7	Teaching 'interactions of energy and matter' in elementary grades

During this unit, Student Teachers will:

- differentiate between physical and chemical properties and physical and chemical change
- gain an understanding that mass is conserved even when materials are dissolved
- investigate how some common materials interact to form new materials
- explain how in physical change, properties of substances remain the same
- provide examples of how the properties of a product of a chemical change are different than the products of the reactants
- provide examples of the natural world in which energy is released (or needed) in chemical reactions (e.g. burning fossil fuels, photosynthesis)
- be able to identify some of the underlying core science concepts in this unit for children in elementary grades
- design age-appropriate, inquiry-based activities and identify learning outcomes
- be aware of misconceptions about energy and matter and learn what to do about them.

UNIT 4: Earth's systems undergoing constant change

Week #	Topics/themes
8	Water, carbon, and rock cycles Theory of plate tectonics: living in the shadow of the big mountains
9	Climate change
10	Teaching 'Earth's systems undergoing constant change' in elementary grades

During this unit, Student Teachers will:

- see the Earth as a system consisting of major interacting components that consistently undergo change; identify physical, chemical, and biological processes that act within and among them on a wide range of scales
- begin to see that there are complex interactions among the atmosphere, the hydrosphere, and the lithosphere
- apply the theory of plate tectonics to explain the formation of Pakistan's mountain ranges and the threat of earthquakes
- recognize how the movement of Earth's lithospheric plates causes slow changes in Earth's surface (e.g. formation of mountains and ocean basins) and rapid ones (e.g. volcanic eruptions and earthquakes)
- give examples of advances in technology that have made it possible to more accurately predict natural disasters
- understand how human activities influence air and water quality, ecosystems, and climate across the globe
- identify the underlying core science concepts in this unit for children in elementary grades
- design age-appropriate, inquiry-based activities and identify learning outcomes.

UNIT 5: Solar system and the universe

Week #	Topics/themes
11	Characteristics of our solar system Earth and Sun compared to other objects in the sky Working with and understanding large distances
12	Origin and evolution of Earth (and the solar system)
13	Teaching 'our solar system and the universe' in elementary grades

During this unit, Student Teachers will:

- differentiate groups of objects in the solar system—including the Sun; the planets and their moons and rings; and smaller objects, such as asteroids and comets—by their size, composition, and position in the solar system

- compare and contrast the properties and characteristics of Earth with those of the other planets in our solar system
- explain, based on the naked eye and telescopic observation, how objects in the solar system change position against the background of stars
- begin to understand the scale of time and distance involved in deep space
- describe how the early Earth was very different from the planet we live on today
- identify the underlying core science concepts in this unit for children in elementary grades
- design age-appropriate, inquiry-based activities and identify learning outcomes.

6 UNIT 6:	**Human body as a system**
Week #	Topics/themes
14	Flow of matter and energy in living systems Circulatory and digestive systems Structure, function, and organization of different cells
15	Cell processes Cellular respiration
16	Teaching 'human body as a system' in elementary grades

During this unit, Student Teachers will:

- connect an organism's need for food with cells' need for food
- explain how multiple body systems work together to meet cells' energy needs
- examine and describe the flow of matter and energy in living systems
- demonstrate through investigations that food is a source of energy (fuel) and building materials for cells
- relate cellular respiration to the functions of body systems (e.g. how body systems function to provide cells with the necessary raw materials).

Suggested Textbooks and references

The Teaching of Science in Primary Schools by Wynne Harlen

Inquiry: Thoughts, Views, and Strategies for the K–5 Classroom, National Science Foundation

Ready, Set, Science! Putting Research to Work in K–8 Science Classrooms, National Research Council

Taking Science to School: Learning and Teaching Science in Grades K–8, National Research Council

The History of Science is a website that provides standards-aligned resources that make it easier to bring the history of science into a classroom. This site focuses on chemistry standards likely to be found in an introductory chemistry or physical science class.

➢ http://cse.edc.org/products/historyscience/default.asp.

Course assignments

Suggested assignments are included in the unit guides of the course. Some are short-term assignments, and some take several weeks to complete. A mixture of individual and group assignments is also provided.

These assignments are designed to deepen Student Teachers' learning and allow them to research and apply their knowledge to topics of personal interest. All the assignments count towards the final grade.

Assignments are similar to those conducted in Science I but are more complex and self-directed, as follows:

- Conduct an investigation on a science topic and present your findings and conclusions
- Develop an investigation around a core science concept for an elementary grade
- Write an editorial for a local newspaper on a relevant science topic, stating an opinion supported by evidence
- Using the inquiry approach, plan and teach a science activity in a local elementary school

In addition, as part of Science II, Student Teachers will conduct an independent research project during the course that will mirror a real-life context and investigation. Examples of such topics could be the following:

- Design a model to explain the greenhouse effect
- Research how Pakistan generates its electricity and provide a report on how some of it could be supplemented by using renewable energy
- Research waste management and recycling
- Research natural resources in Pakistan
- Research natural disasters in Pakistan
- Research infectious diseases

Grading policy

The course grading policy should be determined by the university and its affiliated colleges. The policy should be shared with Student Teachers at the beginning of the course. It is recommended that at least 50% of the final grade be determined by coursework completed by Student Teachers. Coursework may include work completed in assignments in or outside the classroom.

UNIT 1

COURSE INTRODUCTION

Unit Overview

This introductory week of Science II is divided into two parts: session 1 provides Student Teachers with an overview of the course content and the expectations for the course. Sessions 2 and 3 provide a deeper understanding of the nature of science (introduced in Science I). They allow Student Teachers to further hone their skills and the methods that are important for science and science teaching.

In Science II, Student Teachers continue to study science content to deepen and expand their previous science understanding. Science II builds upon Science I. The content covers the four science disciplines: biology, earth and space science, physics, and chemistry.

Science I laid the foundation; Science II builds upon this knowledge and covers more complex and abstract topics, making connections between individual topics and concepts. For instance, forces and energy are woven throughout Science II. Student Teachers can see their application in the different science disciplines. Seeing how science concepts connect across topics (and disciplines) provides them with a deeper conceptual understanding. Teaching science using an inquiry approach requires a solid conceptual understanding of the science concepts as well as pedagogy. If they struggle with some fundamental concepts, you might need to revisit some sections of Science I before moving on.

All the units (2–6) follow a consistent pattern—the same one used in Science I: the first two weeks provide prospective science teachers with learning opportunities to refresh and expand their own science understanding. The third week is dedicated to the art of teaching science concepts in the elementary grades.

As you did in Science I, you should model an inquiry approach when teaching Science II. Provide ample opportunity for hands-on experiences, discussions, and reflections. Be sure to give Student Teachers more opportunity for self-directed learning and teaching that can take place in groups with their peers. Science I experiments and assignments were more prescribed, whereas Science II allows for more freedom and flexibility so they can explore their own ideas (under your guidance). Challenge them with complex and open-ended questions. Whenever possible, substitute direct instruction with facilitated discussions.

The culture of discussing science introduced in Science I should continue in Science II. Student Teachers should feel comfortable asking probing questions, challenging other Student Teachers' responses, and always talking in full sentences to make their case. Reflecting upon newly gained understanding and voicing it allows for deeper learning. Verbal clarification offers an opportunity for others to hear an explanation again but phrased differently.

Student Teachers with more advanced content knowledge should see themselves as mentors. They are partners in the process of learning and teaching science rather than classmates who know it all and always answer the more difficult questions. Every Student Teacher should have ongoing chances to participate actively in all tasks and discussions. All contributions should be treated with respect and should not be dismissed or immediately marked as wrong. Even a 'wrong response' can start a thorough discussion about a concept.

The appeal and fascination of science and science teaching lies in inquiring about the natural world, learning how to study, and making sense of all the wonderful phenomena happening around us. Good science teaching uses this natural motivation and should be modelled in this course. All Student Teachers should use this approach when they teach in the schools.

In addition, this course combines basic ideas about the history of science, science in personal and social perspective, and science and technology. The ideas in each of these areas are not separated out in the units or dealt with individually. Instead, they are integrated, where appropriate, into the flow of the units.

Learning outcomes for this unit

Student Teachers should be able to:

- understand that science reflects its history and is an ongoing, changing enterprise
- read and reflect about the nature of science and apply it to their own learning and teaching
- distinguish between observation and inference
- read about famous scientists and their lives and relate the scientists' quests to their own lives
- investigate and present a science topic of their choice, applying their science and teaching of science knowledge and following specific criteria (e.g. research components, science explanations, and transfer of conclusions to teaching in the elementary school grades).

Unit 1/week 1: Introduction

(Sessions 1–3)

Suggested activity for session 1

Introductions and the role of scientists

In the first session, provide Student Teachers with an overview of the course and the expectations. Address any questions or concerns they might have as well as their expectations.

As part of the logistics of the course, inform them about the long-term projects that are part of this Science II experience and when they are due (suggestions are provided at the end).

Use the remainder of the class for Student Teachers to learn about some famous scientists, their work, their personal lives, and their aspirations and hardships.

You could begin this topic broadly by asking Student Teachers:

- What do you know about scientists and their work or research? Can you provide examples?
- Do you know a scientist or researcher personally? How would you describe his or her work?
- What role do scientists and their research play in society?
- What do you think your role is as a (science) teacher in society?

After Student Teachers discuss their ideas, provide them with some brief biographies about famous scientists and their stories. The reason for providing those brief stories is not as much to cover their scientific achievement but to share their personal stories. (Online examples are provided in the Additional resources section.) As an alternative, you can tell scientists' stories yourself. Ernest Rutherford and Dmitri Ivanovich Mendeleev would be particularly fitting examples for this course, but any scientist would do.

The purpose of this activity is to demystify and personalize the role of scientists. What we know about the world and beyond has been discovered and researched by more or less ordinary men and women, similar to the Student Teachers in this class. Not all were passionate about science when they were young. Some went to school; others didn't. Some were rich and privileged; others lived in poverty. Some worked countless hours in the lab but never made a big discovery. Others made a discovery by serendipity. Some were national heroes. Others were ridiculed for their work or did not receive recognition until after their death. Some were even prosecuted.

The quest to better understand the natural world around us is not over. As the saying goes: 'the more we know, the more we know what we don't know'. Student Teachers might share this feeling as they work through Science II. It is important to assure them that it is OK. Their progress and achievement in Science I and II should not be assessed by the quantity of information they memorize. Instead, focus mainly on the thinking skills that they have developed. Observe the way they apply information to solve a problem or prepare for their own teaching.

Student Teachers need to understand that science is a process that is grounded in content knowledge and skills—research skills as well as thinking skills. In this course, content development and skill development are equally important and should be taught simultaneously.

By the end of this first week of Science II, Student Teachers should be inspired and motivated. They should be eager to return to the class and engage in the process of science learning and science teaching.

Suggested activity for session 2

Review of observation and inference

Review what Student Teachers remember from their experiences in Science I. The main focus was on observations and inference (remind them of the bird tracks in unit 1). Being able to observe and infer are crucial skills for a scientist. It is important that they have a solid understanding before deepening other aspects of scientific skills and processes.

One way to review the concept is to use the following hands-on activity.

Prepare a tube as follows:

1) Acquire a cardboard tube (you can use the inside of a paper towel roll, a mailing tube, or a tube in which posters are stored).
2) Make four holes in the tube, as shown in Figure 1. Label them A, B, C, and D.
3) Acquire two pieces of rope. Each piece of rope should be twice as long as the tube (longer than they appear in Figure 1). Feed one through A and out at C; feed the other through B and out at D. Then tie off the ends so the ropes cannot be pulled out. You can also put the two ropes through a metal ring, as shown in the picture.
4) Cover the top and bottom of the tube so Student Teachers cannot see inside.

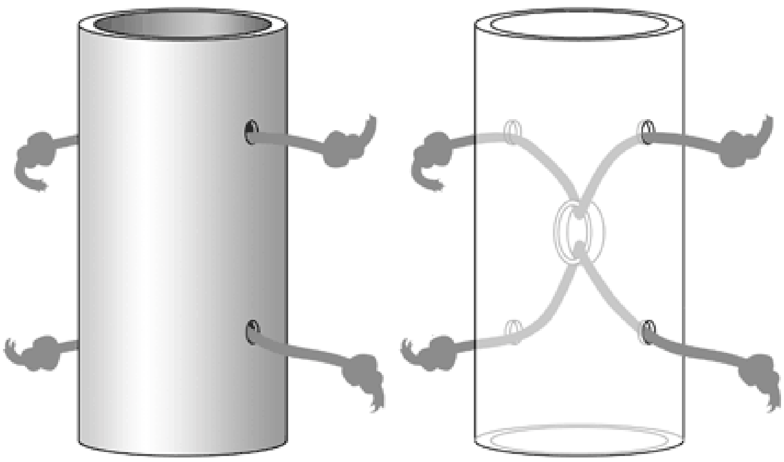


Figure 1: Schematic showing how to prepare the tube.

Present the tube to your Student Teachers and ask them to carefully observe and record all patterns of the ropes on the tube.

Perform the following five moves:

- Pull the rope all the way from A
- Pull the rope all the way from C
- Pull the rope all the way from D
- Pull the rope all the way from B
- Pull the rope all the way from D (again)

Repeat pulling the ropes until participants say that they have enough data to record the patterns of the rope. Give Student Teachers the opportunity to ask any questions and request any further rope movement.

Then have them work in pairs. Ask them to answer the following questions:

- What could the inside of the tube look like?
- What could make the ropes move like that?

Once Student Teachers seem to have a good idea of what the inside of the tube looks like, provide them with small tubes and string. Then ask them to build a model that can replicate the same five moves used in the model in the initial demonstration. Have them test their model by performing the five moves next to you using their model. If they agree that their models work, open all tubes and compare their insides. In most cases, not all tubes will have the same interior design. In fact, several solutions are possible (ropes threaded through a ring or ropes looping).

Debrief this activity by telling Student Teachers that they used observation and inference when they built their models. Just like scientists, they collected and interpreted the same data, but they might have come to different solutions (interior design). Data can sometimes be interpreted in different ways and, thus, result in different explanations of the same phenomenon.

Make it explicit to Student Teachers that what they have done is very similar to what scientists do: they observe phenomena and try to understand what is happening. Scientists are often very imaginative and creative.

Ask them to explain the difference between observation and inference based on this activity. Ask them to think of examples in science where observations are used and where inferences are needed (examples of inferences are the structure of the Earth, gravity, and the structure of the atom).

Conclude this activity by asking Student Teachers to respond to the following questions:

- Is any inference OK in science?
- How do you know which inference is better?
- What do you have to do to make a better inference?

Inform Student Teachers that in Science II (as in Science I), they will have many opportunities to observe and infer. They should use their critical-thinking skills to challenge each other and advance their thinking. As they do, they simulate the way scientists work. When scientists make observations about events, they often make a hypothesis about the cause of those events. They try to explain the underlying mechanism causing the event. (In the preceding activity, they made predictions about how the ropes were connected inside the tube.) When scientists make new observations that contradict their hypothesis, they must modify or totally change their original hypothesis. Scientists perform experiments or make more observations to test their new or modified hypothesis. This experimentation and hypothesis-modification process continues until a hypothesis can explain all of the observed data. Scientists often use models to understand and explain scientific phenomena and to test a hypothesis.

Suggested activities for session 3

Nature of science

Before Student Teachers dive into the content in Science II, session 3 provides a deeper view into the key principle of science. This vital principle is the way of 'knowing' in science, which is often referred to as the 'nature of science'. Understanding the nature of science helps Student Teachers:

- identify the strength and limitations of scientific knowledge
- develop an accurate view of how science differs from other ways of knowing
- determine the types of questions science can and cannot answer.

By now, Student Teachers have been introduced to some of the key principles in science, such as observation and inference and how to conduct an experiment. The goals of this session are to expand on these skills and introduce others. In addition, they reflect on what the nature of science means and apply what it means to them in their personal life and professional life as a teacher.

Form small groups of Student Teachers and hand each group one of the following statements about the nature of science (alternatively, have each group choose a statement). Ask them to discuss whether they agree or disagree with their statement and why. At this point, do not tell them that these are all misconceptions. Rather, facilitate their discussion and encourage them to argue their own opinion and debate with one another.

Misconceptions about the nature of science[2]:

- Hypotheses become theories, which become laws
- A general and universal scientific method exists
- Evidence accumulated carefully will result in sure knowledge
- Science and its methods provide absolute proof
- Science is procedural more than creative
- Experiments are the principal route to scientific knowledge

Next, bring the class together and share with them that in science, these statements are considered false and represent commonly held misconceptions. Ask Student Teachers to think about the statements again, but this time, take the perspective of science. Have them try to come up with explanations that describe why each of those statements is considered wrong.

[2] Adapted from W. F. McComas, ed., *The Nature of Science in Science Education* (Norwell, MA: Kluwer Academic Publishers, 1998), 53–70.

If they struggle, provide them with the following explanations and let them reflect on these explanations[3].

Misconception 1: Hypotheses become theories, which become laws.
This is a myth because laws and theories are different types of knowledge. Laws describe and theories explain. For example, Boyle's law states that the volume of a gas at constant temperature varies inversely with the pressure exerted on it ($PV = P_1V_1$ in a closed container). To explain why, we use the kinetic molecular theory, which states that a gas consists of a collection of small particles; these molecules occupy almost no volume, and there is a lot of empty space around them. When you apply pressure to them in a closed container, the volume decreases; that is the reason pressure and volume are inversely proportional to each other.

Misconception 2: A general and universal scientific method exists.
The set of steps of what we call the scientific method—1) define the problem, 2) gather background information, 3) form a hypothesis, 4) make observations, 5) test the hypothesis, and 6) draw conclusions—is only one way of doing science. There are many other ways of doing science in the different scientific areas. Close inspection reveals that scientists approach and solve problems with imagination, creativity, prior knowledge, and perseverance; thus, they approach and solve problems differently.

Misconception 3: Evidence accumulated carefully will result in sure knowledge.
Collecting evidence and having lots of data does not necessarily result in laws or theories. Scientists use creativity and imagination as well as prior knowledge to think very carefully about the evidence so they can produce knowledge.

Misconception 4: Science and its methods provide absolute proof.
The general success of the scientific endeavour suggests that its products must be valid. However, a hallmark of scientific knowledge is that it is subject to revision when new information is presented. Tentativeness is one of the points that differentiates science from other forms of knowledge. Accumulated evidence can provide support, validation, and substantiation for a law or theory but will never prove those laws and theories to be true.

The problem of induction argues against proof in science. In actuality, the only truly conclusive knowledge produced by science results when a notion is falsified. This means that no matter what scientific idea is considered, once evidence begins to accumulate, at least we know that the notion is untrue. Consider the example of the white swans. One could search the world and see only white swans and arrive at the generalization that all swans are white. However, the discovery of one black swan has the potential to overturn, or at least result in modifications of, this proposed law of nature. Still, whether scientists routinely try to falsify their notions and how much contrary evidence it takes for a scientist's mind to change are issues worth discussing.

Misconception 5: Science is procedural more than creative.
If science is procedural (meaning that producing new knowledge requires you to follow a set of steps that will surely lead you to answer questions and solve scientific problems), then science would be very simple, and everybody would be a scientist.

3 William McComas, *Ten Myths of Science: Reexamining What We Think We Know*, (School Science and Mathematics, 1996), volume 96, issue 1. 10–16.

Actually, only the creativity of the individual scientist permits the discovery of laws and the invention of theories. Set procedures will not lead to the discovery of laws and the invention of theories.

Misconception 6: Experiments are the principal route to scientific knowledge.
Throughout their school science careers, students are encouraged to associate science with experimentation. Virtually all hands-on experiences that students have in science class are called experiments. However, it would be more accurate to call these technical procedures, explorations, or activities. True experiments involve carefully planned procedures along with control and test groups to establish a cause-and-effect relationship. Of course, true experimentation is a useful tool in science, but it is not the only route to knowledge. Many noteworthy scientists have used non-experimental techniques to advance knowledge. In fact, in a number of science disciplines, true experimentation is not possible because of the inability to control variables. Many fundamental discoveries in astronomy are based on extensive observations rather than experiments.

End this session by assigning a long-term project in which Student Teachers reflect further on these principles of science. Have them explain what these principles mean to them and how they might influence their teaching. Examples of possible assignments include the following.

Assignment 1
Ask Student Teachers what new ideas about the nature of science they have acquired as a result of thinking about these myths. Then ask them to write an essay on this topic. In their essays, they should reflect on the following aspects: scientific knowledge is tentative, creative, and imaginative and is socially and culturally embedded. There are important distinctions between phenomena versus data and observation versus inference.

Assignment 2
Ask Student Teachers to collect examples of myths and folktales by interviewing ordinary people. Ask them to select one of these myths and write an essay on the reasons it is not scientific.

Assignment 3
Have Student Teachers research one scientist of their choice in great detail and write an essay about how the scientist's life and work is an inspiration for them.

Assignment 4
Have Student Teachers choose a science topic that is taught in elementary grades and develop a lesson plan with goals, activities, and an assessment. In a separate section, a paragraph should address the expected children's prior knowledge and an explanation of the chosen teaching strategies and materials that are included in the lesson.

Additional resources

The American Association for the Advancement of Science (AAAS) Project 2061. 'The Nature of Science'.

➢ http://www.project2061.org/publications/sfaa/online/chap1.htm

Center of Science Education, EDC. 'The History of Science: Mendeleev'.

➢ http://cse.edc.org/products/historyscience/bios.asp#mendeleev

N. Lederman and F. Abd-El-Khalick, 'Avoiding De-Natured Science: Activities That Promote Understandings of the Nature of Science'.

➢ http://toolbox.learningfocused.com/data/0000/0014/2125/Teaching_the_NatOSci.pdf

W. F. McComas, ed., *The Nature of Science in Science Education* (Norwell, MA: Kluwer Academic Publishers, 1998), 53–70.

W. F. William, *Ten Myths of Science: Reexamining What We Think We Know* (Stillwater, OK: School Science and Mathematics, 1996) vol. 1., 10–16.

UNIT 2

ENERGY TRANSFER, TRANSFORMATIONS, AND CONSERVATION

Unit Overview

Energy is an overarching concept that provides the foundation for many science concepts across all science disciplines. This unit introduces Student Teachers to the study of energy in its various forms. Building upon content learned in Science I (in particular, force and motion and states of matter), they investigate direct applications in the control and use of energy. Topics include energy transformation and transfer as well as basic ideas of energy use and conservation principles. They also develop an understanding of using energy efficiently.

By the end of this unit, Student Teachers progress to an understanding of the flow and applications of energy in various forms, such as thermal energy. Their investigations of the interaction of thermal energy and matter include an understanding of the ways such interactions can perform meaningful work. These interactions perform work through thermal expansion and contraction as well as changes in the state of matter.

Unit 2 ends with an opportunity to explore the idea of energy existing at the microscopic level. Energy is inherently present within all matter as the energy of moving particles.

Unit 3 deepens that conceptual understanding, especially on the particle level and atomic level. The content is expanded to exothermic chemical reaction (optional content could include radioactivity and electricity).

Student Teachers should be given increasing freedom over the course of this semester. They should be able to develop their own methods of collecting and analysing data and relating that data to accepted scientific frameworks. They should receive substantial support in generating hypotheses and designing experiments. However, that support should be reduced over the course of this semester, allowing them to complete more independent work.

Learning outcomes for this unit

Student Teachers should be able to:

- distinguish among different forms of energy (kinetic, potential) and demonstrate that energy can be transferred and transformed
- provide examples of kinetic energy being transformed into potential energy and vice versa
- recognize that heat can spread from one place to another in predictable ways
- provide examples of the transfer of energy from hotter to cooler objects by conduction, radiation, or convection
- explain that energy can be transferred (e.g. by collisions and radiation) but never destroyed (conservation of energy)
- differentiate the states of matter based upon their energy state (e.g. the structure of molecules and atoms in these different states varies from rigid in solids to independent motion in a gas)

- view thermal energy (i.e. heat) in terms of atomic and molecular motion (i.e. the higher the temperature, the greater the atomic or molecular motion)[4]
- compare the transmission, reflection, refraction, and absorption of light using different materials
- listen for Student Teachers' misconceptions about properties and particle theory and try to correct them
- identify the underlying core science concepts in this unit for children in elementary grades and design inquiry-based activities and learning outcomes that are age-appropriate.

Unit 2/week 2: Energy transfer and transformation
(Sessions 1–3)

Student Teachers should be familiar with the concepts of force and motion, as studied in Science I. Begin this week by revisiting their prior knowledge about motion. The primary focus should be on exploring the energy involved in motion.

Student Teachers might be familiar with the phrase 'energy can never be created or destroyed'. But besides reciting it, most do not conceptually understand that energy can change its form. For instance, energy can change its form through collisions, in chemical and nuclear reactions, or in waves, sound, light, and other types of radiation. They may find it hard to accept that the various forms of energy are actually manifestations of the same thing. Allow them time to do hands-on activities to experience energy transfer first-hand.

The core outcome of this week is relatively simple: Student Teachers should begin to develop the idea of potential energy (stored by virtue of the position of a body or the arrangements of particles in a system) and kinetic energy (motion). Energy is a topic that is woven throughout Science II. They will have more opportunities to further develop and apply their understanding of energy.

Suggested activity for session 1

Rube Goldberg machine

Much of the exploratory work in this unit focuses on energy's ability to change form. For Student Teachers to understand that energy is consistent throughout its forms, they must engage in a substantial amount of inquiry. For instance, they will investigate potential and kinetic forms of energy associated with objects in a gravitational field, objects that are elastic, and objects that collide.

Student Teachers might have played with a domino rally and might recall that experience. Otherwise, show them the image of the simple alarm clock provided at the end of this unit. Introduce them to the concept of a Rube Goldberg machine[5] and discuss the different mechanisms that they see in the picture. It begins with a bird catching a worm, and through a series of tasks, ends by waking up the sleeping man.

The key aspects of the discussion should be that motion can be triggered in various ways and that motion can be passed on. But can it go on forever? Have Student

[4] These objectives will be continued and deepened in unit 3, Energy and matter. In that unit, the focus of energy transfers will be on the microscopic level (between and within atoms)—for instance, understanding chemical reactions (exothermic and endothermic) and radioactivity.

[5] A Rube Goldberg apparatus is a device that performs a very simple task in a very indirect way

Teachers think about that question as they brainstorm (in small groups) other simple devices. Then have them construct a series of actions on paper that leads to the accomplishment of a simple task (for example, an alarm clock going off, a ball being kicked into a hole, a tea bag that gets dipped into a cup, etc.).

Student Teachers will most likely start with devices built on the concept of potential kinetic energy (such as something dropping or colliding). Push them to come up with other ideas. For instance, hand out elastic bands or a spring as a prompt and see what they come up with.

Bring the class together and start listing their ideas. Come back to the question of whether those sequences of action could go on forever. Student Teachers might say that at some point, all motion ends because the energy is used up. Introduce them to the concept that, in fact, energy *cannot* be used up or lost but that it just changes form.

Explore energy transfer further. Discuss forms of energy and how energy can be transferred and eventually transformed but that it is never 'lost'. For instance:

- *energy transfer*. Motion (i.e. kinetic energy) can be transferred to kinetic energy (for example, a ball rolls down a ramp, collides with a resting ball, and both continue rolling on). Provide several examples and discuss how the *transfer* of energy happens but that the form of energy remains the same.
- *energy transformation*. Kinetic energy is often also transformed into thermal energy (for example, friction on a moving object causes the object and the surface to warm up).

Mechanical energy (e.g. energy stored in a spring) is often transformed into kinetic energy. Provide several examples and discuss the *transformation* of energy. Other transformation examples besides heat include sound or elastic energy. At this point, Student Teachers do not need to understand how this transformation happens on the microscopic level. They just need to know that energy changes its form.

Suggested activity for session 2

Heat transfer: Real-life applications—Thermometer

A Remind Student Teachers that energy comes in various forms and that energy has the potential to do work or cause change. Introduce them to the scientific words *kinetic energy* and *potential energy*. Tell them that all energy forms fall into those two categories. Kinetic energy is any energy stored in motion. Potential energy is any energy stored based on its position. Ask them to recall the energy forms that they encountered in the previous session and their transformation (can they group them by kinetic or potential?). They might mention thermal/heat energy, sound, and light but will probably not be able to group them correctly at this point. If they can't decide, it is OK to place them in both categories and decide later as the unit progresses.

In addition, Student Teachers have probably heard of electrical energy, nuclear energy, electromagnetic energy, chemical energy, and electrochemical energy. You may list those forms, too. Then spend a few minutes asking them in which context they have seen or heard about these energies. But don't go too deep trying to explain what each is. The underlying science that explains these energy forms is too advanced for them at this point.

In the second part of this session, introduce Student Teachers to energy transfers and transformations on a very small level. Earlier, they were able to witness work done by energy transfers and transformations that were visible to the naked eye. However, the following hands-on activity will give them an opportunity to explore thermal energy in greater detail on the microscopic level.

Present Student Teachers with the following three scenarios:

1) *Conduction*. Why do you burn your hands when you touch a hot plate? Why can you walk barefoot across grass in the summer but not across asphalt? Let Student Teachers add more examples and then try to hypothesize what might be the underlying science principle for all scenarios. Can they conclude that heat is transferred from the hotter object to the colder one and that some materials conduct heat better than others? Why is that? Have them brainstorm ideas.
2) *Convection happens in liquids and gases*. Demonstrate how heat is transferred within a container of water. Add some (food) colouring to the water in a small container and freeze it over night. In class, place the frozen coloured ice block in a larger container filled with tap water. Have Student Teachers observe what happens, especially how the water moves. Supply a thermometer to also take measurements of the temperature of the water over time. Ask them to speculate, again, what is happening.
3) *Radiation happens without being in direct contact with matter*. Ask Student Teachers whether they can think of a scenario where an object is heated without it touching a hotter object. They should come up with fire and the Sun. What about cooling?

Student Teachers have seen evidence of these heat transfers in everyday situations, but they may not have realized it. Ask them for more situations of heat transfer that they encounter and what kind of heat transfer each is.

Student Teachers should conclude that heat can be transferred in various ways (via conduction, convection, and radiation). Also, they should realize that this transfer can be used to explain everyday phenomena that have to do with heating and cooling. They should recognize that heat transfer depends on the properties of the matter involved. In addition, they should realize that heat is transferred from the hotter (higher-energy) level to the cooler (lower-energy) level until both have the same temperature

Please note that real-life situations or applications often involve more than one method of heat transfer. They can become quite complex. Therefore, Student Teachers should become familiar with these methods as opposed to memorizing the situations or terms as absolutes.

Suggested activity for session 3

Heat transfer: Real-life applications—Thermometer

Thermal energy cannot be measured precisely. But temperature can determine the relative level of energy due to the kinetic motion of atoms and molecules and their interaction with a *thermometer*. A thermometer visually displays changes in molecular energy due to a change in some physical property, such as colour or volume

Begin by asking Student Teachers what they think happens when heat energy is transferred or transformed. Have them revisit their observations from the previous sessions. Then push them to consider also what might happen on a very small scale, such as on the molecular level. Have them discuss and critique their initial ideas. But do not correct them at this point.

Hand out thermometers and let them explore in small groups the following bigger questions: heat—or, better, temperature—can be measured with a thermometer. How is this possible? Can the science principles observed in the past couple of sessions help explain how a thermometer works? Why? How? Have them record and present their ideas to the class.

While they work in groups, start guiding their thinking and observations through questions. Help them discover that heat is transferred between the substance and the thermometer. Some unknown substance inside the thermometer expands or shrinks along the scale, listing the temperature.

Revisit the physical properties of substances in unit 6 of Science I and the states of matter. Make sure Student Teachers understand that energy is also transferred on a very small scale invisible to the naked eye. This energy transfer is also responsible for matter going through different states (solid, liquid, gas). Remind them of melting and boiling points and how matter typically expands in volume when heated. If they struggle with this concept, consider repeating the lesson on states of matter from Science I before moving on.

You can also use a steam engine to illustrate the transfer of energy and lead to a similar discussion. The additional application might help Student Teachers become more comfortable with the concept of energy and energy transfer.

Unit 2/week 3: Law of conservation of energy
(Sessions 4–6)

This week (and unit 3), Student Teachers get more opportunity to develop a conceptual understanding of energy transfers on a molecular level. Energy is a very abstract concept. Therefore, it is important to provide them with hands-on activities and as many real-life applications as possible. By connecting the known with the abstract, they can more easily relate to the discussed content and learn the concept.

Suggested activities for session 4

Properties of matter and energy transfer

In this session, Student Teachers explore the idea of energy existing at the microscopic level. Energy is inherent within all matter as the energy of moving particles: molecules, atoms, and subatomic particles.

Building on unit 6 in Science I, ask Student Teachers to try to explain the following scenarios:

- In the summer, you can walk barefoot on grass but not on asphalt.
- A black car gets hotter than a white one when it is parked in the Sun.
- It takes a lot of sunlight to melt a field of snow, but when you put black stones on the field, it melts much quicker.
- A metal spoon is too hot to touch when placed in boiling water, but you can touch a wooden spoon placed in the same water without a problem.

In small groups, have Student Teachers speculate about the underlying principle of these scenarios. Encourage them to come up with more scenarios that illustrate their thinking. Have them discuss these scenarios and question each other's reasoning.

Student Teachers should understand that the properties of matter have an impact on how that material responds to energy inputs and how well it transfers energy. You can broaden the scenarios and include kinetic, electric, sound energy, and so on. Discuss, for instance, when sound travels the best/worst, what is the best/worst material to conduct electricity, which materials respond well to kinetic impacts and which ones don't, and so on.

Allow Student Teachers to conduct some experiments on their own to test and revise their hypotheses. They might not be able to fully explain those scenarios on the molecular level. However, they should be able to connect the molecular level to the properties of matter. They should also hypothesize that energy transfer might have something to do with the particle arrangements and atomic structure of that matter.

In addition, explore the following scenario in a similar way as the preceding ones: why does hot air rise above cold air? Why is warmer water at the surface and cooler water at the bottom of a lake?

In these scenarios, the important property of matter is its density, and density is temperature dependent. Student Teachers should be able to make the connection to states of matter and the particle theory. They should recall that energy input leads to changes of state in matter. Generally speaking, when a substance is heated, a solid turns into a liquid, and that liquid turns into a gas.

End the session with a discussion about how energy is transferred on the particle level. Discuss also how an increase in the energy level results in higher kinetic energy of the particles making up matter. If your Student Teachers still struggle, refer back to the models of particle theory included in Science I, unit 6.

Suggested activities for sessions 5–6

More real-life applications

How can energy be stored? How can energy be conserved? What is an efficient use of energy? Provide Student Teachers with the opportunity to explore some of these questions in greater depth during the remainder of the week. It is essential that they use their newly gained understanding and apply it to some concrete examples. If you have access to additional science books or the Internet, allow them to use those resources. Also, make sure they explain their suggestions based on their newly gained scientific understanding.

Suggested mini-projects for Student Teachers to work on in groups are as follows:

- *Design the most efficient and effective heating or cooling device to warm up a cup of coffee or to keep ice cream cold.*
  Student Teachers should think of all the different energy sources for heat and how to target the energy transfers to best reach their goal. They should determine which transfers to support and which transfers to avoid (for instance, by containing the heat/cold through insulation techniques). They should present their device (as a drawing or as a real model) and explain how it works, using scientific terms whenever possible.
- *Create a Rube Goldberg system with only one energy input at the beginning to carry out a final task. How many different energy forms can you integrate in the system? How many energy transfers and transformations can you achieve?*
  This project is more open than the first project. It allows for more creativity on the part of Student Teachers to come up with a task they want the system to accomplish. In contrast to the first project, the goal here is to use as many different energy sources and energy transformations and transfers as possible. They should present their device (as a drawing or real model) and explain what kind of energy forms, transfers, and transformations are used within their systems. How many were they able to include? Allow them to ask each other questions and critique each other's approaches.

Unit 2/week 4: Teaching energy in elementary grades

(Sessions 7–9)

Dedicate this week to preparing Student Teachers for their teaching of science in elementary school. It is essential to support them in making the transfer from their own study of science to becoming a teacher of science in the elementary grades. Many teaching strategies and pedagogies learned in this course are transferable to teaching at elementary grades. However, the content, activities, and learning objectives have to be adjusted to reflect the difference in age and prior knowledge.

Suggested activity for session 7

Establishing content for elementary grade science

Start this session by explaining to your Student Teachers that this week you will switch from teaching them content that enhances *their* science understanding to discussing how they can foster the science learning of young children in elementary school.

Ask your Student Teachers to reflect on the past two weeks and the content covered. Have them work in pairs and jot down ideas about how they could teach 'energy' to children. What topics would be relevant to teach in grades 1–8? Which principles and concepts do they need to establish as a foundation for learning science in high school and beyond regarding energy, energy transfer, energy transformation, and energy applications and conservation? What main ideas or concepts should be covered with these young children?

Possible answers are almost endless. This is not the time to approve or judge their ideas. Have your Student Teachers discuss the ideas with each other first. Have them explain their reasoning. Only interject if the discussion wanders too far off the topic of energy. Record their ideas on the board or on a poster so that you can refer back to them in the next session.

Also, have your Student Teachers consult Pakistan's National Curriculum for General Science in grades 1–8. Have them analyse whether they have missed any relevant topics that they want to add now. You might want to form groups for different grade levels, for instance, grades 1–3, 4–6, and 7–8. Again, focus the discussion on only science concepts that relate to energy.

If possible, establish a 'content progression chart' on the board. List all your Student Teachers' content ideas for each grade level. Ask them to step back and take a critical look at how the content is building from one grade level to the next. Ask if they would like to make any changes.

This exercise raises awareness that content cannot be viewed in isolation. Learning is a progression. Each topic builds on content learned before and becomes the basis for new content learned in the future. Student Teachers must learn to scaffold content and allow for such meaningful progressions.

A sample learning progression for 'energy'

A child in grades 1–3:

- Demonstrates that heat can be produced in many ways (e.g. flames, light bulbs, flashlights, heating elements)
- Examines how light travels in a straight line until it reaches an object and that it can travel through or be reflected off the object
- Investigates how vibrations produce sound and that sound can travel through many materials
- Builds awareness of how electrical flow can produce light, movement, heat, and magnetic fields

A child in grades 4–6:

- Demonstrates that heat moves from one place to another by conduction
- Compares materials for their ability to conduct heat
- Recognizes that heat, light, sound, electricity, magnetism, and motion are associated with energy
- Demonstrates that energy can be changed from one form into another (e.g. electrical energy into light, sunlight into heat or electricity)

A young adult in grades 7–8:

- Investigates the transfer of (heat) energy
- Investigates and explains that heat energy moves in predictable ways, flowing from warmer objects to cooler ones until both are at the same temperature
- Differentiates among conduction, convection, and radiation

In the following two sessions, it is important that the Student Teachers understand the expectations for children in elementary grades. Science content can and should be taught to young learners. However, it needs to happen in an age-appropriate, concrete, and hands-on inquiry way.

Suggested activities for sessions 8–9

Designing activities for elementary grade science

Grades 1–3 do not explicitly specify 'energy' as learning content. However, it is contained in grades 2–3 under the theme 'Heat and light' and to some extent in 'Conservation of natural resources'. In addition, elementary grade teachers need to teach the following process skills:

- asking questions
- problem solving
- making an argument
- defending an idea
- making and recording observations
- categorizing
- and more.

These skills should be taught in meaningful context at all grade levels and should be introduced in grades 1–3.

Regardless of the grade level, energy is an overarching abstract theme that in elementary grades is mainly addressed by concretizing it in the form of heat, light, and sound. In grades 4–8, 'energy' is the backbone of almost all the physical science themes.

Building a conceptual understanding of the different kinds of energy as well as energy transfers and transformations requires a solid foundation, which is developed over the years. When children in elementary grades reach higher grade levels, they will have the necessary prior knowledge to comprehend the laws of energy, entropy, and thermodynamics. Carefully crafted learning progressions and activities will help lay such a foundation.

Begin by using ideas generated by Student Teachers that you recorded in session 7. Have them choose a specific topic and grade level that they will discuss in a smaller group. Their task is to identify age-appropriate activities that teach their concept of choice to children in elementary grades. Remind them to use hands-on inquiry activities if possible and to make them intriguing. Ask the following questions: what kind of question could children in elementary grades investigate? What kind of challenge could they solve, and what concept would they learn as a result? What kind of learning outcomes could be expected at that age level?

Keep reminding the Student Teachers that a chosen activity needs to be a good example of investigating a specific science concept. It is not enough if the activity is just a fun experiment. Meaningful learning needs to be supported by it. In addition, the activity needs to be aligned with the prior knowledge and age of the children.

The following age-appropriate suggestions are provided for elementary grade energy activities. Instead of handing out these ideas to the Student Teachers, it would be more beneficial for them to come up with their own ideas. If they struggle to come up with their own ideas, consider using the suggestions to jump-start a discussion. This exchange should then lead teachers to quickly develop new activities.

Sample activity: Introduction to energy (light and shadows)

Exploring light and shadows is a very concrete introduction to a form of energy that young children can relate to from their day-to-day experience. Activities in grades 1–2 should provide children with a close examination of how an object's properties affect its interaction with light and how shadows are created. Children could explore different materials with a flashlight and determine which materials let light through, which block light, and which let some light through. They identify conditions that create shadows and make shadows change. To further integrate their findings with the natural world around them, children could also investigate the major source of light on Earth—the Sun. By observing the shadows they find, they can then create a variety of their own.

The main goals for children in elementary grades are to:

- begin to understand some of the observable properties of light
- understand that location of a shadow depends on the position of a light source relative to the object casting the shadow.

Children can experiment with mirrors to demonstrate how light can be reflected. They can then examine how light reflects off certain materials more easily than others. They can examine beams of light to understand how light travels in straight lines and observe that light can't go around corners. Children notice differences in how light interacts with opaque and transparent objects. They examine and compare the shadows made by different objects. They categorize objects that make shadows and how they can make those shadows change.

Through hands-on experiments, children identify the relationships among the three components of shadow making. They manipulate the light source, the object, and the background needed to make shadows. Children can gain this insight by creating shadows that are long, short, clear, and fuzzy. They can create shadows that look like the objects that made them and make shadows that look very different. They can also find three ways to change the direction of the shadow:

- by moving just the light source
- by moving just the object
- by moving just the background on which the shadow is made.

As a learning outcome, they should be able to articulate the relationships among the light source, object, and background in their investigations. Then, have children go outside and collect data on the changes outside shadows make. Have them observe the way shadows of non-moving objects change as they track the Sun's position in the sky during the day.

Sample activity: Introduction to energy (solar energy/heat)

This suggestion is for children in about grade 5. The activity focuses on the Sun's energy and on the fact that its intensity depends on various factors. For example, children might have examined seasonal changes. In about grade 5, they are ready to explore the effect of the intensity of sunlight due to the angle in more detail. They should consider how different areas of the Earth receive different amounts of intensities of sunlight throughout the year.

Such activities lay the foundation for children to learn *how* the Sun's energy interacts with matter on Earth. In grade 5, children are better able to understand the microscopic properties of all matter and the interaction of energy with the molecular structure of different types of matter.

Developing intriguing activities: Solar energy/heat

If Student Teachers struggle to come up with challenges or ideas for activities, supply some examples, such as the following:

- What can the Sun's energy do?
- What factors affect the Sun's ability to heat matter?
- How do distance and angle affect the amount of heat received from a heat source?
- What can children learn about the Sun's ability to heat matter by conducting their own investigations?
- What are some sources of energy, and what can they do?
- What device can be used to transform energy from the Sun into electrical energy?
- How is the energy conversion that occurs in a solar cell similar to the process of photosynthesis?

Sample activity: Energy (heat transfer)

Grades 7–8 can investigate heat transfer by conduction, convection, and radiation in hands-on activities. For instance, they can explore the factors that affect heat transfer by completing a task, such as warming up soup or keeping ice from melting. Children examine heat flow and create visualizations to describe the effect of heat on matter. They should realize that:

- heat transfer occurs whenever a temperature difference occurs in a medium or between media
- heat moves through materials at different rates
- heat can be transferred by contact of two objects or liquids as well as across space.

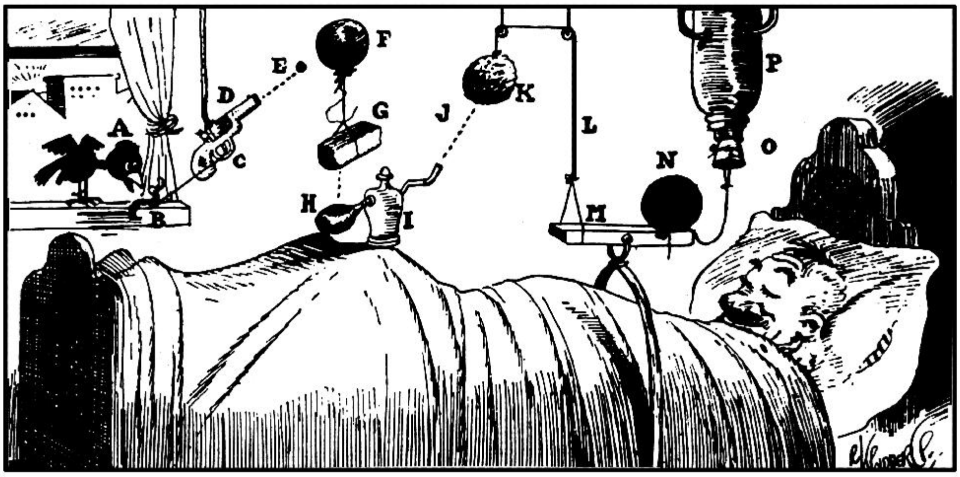
If Student Teachers struggle to come up with challenges or ideas for activities, supply some of the following sample questions to investigate:

- How does heat transfer form materials?
- Does the quantity or shape of materials affect heat transfer?
- Does heat transfer at different rates?
- Does heat transfer through air (gas)?
- Do different materials transfer heat at different rates?
- What changes occur when heat is removed from a material?

Additional resources

Example of a Rube Goldberg device

Simple Alarm Clock



The early bird (**A**) arrives and catches worm (**B**), pulling string (**C**) and shooting off pistol (**D**). Bullet (**E**) busts balloon (**F**), dropping brick (**G**) on bulb (**H**) of atomizer (**I**) and shooting perfume (**J**) on sponge (**K**)–As sponge gains in weight, it lowers itself and pulls string (**L**), raising end of board (**M**)–Cannon ball (**N**) drops on nose of sleeping gentleman–String tied to cannon ball releases cork (**O**) of vacuum bottle (**P**) and ice water falls on sleeper's face to assist the cannon ball in its good work.

Figure 2: Simple Alarm Clock. Source:

- ➢ http://latzeng.wordpress.com/2011/04/10/austins-rube-goldberg-project/

Note that many Rube Goldberg devices are online as images or videos. You can use any of them to begin the discussion about potential energy that is being transferred to do some work.

Khan Academy. 'States of Matter'.

- ➢ http://www.khanacademy.org/science/chemistry/states-of-matter.

Glencoe Science: Chemistry: Matter and Change (The McGraw Hill Companies, Inc., 2005).

- Chapter 3: Matter—Properties and Changes, p. 54
- Chapter 6: The Periodic Table and Periodic Law, p. 150
- Chapter 7: The Elements, p. 178

UNIT 3

INTERACTIONS OF ENERGY AND MATTER

Unit Overview

Unit 3 builds on the previous unit, in which Student Teachers investigated the transfer of energy and the connection between energy and state of matter. They began to explore the change of physical properties and the reversibility of that physical change—for instance, by heating up and cooling down water.

In this unit, Student Teachers learn to contrast physical properties with chemical properties and physical change with chemical change. They also learn the role of energy. Through various activities, they gain a hands-on experience with chemical change (chemical reactions). They are introduced to exothermic (and endothermic) reactions. Building on their prior understanding of the atomic model and the periodic table, they develop a deeper conceptual understanding of energy and matter on the atomic level.

They learn the following about chemical change:

- During chemical change, mass is conserved and new substances are produced
- The products from reactions contain the same atoms as the reactants
- Chemical change is often accompanied by changes in temperature

As Student Teachers investigate chemical change, they apply many of the same concepts they developed while investigating physical change. Encourage them to compare and discuss chemical and physical properties and chemical and physical change throughout these activities. As a result, they will practice and fine-tune their new understanding and vocabulary.

Also, point out that although chemists have traditionally distinguished physical and chemical change, the distinction has blurred as scientific knowledge has increased. In many real-world applications, the distinction between physical and chemical properties and physical and chemical change have begun to become so complex that they begin to blur. In the interest of simplicity, use only the examples given here for the class discussions. If your Student Teachers bring up those more complex situations, invite them to discuss the issue using all the knowledge and understanding that they have. However, inform them that they might not reach consensus. Sometimes the real world is more complex than what they can cover at that grade level.

In addition, this unit introduces chemical bonds in the context of energy. Building on the previous unit, it is easier for Student Teachers to keep the focus on energy to develop a conceptual understanding of chemical change and changes in state of matter.

For Student Teachers more advanced in their understanding of energy and bonds, it is possible to introduce them to the role of electrons in chemical reactions (including stoichiometry). However, for most of them, it would be more appropriate to hold off developing those ideas until Science III. When revisiting chemical reactions in Science III, stoichiometry will build on and verify the conceptual understanding developed here.

Rather than introducing chemical equations, use this unit to explore radioactivity and/or electricity. If you consider those topics essential for your Student Teachers, this would be a good time in the course to discuss them.

Learning outcomes for this unit

Student Teachers should be able to:

- differentiate between physical and chemical properties and physical and chemical change
- gain an understanding that mass is conserved even when materials are dissolved
- investigate how some common materials interact to form new materials
- explain how in physical change, properties of substances remain the same
- provide examples of how the properties of a product of a chemical change are different than the products of the reactants
- provide examples of the natural world in which energy is released (or needed) in chemical reactions (e.g. burning fossil fuels, photosynthesis)
- be able to identify some of the underlying core science concepts in this unit for children in elementary grades and design inquiry-based activities and learning outcomes that are age appropriate
- be aware of misconceptions about energy and matter and what to do about them.

Unit 3/week 5: Solutions, properties, and conservation of mass

(**Sessions 1–3**)

This week on physical and chemical change builds on Science I, unit 6, Properties of matter. In that unit, Student Teachers explored the nature of physical and chemical properties and physical change (and to some extent chemical change) without discussing in detail the molecular level.

Begin this week with a solid review of Student Teachers' prior knowledge on matter, properties of matter, and particle theory from Science I (if you need review questions, please consult Science I, unit 6).

By now, Student Teachers should know that matter is made of particles; that matter can exist as a solid, a liquid, and a gas; and that all matter has mass. They should also know that mixtures of substances can be separated by physical means using the difference in properties and should be able to apply this knowledge.

They should be able to discuss physical properties of a substance, such as mass, density, colour, odour, hardness, melting and freezing points, boiling point, and density.

From Science I, Student Teachers are also familiar with mixtures (for instance, making solid mixtures and then physically separating them using tools based on the physical properties found in the mixture). They should have a vague idea of what *element* means and of the differences among *elements*, *compounds*, and *mixtures*. Although they may be familiar with the terms, their conceptual understanding of these terms should be developed greatly throughout this unit.

Suggested activity for session 1

Homogenous and heterogeneous mixtures

To get a better understanding of Student Teachers' prior knowledge, begin this unit by showing them some small containers filled with various solid mixtures, liquid mixtures, and solid-liquid mixtures. Ask them to observe and describe what they see and what they think each could be. Allow them to handle the containers for closer observation. As they describe what they see, encourage them to use scientific language. Push them to provide a thorough description of their observation rather than just a one-word answer containing the scientific name of that type of mixture.

Listen carefully and ask probing questions to get a better sense of what Student Teachers already know and what they might still be struggling with. This information will help you plan and develop the 'right' activities for the following sessions.

You can wrap up this conversation by posing one of the following challenges:

- If we assume that these are all mixtures, how can we prove it?
- If these are indeed all mixtures, is there a way to physically separate the components of each?

Have Student Teachers work in pairs to discuss how to answer the challenge question. If possible, hand them samples of the different mixtures so they can construct concrete proposals on how to separate the mixtures.

Possible sample mixtures could include:

- Mixtures of solids in which physical properties, such as size (sieve), metallic/non-metallic (magnet), and density (floats in water or sinks) can be used to physically separate the mixture.
- Mixtures of solid and liquids in which the physical properties of density (decant) and size (filter) can be used to separate the substances.
- Mixtures of liquids in which density or boiling point can be used to separate the substances.
- Mixtures of gas and liquids (for instance, a soda like Pepsi that contains carbonated water as well as sugars etc.). A physical separation capturing all the components of the mixture is hard to do, but you could do it theoretically by talking through the steps.

As you circulate among the pairs, make sure Student Teachers focus first on the macroscopic properties of the materials. Then push them to think about how the particulate matter could relate to the macroscopic world.

As you discuss the answers with the entire class, introduce the terms *homogenous* mixture and *heterogeneous* mixture. Discuss the physical properties and tools to physically separate the mixtures. Make sure Student Teachers understand that the properties of the substances do not change when they are in isolation or when they are part of a mixture.

Suggested activities for sessions 2–3

Mixtures/solutions and conservation of mass

In this session, engage your Student Teachers in activities that help them distinguish between a mixture and a solution (i.e. homogenous mixture). They investigate how a particular substance dissolves in a certain solution and determine when the solution reaches a saturation point. They test the same substance with other liquids to find out whether it also dissolves in these liquids or not.

These sessions lend themselves to hands-on experiments that Student Teachers self-design as much as possible. Ask them to systematically study the solubility of a substance in different solvents (e.g. provide them with water, oil, and alcohol). Remind them to be methodical in their approach. Tell them to vary only one variable at a time—for instance, the amount of solute in a fixed amount of solvent.

As Student Teachers proceed with their experiments, ask them to carefully observe and record all data. Encourage them to hypothesize what they think happens when a substance dissolves in a liquid. If they lack words to describe their thinking, have them develop a visual model of what they think the solution might look like—even on a particle level.

In a second part of the experiment, Student Teachers use the same substances to explore conservation of mass. Again, they can do this in a self-designed experiment. Have them carefully record and compare the individual weight (and volume) of the solute and solvent and the total weight (and volume) of the solution. At this point, they should discover that the mass of a mixture is equal to the sum of the masses of its components (e.g. by weighing salt or alcohol and water before and after they are mixed). Next, they consider and hypothesize why the volume of the solution of alcohol and water is less than the volume of the two measured separately.

This investigation should help Student Teachers refine their visual model of what is happening at the particle level when substances are mixed.

Background information to facilitate the experiment

Solubility is the ability of one substance to mix with another substance. Solutions can be mixtures of solids and liquids or liquids and liquids. Another kind of solution is soda water, in which a gas is dissolved in a liquid. Solids can also dissolve in solids.

The solubility of substances varies greatly and depends on conditions, such as temperature and pressure. An increase in temperature increases the solubility of many solids; however, it causes gases to become less soluble in a solvent like water. In some other kinds of liquid solvents, gases may become more soluble as temperature increases. Gases tend to become more soluble when the pressure is increased.

Water will dissolve many substances. A wide variety of coloured substances can dissolve in water (for instance, ink or most food colourings).

At the molecular level, which substance dissolves depends on the kind of molecule it is and its interaction with the solvent's molecules. In liquids, there is some mutual attraction between the molecules. The solute molecules act in a way that works against this mutual attraction. When the solute molecules have a similar attraction to each other as the solvent molecules, the solute and solvent will tend to mix. However, if there is a big enough difference, they will not mix.

Questions to guide the final class discussion could include:

- How can the properties of the components of a mixture be used to separate the mixture?
- What are the properties of the mixture?
- How do different substances dissolve in different liquids?
- Do different concentrations of substances affect how substances can be separated?
- What is the relationship between the total mass of the solution and the masses of its components?

Make sure all Student Teachers understand how to compare and contrast physical properties of materials. They should understand that materials can exist as solids, liquids, or gases, which is one way to classify materials. They have observed materials changing shape, size, and so on but understand that the fundamental properties of the materials have not been changed. In addition, they determine that the mass of a mixture is equal to the sum of the masses of its components. They should realize that the volume of a solution is less than the volume of its components.

Unit 3/week 6: Chemical change

(**Sessions 4–6**)

By now, Student Teachers should have a good understanding of chemical and physical properties. They should also comprehend the concept that mixtures can be separated by physical means but substances (compounds) cannot (Science I, unit 6). In the past week, they explored mixtures and solubility. They thought about what might be happening at the particle level when substances dissolve.

This week introduces chemical reactions. The purpose is threefold: Student Teachers gain a basic understanding of physical and chemical processes, are able to differentiate the two, and develop a better conceptual understanding of preservation of mass.

As a secondary goal, Student Teachers revisit the periodic table, which was first introduced in Science I. They begin to understand that the periodic table is a helpful tool in predicting the result of chemical reactions.

Suggested activities for sessions 4–5

Water and electrolysis

Begin this session by providing Student Teachers with a sample of water. Using their prior knowledge, ask them to describe the properties of water (physical and chemical). Then ask them: what is water? Is it a mixture? Is it an element? Is it a compound?

Guide Student Teachers' thinking with questions, such as: could water be separated into smaller substances? How could they find out? Engage all of them in this discussion. Push their thinking by asking questions rather than correcting their answers. This kind of opening discussion among Student Teachers is ideal to test their understanding and identify weak spots in their thinking that might require re-teaching.

Electrolysis experiment

After the initial discussion, have Student Teachers conduct an electrolysis of water.

Materials for each group of Student Teachers include the following:

- One nine-volt battery
- One wide (glass) jar
- Two copper wires (long enough to reach from the battery to the bottom of the jar)
- Two test tubes with stoppers
- 300 millilitres (tap) water (Hint: the electrolysis principle is best visible if you add a little bit of table salt to the water. The salt acts like an electrolyte and enhances the conductivity but does not change the chemical reaction. For simplicity reasons, it is best not to mention the salt to the Student Teachers in this experiment.)

Part 1: Setup, experiment, and observation

Instruct Student Teachers to add the water to the jar and connect the copper wires to the two poles of the nine-volt battery. Then have them observe what happens.

Student Teachers should notice bubbles rising from the water. They should also notice that they form at the end of the two copper wires. Once they make that observation, ask them what they think is happening. Have them speculate what these bubbles could be. Encourage them to use their science thinking and prior knowledge to hypothesize what these bubbles could be.

They should be able to observe a clear, odourless gas forming at the tip of the wires that is submerged in water. They should notice that the gas is forming at different rates on the two wire tips: at the copper tip connected to the cathode, more gas is forming than at the anode. Based on these observations, Student Teachers should be able to hypothesize what these bubbles could be and explain their thinking.

Many Student Teachers might think that the bubbles are water (based on their observation from watching boiling water). Some of them with a better chemical background might say that it is oxygen and/or hydrogen. Others might argue that it is an impurity or something that was in the air. Accept all answers at this point as long as the answers are based on shared observations. They should provide some rationale for their thinking that the other Student Teachers accept.

Part 2: Conclusions

List all the hypotheses on the board. Ask Student Teachers to design and conduct an experiment that would help them find out what the mystery bubbles are. As a first step, they should find out whether all bubbles are the same or different.

Student Teachers should realize that they need to capture the bubbles so they can study the gas in isolation. Some of them might speculate that there might be a difference in the gas because the wires are connected to two different poles of the battery. Hand them the test tubes and stoppers so they can collect their sample of the bubbles. Have them record their observations of the gas collected. Then ask them to record their hypothesis about whether it is one kind of gas or two different gases.

If a group of Student Teachers still believes that the bubbles are water, ask them how that could be if water is a liquid at room temperature. If they argue that it might have to do with the battery, ask them what they would expect to happen inside the test tube if the gas was indeed water. They should expect the gas to condensate and form water again.

After establishing that the bubbles cannot be water, introduce Student Teachers to a couple of tests that allow for the identification of clear and odourless gases. The tests should include:

- Testing for oxygen (supports burning and can be demonstrated by reigniting a glowing wood splint)
- Testing for carbon dioxide (does not support burning and can be shown by burning a wood splint inserted into the test tube)
- Testing for hydrogen (inserting a lighted splint will create a loud pop; while in the presence of oxygen, it will only burn brighter)

Demonstrate all three tests if possible. Then have Student Teachers apply their newly gained knowledge to their experiment. All groups might not be able to collect enough gas to conduct the testing with 100% accuracy. But as a class, there should be enough evidence to conclude that the bubbles formed are indeed two different gases, most likely oxygen and hydrogen. They can also infer that the two gases must have come from the water because both elements, hydrogen and oxygen, make up water.

Remind Student Teachers that physical properties of a substance stay the same if they undergo physical change. However, the properties change if a chemical change happens. Based on their observations and conclusions, ask them to decide and explain whether they observed a chemical or physical change when they conducted the experiment.

All Student Teachers should be able to conclude that the physical properties have changed; therefore, a chemical change must have happened.

To reinforce the difference between chemical and physical change in Student Teachers' minds, contrast the water electrolysis experiment to the boiling of water. Then ask them to explain the difference.

Student Teachers should realize that when they boil water, the water goes from liquid to gas, but as it cools, it reverts back to water in its liquid state. This is a physical change, not a chemical change. At no point did the boiling water undergo a chemical reaction that split the bonds between the hydrogen and oxygen to produce oxygen and hydrogen. In boiling water, no elements are rearranged; instead, the bonds remain unchanged. Only the energy level of the particles changed; thus, water changed its state of matter from a liquid to a gas.

Student Teachers should conclude that during physical change, the properties of the substance do not change, and the change is reversible—whereas in a chemical change, properties change, and the change is not easily reversible (i.e. happens automatically).

Suggested activity for session 6

Exothermic reaction

In this session, have Student Teachers experience an exothermic reaction so they can compare it to the endothermic reaction of electrolysis.

To conduct an easy exothermic classroom experiment, provide each group with the following materials:

- One package of baking soda
- One package of calcium chloride (available in hardware stores as a moisture absorber)
- Two glass jars
- One tablespoon
- Thermometer (optional)

With this lab, it is very important to review the safety rules and to make sure that all Student Teachers follow them at all times. One of the products of the experiment is chlorine gas, which can lead to health problems if inhaled in large quantities.

Have Student Teachers follow these instructions:

1) Add one tablespoon of calcium chloride to the first glass jar
2) In the second glass jar, dissolve two tablespoons of baking soda in about 100 millilitres of water (it is OK if not all of the baking soda is fully dissolved)
3) Pour the baking soda solution from the second jar into the first jar
4) Insert a thermometer into the liquid (optional) and observe

Student Teachers should be able to observe an increase in temperature along with the production of a gas and a white precipitate. If a thermometer is not available, have them touch the glass before and during the experiment.

Have Student Teachers compare and contrast their observations of this experiment to the one in the previous session. You can use the same questions to guide their thinking.

Student Teachers should realize that another chemical change occurred. They should recognize that physical properties changed between the reactants and the products of the reaction (for instance, a yellow-green gas with an irritating smell formed). They should also realize that this chemical change happened without any input of energy but that, in fact, energy was released (observable in the temperature change).

At this point, direct Student Teachers' attention to the periodic table. Have them identify oxygen and hydrogen. Then have them review what they learned in Science I about the information contained in the periodic table, using oxygen and hydrogen as an example. In this context, review the physical properties of oxygen, hydrogen, and water. Make sure they recall the difference between a compound and an element by asking them why water is not listed on the periodic table.

In contrast to the electrolysis of water, this session's experiment uses substances that are chemically unknown to Student Teachers. It is best not to explain the chemical composition of the reactants and products of the chemical reaction. Instead, focus the explanation of a chemical reaction on how the energy involved in the change relates to the bonds rather than the electrons involved.

An interesting and very useful application of endothermic reactions, such as the water electrolysis, is found in many technologies that we use—for instance, the fuel cell in cars. You could use this example to apply and deepen Student Teachers' conceptual understanding of energy transfer and transformation by discussing how hydrogen cars work.

Unit 3/week 7: Teaching energy in elementary grades

(**Sessions 7–9**)

Dedicate this week to preparing Student Teachers for their teaching of science in elementary school. It is essential to support them in making the transfer from their own study of science to becoming a teacher of science in the elementary grades. Many teaching strategies and pedagogies learned in this course are transferable to teaching at elementary grades. However, the content, activities, and learning objectives have to be adjusted to reflect the difference in age and prior knowledge.

Units 2 and 3 are not that different from each other: both deal with energy and matter. Because this topic is abstract and complex, only a few basic energy and matter topics can successfully be introduced to young children. Thus, several of the suggestions made in unit 2, week 3 also apply to the entire unit, especially in the lower elementary grades.

Suggested activity for session 7

Establishing content for elementary grade science

Discuss with your Student Teachers which of the topics or content covered in the past two weeks they could introduce in the elementary grades. As in the other units, they should refer to Pakistan's National Curriculum for General Science. Have them confirm that their suggested topic aligns with the requirements of that particular elementary grade.

You could also have your Student Teachers expand on some of the ideas or lesson plans that they worked on in the previous unit.

A sample learning progression for 'energy and matter'

A child in grades 1–3:

- Generalizes that all liquids pour and take the shape of the containers
- Observes that solid objects in liquids either float on the surface (or partway down) or sink
- Explores physical properties, such as colour, viscosity, and cohesion, and realizes that they differ from substance to substance
- Demonstrates that heat can be produced in many ways (e.g. flames, light bulbs, flashlights, heating elements)

- Examines how light travels in a straight line until it reaches an object and that it can travel through or be reflected off the object
- Investigates how vibrations produce sound and that sound can travel through many materials
- Builds awareness of how electrical flow can produce light, movement, heat, and magnetic fields

A child in grades 4–6:

- Relates buoyancy to weight and volume of the object and the density of the liquid
- Demonstrates that heat moves from one place to another by conduction
- Compares materials for their ability to conduct heat
- Recognizes that heat, light, sound, electricity, magnetism, and motion are associated with energy
- Demonstrates that energy can be changed from one form into another (e.g. electrical energy into light, sunlight into heat or electricity)

A young adult in grades 7–8:

- Understands that properties of substances change in chemical reactions
- Investigates the transfer of (heat) energy
- Investigates and explains that heat energy moves in predictable ways, flowing from warmer objects to cooler ones until both are at the same temperature
- Differentiates among conduction, convection, and radiation

In the following two sessions, it is important that Student Teachers understand the expectations for children in elementary grades. Science content can and should be taught to young learners. However, it needs to happen in an age-appropriate, concrete, and hands-on inquiry way.

Suggested activities for sessions 8–9

Designing activities for elementary grade science

As mentioned in unit 2, Pakistan's National Curriculum does not mention explicitly 'energy' or 'matter' in grades 1–3. The topics are too abstract to be taught in elementary grades without a specific application, such as in heat and light (which are mentioned in grades 2 and 3).

Teaching elementary grade science is an opportunity to focus also on teaching the following process skills:

- Asking questions
- Problem solving
- Making an argument
- Defending an idea
- Making and recording observations
- Categorizing

In the context of exploring light and shadows; heat and cold; or liquids, solids, and solutions, you can introduce children in elementary grades to the nature of science and its tools.

In addition to the activities suggested in unit 2, the following activity provides ideas on how you can introduce younger children to matter (and energy) in the context of liquids.

Instead of handing out these ideas to Student Teachers, it would be more beneficial for them to come up with their own ideas. If they struggle to come up with their own ideas, consider using the suggestions to jump-start a discussion. This exchange should then lead teachers to quickly develop new activities.

Sample activity: Introduction to liquids

Liquids are easy to find because they are part of our daily lives. Young children can easily list liquids that they encounter every day. They drink liquids; liquids are in food; they are used for cooking and cleaning; they play a role in machines; and boats float on rivers, transporting goods and passengers.

Based on this list, children can observe and describe the different liquids. In doing so, they see that liquids have different properties and behave differently. They can begin with some simple investigations to identify the unique characteristics of all liquids and what differentiates some liquids from other liquids. They can also conduct some experiments to see what happens when liquids and solids mix—or even liquids and liquids.

When younger children conduct simple experiments, it is best to present them with only a few materials at a time to avoid overwhelming them with the materials. It is more important for children to freely experiment with the materials they are given. They should primarily focus on careful and detailed observations. These experiments lay the foundation for more complex and self-designed experiments later in the children's studies.

Additional resources

Hydro Steed. 'Electrolysis'.
➢ http://hydrosteed.com/images/PD8.pdf.

Visionlearning. 'Chemical Reactions'. (The reaction between hydrogen and oxygen to form water).
➢ http://visionlearning.com/library/module_viewer.php?mid=56.

NASA Explores. 'Science Lessons with Resources'.
➢ http://www.nasaexplores.com/show2_articlea.php?id=01-009.

Khan Academy. 'Periodic Table, Trends, and Bonding'.
➢ http://www.khanacademy.org/science/chemistry/periodic-table-trends-bonding.

Khan Academy. 'Orbits and Electrons'.
➢ http://www.khanacademy.org/science/chemistry/orbitals-and-electrons.

Glencoe Science: Chemistry: Matter and Change (The McGraw Hill Companies, Inc., 2005).

- Chapter 3: Matter—Properties and Changes, p. 54
- Chapter 6: The Periodic Table and Periodic Law, p. 150
- Chapter 7: The Elements, p. 178

UNIT 4

EARTH'S SYSTEMS UNDERGOING CHANGE

Unit Overview

This unit builds on Science I, unit 4, which introduced surface features of Earth and the forces that lead to their formation and change (for instance, rivers and erosion). But it also builds on several other concepts introduced in Science I and the previous units in Science II. Such topics include weather, energy flow, properties of matter, and causes and effects in systems responding to change.

This unit is divided into two major parts:

1) Earth's structure, the rock cycle, and plate tectonics
2) Water, the carbon cycle, and climate change

With so many important and vast topics packed into one unit, there is not enough time to teach all the details of each topic. Instead, this unit focuses on the big idea of Earth undergoing constant change and how Earth's systems respond to changes. Developing a conceptual understanding of these topics is more important than teaching specific details, such as the names of different rocks and the exact nature of the formation of these rocks. The goal of this course and this unit is to focus on the overarching concepts to provide Student Teachers with a generic foundation. More details can later be built on this foundation, either through additional courses or self-study programs.

Learning outcomes for this unit

Student Teachers should be able to:

- See the Earth as a system consisting of major interacting components that consistently undergo change. Physical, chemical, and biological processes act within and among them on a wide range of scales.
- Begin to see that there are complex interactions among the atmosphere, the hydrosphere, and the lithosphere.
- Apply the theory of plate tectonics to explain the formation of Pakistan's mountain ranges and the threat of earthquakes.
- Recognize how the movement of Earth's lithospheric plates causes slow changes in Earth's surface (e.g. formation of mountains and ocean basins) and rapid ones (e.g. volcanic eruptions and earthquakes).
- Give examples of advances in technology that have made it possible to more accurately predict natural disasters.
- Understand how human activities influence air and water quality, ecosystems, and climate across the globe.
- Identify the underlying core science concepts in this unit for children in elementary grades and design inquiry-based activities and learning outcomes that are age appropriate.

Unit 4/week 8: Earth's systems: Rock cycle and plate tectonics

(Sessions 1–3)

This week builds on the content covered in Science I, unit 4 (erosion, volcanism, earthquakes, etc.). In that unit, Student Teachers learned how Earth's surfaces undergo constant change. In Science II, they are ready to develop a more holistic picture by learning about the processes in Earth's lithosphere (rock cycle and plate tectonics).

Earth's crust is formed through the mechanism of plate tectonics. In this process, rocks are formed and transformed. These processes have been at work since Earth's formation billions of years ago. They provide a good context for a conceptual understanding of the history and age of Earth and how Earth undergoes slow and fast changes at all times.

The theory of plate tectonics is also a wonderful example to use to study how science and scientific understanding evolves. As technology evolves and scientific instruments advance, scientists can make better observations and collect data that was previously out of reach. The understanding of plate tectonics has evolved rapidly in the decades since Wegner.

As an independent research project, you might want to assign Student Teachers the task of researching the evolution of the theory of plate tectonics. By understanding the history of the scientific arguments made over the centuries, they will have a deeper understanding of the concepts. The information can also create an appreciation for the nature of science and how this knowledge is constantly growing based on previous knowledge, theories, and hypotheses.

Suggested activity for session 1

Formation of rocks

Begin this session by asking an open-ended and seemingly simple question: where do rocks come from? (If possible, point to some rocks that you might see through the classroom window or refer to some that can be found in the vicinity.) Listen to Student Teachers' answers. Encourage all of them to participate in this conversation. Eventually, push their thinking by adding more probing questions about the origin of rocks. For instance, they might say that trucks bring the rocks to the city. If so, ask where the rocks come from—before they were loaded on the truck, before they were washed down a riverbed, and so on. Throughout this initial conversation, do not correct their responses. Rather, have them debate each other's ideas or have them expand on them. By listening rather than lecturing at this point, you can get a good idea about their prior knowledge and potential misconceptions. This information will help you customize your teaching to tailor it to their level of understanding.

Next, provide Student Teachers with rock samples representing the three major types of rock: igneous, metamorphic, and sedimentary rock. (If physical samples are not available, obtain images from textbooks or the Internet.) Continue the conversation by asking them to compare and contrast the rocks and describe the physical properties. Are they all alike? What are the differences? What do they have in common? Is it possible to predict where they could be found? The purpose of this conversation is once again to make them think deeply and solicit prior knowledge. Do not accept single-word answers. Have them speak in full sentences and explain their thinking. Some of them might recall certain terms, such as *sandstone*. However, they may not have any conceptual understanding of the connections between these rocks, the rock cycle, the structure of the Earth, and plate tectonics. Make sure all of them contribute to this conversation. Student Teachers with more prior knowledge should not dominate the conversation. To keep the conversation flowing, ask questions such as: why do you think it is X? How can you tell? Also, ask other Student Teachers whether they agree or disagree and why.

In addition, ask Student Teachers whether they think it is possible for one of those rocks to be transformed into the other, and if so, how?

It is OK to spend an entire session having Student Teachers discuss their ideas with one another. You should facilitate their discussion rather than correcting their answers or beginning to lecture on those topics. You may write down some of their ideas (right *and* wrong) on the board to be revisited in the next two sessions. During those sessions, you will dive deeper into the concept of rock formation and plate tectonics. As a result, you will help them turn their partial recall knowledge into a deeper conceptual understanding of the changes occurring in Earth's lithosphere.

Suggested activity for session 2

Rock cycle in the lithosphere

Using Student Teachers' responses from the first session, address any misconceptions or shortcomings in their understanding of the rock cycle. Refer to selected Student Teachers' responses that were captured on the board. For better visualization, use a diagram of the rock cycle to walk them through the formation and reformation of rocks. The diagram should illustrate the differences of the three rock types and their formation (pay specific attention to the physical properties of those rocks because they yield clues to the rocks' formation).

It is important that Student Teachers understand that Earth's crust is constantly formed and reformed:

- on the surface through erosion
- below the surface by physical processes (mainly pressure and heat).

The rock cycle illustrates the system in which that change occurs.

Student Teachers tend to view rocks as objects that are static and unchanging. In general, it is easy for them to understand surface changes caused by weathering and erosion and how big rocks can turn into sand (refer to Science I). It is more difficult for them to realize that all those rocks stem from Earth's crust, which is also undergoing constant changes. When asked to sort and identify rock samples, they tend to focus on characteristics, such as their colour or shape. They will not generalize to features, such as rock texture, that relate to the processes by which the rock formed. They may not understand that the rocks represent samples broken off from bedrock outcroppings and that this bedrock makes up Earth's crust.

In this context, it is crucial to convey to Student Teachers that these processes occur on a geologic timescale. Even though they may be able to quote the age of the Earth, they tend to describe the rock cycle processes on a human timescale. For example, many will say that 'rocks' form by accretion on the bottom of streams as sediment sticks together. Or, they will say that rocks form when puddles dry up and dirt hardens. It is important to stress that these processes occur very slowly over thousands of years and involve pressure.

As an additional aid, you might want to present Student Teachers with an image of Earth's interior structure. Point out that the entire rock cycle takes place in the lithosphere. Tell them that the lithosphere is composed of many different layers of different rocks. The formation (and destruction) of the lithosphere is an ongoing process. In fact, this process is still happening right now under their feet. Also, the different layers in Earth's crust are usually stacked sequentially: the most recent layer is on the top, and the older ones are below. Scientists can date the layers of rock. They then use the information obtained from the rocks to create geologic timelines and learn more about Earth's past.

You might also want to spend some time this session revisiting geologic timescales. Student Teachers will then have a better sense of the scale of time involved in documenting Earth's history. In addition, they can learn some of the tools scientists use to trace Earth's history through its rocks.

If there is time, apply this theoretical knowledge to the geology of the region. You may want to discuss the local rock layers, how they were formed, and when. It is also possible to turn this into a self-study assignment to be completed by the end of this course.

Suggested activity for session 3

Theory of plate tectonics

End this week by using session 3 to connect the rock cycle with the theory of plate tectonics. You can begin this session by asking Student Teachers how the mountain ranges in northern Pakistan came about. Then ask them what kinds of rocks can be found there. Some of them will probably cite plate tectonics or tectonic upheaval as the cause. But as with the rock cycle, it is essential to move them beyond reciting scientific terms to make deeper connections. At the end of this session, Student Teachers should be able to explain how the rock cycle and plate tectonics are essential driving forces on Earth; they contribute to constant change. It will also help them better understand the landscapes around them: they should know how they came about, how they are changing, and what is under the surface.

Student Teachers have difficulty understanding concepts related to Earth's interior and plate tectonics because the internal layers and processes are outside their direct experience. The size scale is difficult to conceptualize, as is the extremely long timescale over which plate tectonic features form. Often, there is confusion about the nature and the location of the tectonic plates. In many cases, they disconnect the plates and their motion from the ground on which they stand. Instead, they envision the plates buried deep below the surface because they cannot see or feel the movement. You can show drawings and diagrams that explain the theory of plate tectonics and what happens at the different plate boundaries. However, it might be useful to build some three-dimensional models illustrating the layers of rock making up a plate. The models can show how the plate moves in respect to another plate and the consequences of that movement.

Appreciation for time and spatial ability to read (3D) diagrams are vital to successfully understand Earth and space science concepts. Both should be integrated into the teaching whenever possible.

Developing a basic, comprehensive, and conceptual understanding builds the necessary foundation for more in-depth topics. You can then consider teaching Student Teachers about convection currents that cause the movement of the lithospheric plates. Or, you can teach volcanic activity or earthquakes in greater depth.

More advanced Student Teachers with solid prior knowledge and a good conceptual understanding of the preceding concepts might hold a common misconception: people often believe that the Earth is molten, except for its crust. Many people do not understand that Earth's interior can be divided into layers based on chemical composition (crust, mantle, core) or based on physical properties (lithosphere, asthenosphere). Revisit Student Teachers' prior knowledge developed in Science I to illustrate how pressure and temperature rise as you go deeper into Earth's crust. This will reinforce their understanding. Based on their knowledge of properties of matter, they should understand that physical and chemical processes occur under such conditions. They should also realize that Earth's interior is not a homogenous substance but a mixture of different components.

Overall, it is challenging for Student Teachers to conceptualize dynamic systems. They try to identify a single causal force or a linear chain of causal forces to explain complex natural phenomena. Help them mentally process the multiple factors that interact with one another to cause plates to move, a volcanic eruption to occur, or an earthquake to happen. This complexity also makes it difficult to predict exactly when natural disasters will occur. Being able to make more precise predictions about future occurrences of natural disasters is part of ongoing research.

Student Teachers may have difficulty understanding why scientists can have more than one idea about processes in the natural world. Research has shown that people's ideas about the nature of knowledge develop through stages. In the first stage, knowledge is perceived as simply right or wrong. Throughout Science II, help the Student Teachers abandon this belief so they can view scientific knowledge as informed and supported with reasons. The development of the plate tectonics theory or the prediction of volcanic eruptions or earthquakes is a great example to illustrate this process of knowing.

Unit 4/week 9: Water and carbon cycle and climate change

(Sessions 4–6)

This week is also packed with a lot of content. Not all of it can be taught in the three sessions. Therefore, it is best to focus on the overarching idea of systems reacting to change rather than going too deep into a subtopic.

This week, challenge Student Teachers to build on their prior knowledge and develop a more sophisticated understanding of the Earth as a system in dynamic equilibrium. They can accomplish this by investigating the multiple interacting factors, and their consequences, that influence Earth's climate system. Each of the following topics can be used to achieve this understanding:

- The greenhouse effect (the carbon cycle)
- The composition of the atmosphere
- The uneven heating of Earth and the resulting prevailing wind patterns and ocean currents
- The albedo of Earth's surface and clouds

Student Teachers should end this week by hypothesizing how changes in certain factors, such as an increase in carbon dioxide or land cover, could affect other factors, such as the amount of heat retained in Earth's atmosphere. Also, they should discuss the role of human activity as a contributing factor to climate change.

As a long-term project for the remainder of the semester, have Student Teachers design and execute their own experiments. They can investigate processes, such as the greenhouse effect and albedo effect. They can also explore the negative and positive feedback loops of the system that can stabilize Earth's climate or cause it to change.

Suggested activity for session 4

Climate change: Evidence

To introduce the topic of climate change, you could begin this session in several ways:

- Present a newspaper article or textbook excerpt that discusses whether Earth's climate is changing
- Show global and regional climate data over a long period of time
- Show photos from receding glaciers

Give Student Teachers the opportunity to share their opinions on whether the Earth is warming, why, and what the consequences might be. Tell them to back up their opinions with as much evidence as they can. Then launch into a discussion on how scientists gather evidence to strengthen a hypothesis.

Capture Student Teachers' responses on the evidence they have heard that Earth's climate is changing. If necessary, revisit the difference between weather (short term) and climate (long term). Make sure they understand the difference between the natural fluctuation of weather and climate and a climate shift.

Tell Student Teachers that the remainder of the week, they will explore major factors that affect climate and what role humans might play. They will also look at climate data (historic and current) and discuss how to assess trends.

Most scientists and the general public agree that Earth's climate is changing. However, Earth's climate is such a complex system that even with the most sophisticated computer models, it is still difficult to predict what will happen. This week, Student Teachers should see first-hand how to research complex topics and make a case based on scientific evidence.

Suggested activity for session 5

Learning stations

Divide the class into two groups. Have the first group begin at station 1 and the second group begin at station 2. When half the session is over, have them switch stations. If you have a large class, form four groups and duplicate both stations, running two parallel tracks to accommodate the four groups.

It is best if each group has access to the Internet to research information on the questions posed. If that is not possible, select samples of the suggested resources in the Additional resources section and provide electronic or paper copies at the stations.

Station 1: Climate data (historic and current)

At this station, present Student Teachers with resources that allow them to read about and answer the following questions:

- How is climate data collected?
- How do we know what the climate was like hundreds or thousands of years ago?

Student Teachers should discuss the following question in their groups (ask them to be prepared to explain their answer to the class in the next session): looking at current and historic climate data, is Earth experiencing a climate change, or is the current increase in temperature just part of the naturally occurring fluctuation? Explain your answer.

Station 2: Greenhouse effect and global warming

At this station, present Student Teachers with resources that allow them to read about and answer the following questions:

- What is the greenhouse effect, and how does it relate to global warming?
- What are the factors that can cause an increase or decrease in the amount of carbon that is stored in a certain reservoir, such as the atmosphere?

Student Teachers should discuss the following question in their groups (ask them to be prepared to explain their answer to the class in the next session): in what ways do humans contribute to global warming? Explain your answer.

Remind Student Teachers that in the next session they will present their responses to the other group and discuss their conclusions.

Suggested activity for session 6

Presentations

Use this session to have both groups present their responses and discuss their answers. Make sure Student Teachers support their answers with scientific evidence and cite their data accurately. You might want to spend a few minutes reviewing how to read climate graphs or data, especially if they include them in their presentations.

In the second part of the class, have the class discuss potential consequences of global climate change. Have Student Teachers engage in discussions about cause and effect. For instance, if glaciers disappear, less freshwater in the summer months will flow into rivers that support people and agriculture downstream.

If there is time, extend the discussion by asking what people can do to lessen their impact on climate change. A possible answer could be using renewable energy sources instead of fossil fuels that contribute to the greenhouse effect. Listen carefully to Student Teachers' answers. Ensure that they understand the connection between the burning of fossil fuels and the emission of greenhouse gases, which lead to an increase in Earth's temperature.

Remind Student Teachers that Earth is constantly undergoing changes, and changes in climate are not unusual. However, evidence suggests that the current changes in the climate are outside natural fluctuation. There is concern among scientists, politicians, and the public that the increase in global temperatures could be irreversible. The consequences of such global warming could have far-reaching and disastrous consequences for people worldwide. But not all is caused by human activity. The burning of fossil fuels is an essential contributor to the greenhouse effect. But naturally occurring events, such as volcanic eruptions, also contribute to the greenhouse effect.

The concepts covered in this unit are sophisticated. Each challenges Student Teachers to use all of the skills they have acquired during this course. Many of them are still likely to have difficulties visualizing Earth's processes in three dimensions. Some may struggle to understand that small, incremental changes over millions of years can have dramatic effects. Be aware of these challenges as you listen to Student Teachers during class discussions and review their work.

Misconceptions about Earth's history may also become apparent when investigating past climate change. For example, many people think that during the Pleistocene, the temperatures were constantly below freezing. They don't understand that there were periods during which the climate was as warm as today. The Ice Age was actually a period of climate instability with dramatic fluctuations in temperature. Student Teachers might also have difficulty comprehending the extremely long timescale over which events in Earth's history occur.

The topic of climate change and global warming is widely reported in the media today. While raising awareness, popular reporting has also created misconceptions among the public. For example, many have the impression that there is significant disagreement among scientists about whether or not global warming is occurring. In actuality, there is widespread agreement in the scientific community that the climate is warming. Many scientists believe that the activities of humans are contributing to this warming. Scientists are debating how much warming will occur and what the specific impacts of global warming will be in the future.

You might want to have Student Teachers research this topic further in a special research assignment that will be due at the end of this course.

Unit 4/week 10: Teaching Earth's systems in elementary grades

(**Sessions** 7–9)

Dedicate this week to preparing Student Teachers for their teaching of science in elementary school. It is essential to support them in making the transfer from their own study of science to becoming a teacher of science in the elementary grades. Many teaching strategies and pedagogies learned in this course are transferable to teaching at elementary grades. However, the content, activities, and learning objectives have to be adjusted to reflect the difference in age and prior knowledge.

Suggested activity for session 7

Establishing content for elementary grade science

Start this session by explaining to your Student Teachers that this week you will switch from teaching them content that enhances *their* science understanding to discussing how they can foster the science learning of young pupils in elementary school.

Ask your Student Teachers to reflect on the past two weeks and the content covered. Have them work in pairs and jot down ideas about how they could teach the topic of 'Earth's systems' to children. What science topics would be relevant to teach in grades 1–8? Which principles and concepts do they need to establish as a foundation for learning science in high school and beyond regarding the rock cycle, plate tectonics, and Earth's major spheres (atmosphere, hydrosphere, lithosphere, and geosphere)? How do these all interconnect to form systems that also undergo constant change? What main ideas or concepts should be covered with these young children?

Possible answers are almost endless. This is not the time to approve or judge their ideas. Have your Student Teachers discuss the ideas with each other first. Have them explain their reasoning. Only interject if the discussion wanders too far off topic. Record their ideas on the board or on a poster so that you can refer back to them in the next session.

Also, have your Student Teachers consult Pakistan's National Curriculum for General Science in grades 1–8. Have them analyse whether they have missed any relevant topics that they want to add now. You might want to form groups for different grade levels, for instance, grades 1–3, 4–6, and 7–8. Again, focus the discussion on only science concepts that relate to Earth's systems.

If possible, establish a 'content progression chart' on the board. List all your Student Teachers' content ideas for each grade level. Ask them to step back and take a critical look at how the content is building from one grade level to the next. Ask if they would like to make any changes.

This exercise raises awareness that content cannot be viewed in isolation. Learning is a progression. Each topic builds on content learned before and becomes the basis for new content learned in the future. Student Teachers must learn to scaffold content and allow for such meaningful progressions.

A sample learning progression for 'rocks and the theory of plate tectonics'

A child in grades 1–3:

- Investigates how weather can cause change (e.g. the effect of rain on different materials)
- Identifies patterns of seasonal changes in weather (temperature, precipitation, and wind)
- Examines how rocks and soils can vary greatly in appearance
- Gains an understanding of how some earth materials are created and change (e.g. the difference of sand and soil formation)

A child in grades 4–6:

- Realizes that some Earth processes are rapid and some are slow (e.g. volcanic eruption vs. formation of metamorphic rock)
- Investigates landforms and relates a combination of constructive and destructive forces to their formation
- Describes and gives examples of ways in which Earth's surface is built up and torn down by natural processes
- Differentiates the layers of the geosphere, including the lithosphere, the hot convecting mantle, and the dense metallic core

A young adult in grades 7–8:

- Recognizes how the movement of Earth's lithospheric plates causes slow changes in Earth's surface (e.g. formation of mountains and ocean basins) and rapid ones (e.g. volcanic eruptions and earthquakes)
- Analyses the interaction of the four spheres (hydrosphere, geosphere, atmosphere, and biosphere) on Earth's system
- Evaluates the impact of changes in the atmosphere and hydrosphere on weather, climate, and landforms

In the following two sessions, it is important that the Student Teachers understand the expectations for children in elementary grades. Science content can and should be taught to young learners. However, it needs to happen in an age-appropriate, concrete, and hands-on inquiry way.

Suggested activities for sessions 8–9

Designing activities for elementary grade science

In grades 1–3, the National Curriculum covers several of the mentioned concepts in age-appropriate themes. For instance, in grade 1, 'Weather' and 'Seasons' are explicitly listed. 'Water' and 'Earth's resources' are themes in grade 2; grade 3 addresses 'Natural resources'.

Grades 4–8 increase the complexity and difficulty levels and include the following themes:

- 'Movement of the Earth' (grade 4)
- 'Water cycle' and 'Soils' (grade 4)
- 'Environmental pollution', 'Evaporation and condensation', and 'Soils' (grade 5)
- 'Environment and interactions', 'Air', and 'Renewable energy resources' (grade 6)
- 'Water' and 'Physical and chemical changes' (grade 7)
- 'Pollutants and their effect on the environment' (grade 8)

The purpose of sessions 8 and 9 is to take these extensive earth science themes and help Student Teachers identify age-appropriate content for children in elementary grades. Plate tectonics and climate change are big and complex topics. They should not be addressed with young children. However, these sizeable topics can be broken down into smaller, more tangible topics appropriate for children in the lower elementary grades. Topics such as the weather, erosion, volcanic activity, or sand and soil can be taught to children in grades 1–6 in a hands-on way. As a result, children will be motivated to learn more. Their prior knowledge will lay the foundation for the higher grades, which will address more complex and abstract topics, such as plate tectonics and the consequences of climate change.

Have Student Teachers choose a specific topic and grade level that they will discuss in a smaller group. These discussions and exercises should prepare them for the time when they will be selecting topics for their own classes and preparing their lessons.

Remind them that the goal is to develop meaningful and age-appropriate activities that teach relevant science content to children in a specific grade. If possible, the activities should be hands-on and intriguing. Guiding questions for the Student Teachers could be: what kind of question could children in elementary grades investigate? What kind of challenge could they solve, and what concept would they learn as a result? What kind of learning outcomes could be expected at that age level? Are those learning outcomes aligned with the expectation of a child in that grade? Have they considered prior knowledge and built the lessons accordingly?

Some suggestions for elementary grade activities follow that will lay the foundation to teach rock formation, plate tectonics, and climate (change) in the higher grades. These are just a few viable options. Many other topics can be taught to young children to introduce them to the basic foundations of earth and space science.

Therefore, let your Student Teachers develop some of their own activities first before you give them the following suggestions. As Student Teachers, it is crucial that they have ample opportunity to develop good lessons. If they don't keep practicing this during this course while they still can get help from you, the faculty, and their peers, they will not be as well prepared for their teaching as they should be.

Developing intriguing activities: Weather in early elementary grades

Observing the weather and beginning to record weather data is a very appropriate assignment for children of early elementary grades (grades 1 and 2). The theme 'Weather' is ideal to introduce young children to the idea of observing natural phenomena that happens around them. In this context, they learn to write down their observations in a structured way and eventually collect data and record that data. From these observations and data, children learn to identify trends, make predictions, and come to conclusions. All these are essential science skills that should be introduced in early elementary grades at a simple level. As children get older and can master more difficult tasks, observations and the collection and analysis of data should become more complex and demanding in nature.

Suggested sequence:

1) Children observe and describe today's weather in their own words. How does it compare to yesterday? They learn to take notes and draw pictures representing what they see.
2) Children observe and describe the sky in great detail. They use words, such as *sunny* and *cloudy*, and try to describe the type and amount of clouds. They take notes, draw pictures, and begin to compare the weather of different days.
3) Children discuss the effects of Sun and clouds: how does it affect the children when it is sunny/cloudy? How does a sunny/cloudy day impact the environment?
4) Introduce thermometers to record current temperatures and explain how to keep track of temperature over time. Children learn to create and read data tables.
5) Children discuss the effects of hot and cold weather and record their observations.
6) Children observe and record wind data (use a ribbon stick to measure the intensity of the wind) and then discuss the effects of wind.
7) Children observe and record different kinds of rain, learn to use a simple rain gauge, and discuss the effects of rain.
8) Children are assigned to keep track of the weather for an extended period of time.
9) Children compare the weather in different seasons and use their long-term data set as evidence for seasonal change.

Developing intriguing activities: Rocks, minerals, and soil

Rocks come in such a variety and are easily accessible everywhere. Rocks make up most of the Earth. When they break apart, they become the major component of soil (sand and clay). Soil plays an important role on Earth because it anchors plants, stores water, and is the home for many animals.

In the context of rocks, minerals, and soil, children in elementary grades learn about the relationships between rocks, minerals, and soils. They learn to systematically describe various properties of materials to help them identify them. They also develop skills to describe and classify materials using certain tests.

Suggested sequence:

1) Children explore the ground outdoors and collect samples so they can take a closer look in the classroom. They should collect samples from 'in' and 'on' the ground. Children then sort them into 'natural materials' versus 'people-made materials'.
2) Children separate the objects from their samples that they think are 'rocks' and discuss why they think these qualify as rocks.
3) Children focus on the physical characteristics of their rocks. They identify the characteristics that are shared by all their rocks and characteristics of materials that they think are not rocks.
4) Children break a rock to look at the pieces and compare the inside to the outside. They discuss why some of them might differ and notice that most of them are made up of two or more materials.
5) Introduce children to minerals. Then have them test and describe those minerals precisely in regard to colour (using a streak test), transparency and lustre (pen lights), hardness (hardness test and Mohs scale).
6) Children apply all their knowledge and testing skills to correctly identify a 'mystery mineral'.
7) Children return to their rock collection and sort them by size. They look closely at samples of sand and gravel, compare them, and discuss how they think rocks get smaller and smaller.
8) Children take soil samples and study the samples with a magnifying glass. They should consider the relationship between the soil sample and the location from which it was obtained.
9) Introduce children to the three components of soil—sand, clay, and humus—and have them identify each in the samples. Children sift the soil through different screen sizes and describe the different particles.
10) Children test the samples when they settle in a jar of water. What kind of layers form, and what might they be made up of?
11) Children apply their new knowledge and skills to explore how rocks, minerals, and soils are used as local building materials.

Additional resources

For rock formation and plate tectonics

Rock Cycle Animation.
➢ http://www.teachersdomain.org/resources/ess05/sci/ess/earthsys/rockcycle/.

Essay on Earth's History Told in the Stratigraphic Record by William L. Newman's Geological Time, 1997. The online edition is available at:
➢ http://pubs.usgs.gov/gip/geotime/contents.html.

Essential Science for Teachers, an Annenberg Media resource from learner.org, has two video programs that address rock formation and plate tectonics. Each lasts about an hour, and both are accessible at:
➢ http://www.learner.org/resources/series195.html.

- *Session 2: Every Rock Tells a Story*
  How can we use rocks to understand events in the Earth's past? In this session, participants explore the processes that form sedimentary rocks, learn how fossils are preserved, and are introduced to the theory of plate tectonics.
- *Session 5: When Continents Collide*
  How is it possible that marine fossils are found on Mount Everest, the world's highest continental mountain? In this session, participants learn what happens when continents collide and how this process shapes the surface of the Earth.

For Climate (Change)

NASA photograph of the retreat of the Gangotri Glacier in India over the past century:
➢ http://earthobservatory.nasa.gov/IOTD/view.php?id=4594.

Video documentary on the effect of global warming on glaciers (Gangotri Glacier in the Himalayan Mountains) and, therefore, indirectly on human freshwater supply and food:
➢ http://www.pbs.org/now/shows/516/index.html.

Climate data and graphs can be obtained through NOAA and NASA:

NOAA Paleoclimatology is a branch of NOAA's National Climatic Data Center. Paleo data come from natural sources, such as tree rings, ice cores, corals, and ocean and lake sediments—and extend the archive of weather and climate back hundreds to millions of years. NOAA Paleo provides data and information scientists need to understand natural climate variability and future climate change. They also operate the World Data Center for Paleoclimatology, which distributes data contributed by scientists around the world.

Access Climate Data Online at:

- http://www.ncdc.noaa.gov/oa/ncdc.html.

Access Paleoclimatology at:

- http://www.ncdc.noaa.gov/paleo/paleo.html.

NASA Godard Institute for Space Studies (GISS)—Research at the NASA Goddard Institute for Space Studies (GISS) emphasizes a broad study of global change, which is an interdisciplinary initiative addressing natural and man-made changes in our environment that occur on various timescales—from one-time forcings, such as volcanic explosions, to seasonal and annual effects, such as El Niño, and on up to the millennia of ice ages—and that affect the habitability of our planet.

Access GISS Data Collection on Global Temperatures over the past approximately 150 years at:

- http://data.giss.nasa.gov/gistemp/graphs_v3/.

Be mindful about Student Teachers' ability to analyse graphs and data of such complexity. You might have to provide them with assistance in order for them to understand what the data are showing)

UNIT 5

SOLAR SYSTEM AND THE UNIVERSE

Unit Overview

This unit builds on Science I, unit 4, which introduced Earth as a very unique planet in the universe. In Science I, the main focus was on Earth, with only some loose ties to the Sun and the Moon. Science II extends these concepts to cover Earth's place in the solar system (universe) and its origin.

In this unit, Student Teachers continue their investigation of the alignments and motions of the Sun, Earth, and Moon. They further explore phenomena that each produces, such as day and night, the year, lunar phases, eclipses of the Sun and Moon, seasons, and tides. They investigate the planets and other objects that orbit the Sun. They also learn about the characteristics and properties that make these objects a coherent system. In addition, they use their observations (with their naked eyes or telescope) and conclude that objects in the solar system change position against the background of stars. As a result, Student Teachers develop a deeper appreciation for scale in space.

If Student Teachers struggled to explain the seasonal changes in Science I, this is another opportunity for them to reach the conceptual understanding necessary to teach this topic.

Learning outcomes for this unit

During this unit, Student Teachers should be able to:

- Differentiate groups of objects in the solar system—including the Sun; the planets and their moons and rings; and smaller objects, such as asteroids and comets—by their size, composition, and position in the solar system
- Compare and contrast the properties and characteristics of Earth with those of the other planets in our solar system
- Explain, based on the naked eye and telescopic observation, how objects in the solar system change position against the background of stars
- Begin to understand the scale of time and distance involved in deep space
- Describe how the early Earth was very different from the planet we live on today
- Identify the underlying core science concepts in this unit for children in elementary grades
- Design age-appropriate, inquiry-based activities and identify learning outcomes

Unit 5/week 11: Solar system

(Sessions 1–3)

This week, the goal is to make sure all Student Teachers master the key concept that phenomena—such as the lunar phases, eclipses, season changes, and tides—can be explained by movements in space (rotations and revolution) and the relative position of the Sun, Earth, and Moon to one another.

Understanding the changes of the tides requires an additional understanding of gravity, which was briefly introduced in Science I.

In Science I, Student Teachers' perspective of the solar system was geocentric—that is, as it appears from Earth. In Science II, they build on this and examine the Sun-Earth-Moon relationships from space. They study the relative alignments and underlying motions of these bodies so they can fully comprehend and explain the causes of not just night and day, but seasons, lunar phases, and eclipses of the Sun and the Moon. They also study the role of gravity in the Sun-Earth-Moon system in the context of tides.

All of the concepts studied are subject to many misconceptions among children and adults. Therefore, it is important for Student Teachers to clarify their own possible misconceptions first. Then they should provide opportunities for children in elementary grades to articulate and grapple with their misconceptions throughout this unit.

Because it is impossible to experience the objects of this unit first-hand by, for instance, going into space, it is important to use models and simulations to present those perspectives.

Suggested activity for session 1

Solar system

Begin this unit by asking Student Teachers to brainstorm all the objects in the solar system that they are familiar with. Ask them to explain what they know about the object, where they heard about it, and whether they can observe it with the naked eye (or a good telescope) from Earth. They will most likely make mistakes. For instance, they may mention objects from outside our solar system, such as the stars we see at night.

If several Student Teachers struggle here, ask them to work with a partner and make a sketch of the solar system as they picture it. Have them list all the objects and draw them in relation to one another. You might want to begin by asking the class what object is in the centre of our solar system. Once they have established the Sun as the centre, ask them to add the Earth and its moon. Then ask them to add all the other objects in the order that they envision them. Give them only a couple of minutes to complete this task. In this instance, 100% accuracy is less important than making them think about relationships and distances in space. During this unit, they should gain a better sense of the solar system and be able to revise their sketches on their own.

Next, guide Student Teachers to narrow their list to include at least the following: one star (the Sun), several planets, one dwarf planet, one moon, one comet, and one asteroid. Using satellite images, show them solar system objects with accompanying physical data, such as size, distance from the Sun, composition, and the object it orbits. Then have them create their own schemes to group the objects.

In addition, have them compare their schemes with those created by other Student Teachers and discuss how to classify these objects. Ask them to derive their own definitions for terms such as *planet*, *star*, *moon*, *comet*, and *asteroid*. If you have time, begin a discussion on whether they think Pluto is a planet or something else. (Astronomers are still debating this point to date.)

To get a better sense of their level of understanding of the scale and makeup of our solar system, ask them where they would place the stars that they see at night. Have them use their sketch of the solar system and add the stars.

Before you reveal the answer, have each Student Teacher answer (or draw) and debate with one another if there is no consent.

If several Student Teachers place the stars within the solar system, consider conducting the suggested activity for children in elementary grades that involves building a model of the solar system. (To save time, you might want to do it theoretically in the classroom rather than building a real model outside.)

Suggested activity for session 2

Sun-Earth-Moon system: Phases of the Moon

As with the seasons, strong misconceptions can be held about the phases of the Moon. If many of your Student Teachers believe that it is the Earth's shadow that causes the phases of the Moon, spend some time correcting this misconception.

To begin with, it is important for Student Teachers to recall that the Moon does not emit any visual light. We can only see the part that is lit up by the Sun. The Sun's rays are reflected off the Moon's surface.

Ask Student Teachers to explain what causes the phases of the Moon. Then have them discuss the following set of questions with their partner. Encourage them to draw or use a model (you can hand out three balls of different sizes to model the Sun, Earth, and Moon). Before you begin, make sure all of them understand what a full, new, and crescent moon looks like.

1. What is the position of the Sun, Earth, and Moon during:
   - a new moon?
   - a full moon?
   - a crescent moon?

Have Student Teachers discuss their answers and come to a conclusion. Make sure they do not refer to Earth's shadow on the moon anymore. If they do, stop the discussion, have the class correct it, and explain why it cannot be the Earth's shadow.

If Student Teachers wonder why there is no eclipse every month, draw their attention to the third dimension in the model. The Moon's orbit is tilted relative to the Earth's orbit; therefore, the Moon very rarely is directly between the Sun and the Earth (solar eclipse) or directly behind the Sun (lunar eclipse). Do not go into more detail about eclipses at this point. If they show an interest in discussing eclipses, do that after the completion of this session.

2. What percentage of the Moon's surface is lit during:

- a new moon?
- a full moon?
- a crescent moon?

Have Student Teachers discuss their answers and come to a conclusion. By the end, make sure they all understand that the Sun always lights up 50% of the Moon's surface. (Use graphics and/or model this with a flashlight (Sun) and a ball (Moon) to demonstrate.) It is the rotation of the Moon around the Earth that allows us to see more or less of the illuminated side of the moon. That's how we experience the 'phases of the Moon' over the course of a month. Make sure they understand the limitations of the geocentric view because that is how we experience the world. Challenge them to try and place themselves outside the solar system (into space) and view the system from a different perspective to fully understand what is happening.

3. Bonus question: which side of the moon do we see at what point during the month? Explain your thinking.

Student Teachers will probably have different opinions on what the correct answer could be. Have them discuss their ideas using their scientific knowledge and reasoning skills. Instead of giving them the correct answer, ask them to observe the Moon over the next four weeks and record their observations. If they watch carefully, they should see that certain structures on the Moon's landscape are visible every night. Indeed, we always see the same side of the moon. The reason is that the Moon rotates around its own axis at the same speed as the Moon rotates around the Earth.

Demonstrate the Moon's rotation around Earth to make sure that Student Teachers fully understand it. Sometimes the public or magazines refer to the 'dark side of the Moon', but this is scientifically incorrect.

In class (or as homework), test Student Teachers' individual understanding before you move on. Give them the opportunity to explain what causes night and day and what causes the phases of the Moon (with the help of a model or drawings).

If your Student Teachers have a hard time understanding the preceding concepts, spend more time on the models. Or perhaps select an appropriate activity suggested in the third week of unit 4 in Science I and Science II, and in this unit. If they have mastered understanding and explaining the season changes, day and night, and the phases of the Moon, you could introduce them to the more special cases. For example, you could discuss eclipses (lunar and/or solar) or move on to the next session, which introduces tides on Earth and explores the role of gravity in this context.

Suggested activity for session 3

Gravity (and tides)

By now, Student Teachers should be quite knowledgeable about the alignments and motions of the Sun, Earth, and Moon, and the phenomena they can observe. In Science I, they were also introduced to forces, such as gravity. They learned that the Earth pulls any object towards its centre, no matter where it is on the Earth. In this session, they will combine those two ideas to understand what causes tides.

Begin by asking Student Teachers why they think nothing falls off the Earth. Don't just accept the word *gravity* as a one-word answer if a Student Teacher should mention it. Instead, encourage all of them to participate and explain their thinking. Have them reason with one another while you facilitate the discussion.

Next, ask Student Teachers to revisit their sketches of the solar system. At this point, debrief the model with a particular focus on scale. It is important for them to consider the vast size difference between the Sun and the planets and the vast distances between planets. The space between the planets is basically empty space. If Student Teachers represent the locations of the planets in this model, they should place them at different locations around the full orbits of the planets. The planets should not all appear to be on the same side of the Sun at the same time (an extremely rare occurrence). Reinforce the idea that there are great distances between even our nearest celestial neighbours.

As Student Teachers discuss the distances and orbital paths around the Sun, ask them: what holds the solar system together? Why do these planets stay on an orbital path around the Sun? Draw their attention to the relative sizes of the different planets. Discuss how gravity affects their movement and their orbits.

Use Student Teachers' prior knowledge from Science I, unit 5, Force and motion. Have them apply their understanding of inertia as the force that keeps planets moving through space in a straight line without the countervailing gravitational pull of, for instance, the Sun. Make sure they understand that any mass exerts a gravitational pull; however, the strength of the force depends on its mass.

Especially if you live close to the coast, have Student Teachers apply what they have learned about the constellations in the solar system and gravity to the phenomena of the tides shifting every six hours. What causes the tides?

Student Teachers should know that tides exist because of the interaction of Earth's and the Moon's gravitational forces and the Earth spinning around its axis once a day. The gravitational forces of the Moon pull Earth's water away from Earth and towards the Moon. This causes a high tide in one hemisphere and a low tide in the other hemisphere. But because the Earth rotates around its axis in 24 hours, we experience two high and two low tides every 24 hours. Spring tides (extreme tidal differences) happen twice a month. They occur during the phase of the new moon and the full moon as the Sun lines up with the Earth and the Moon, combining the Sun's gravitational pull with that of the Moon's.

As a long-term project, Student Teachers can collect and graph data from the Web or newspapers on tidal variations in one location over the course of a month. They can then verify their thinking and any simulations or illustrations they might have seen with evidence based on quantitative data.

As a final activity this week (or over the remainder of this semester), have Student Teachers investigate the motion of planets against the background of the stars. For instance, they can select one or more planets in a certain portion of the night sky that is visible from where they are. With the help of photographs or drawings, Student Teachers can identify the direction and distance the planet moved from day to day. If they choose more than one planet, they can compare their directions and rates of movement.

More advanced Student Teachers can also try to simulate the movement of a planet against the background of stars. They can then determine why planets do not always appear (from Earth) to move in a constant direction across the sky.

Unit 5/week 12: Deep space and time

(**Sessions 4–6**)

This week, Student Teachers extend their exploration of space to objects beyond the solar system. They investigate stars and galaxies and deepen their understanding of time and distance in space.

They also begin to think about the origin of the universe, the origin of Earth, and the type of evidence we have about these origins.

Suggested activity for session 4

Beyond the solar system

Begin this week by having Student Teachers create a physical model or sketch of the universe. The model should help them express their preconception of:

- what is in the universe
- where the objects are located relative to each other
- how densely the universe is populated with objects.

Research on people's conceptions about the universe suggests that they have well-conceived mental models; however, they include many misconceptions of relative size, location, and density of objects. Putting their ideas on paper and sharing and discussing them will help Student Teachers get ready for another week of complex and abstract topics.

This unit is not meant to instruct Student Teachers to become astronomers. The point of this session is primarily to give them an idea of space and time. Also, they should realize that Earth is just one of many planets, but it is a planet with very special conditions that allows life as we know it. Going farther out into space, they should also realize that:

- our Sun is one of many suns
- our vast solar system is just one of many in the Milky Way Galaxy
- the Milky Way Galaxy is just one galaxy of billions in the universe.

To illustrate the vastness of space, show some photos and provide Student Teachers with some data about the distances. You may introduce the light year as the unit of measurement in space. One light year equals six trillion (or six million million, or 6,000,000,000,000,000,000) miles. Such numbers are inconceivable for most people. Tell Student Teachers that in a model of the solar system in which Pluto is 1,000 yards away from Earth, the true limit of our solar system is 2,000 miles farther, or two light years out. The distance to the nearest star outside our solar system, Proxima Centauri, is 4.2 light years.

These numbers are difficult to write, let alone comprehend. It is important for Student Teachers to realize how vast and empty the universe is. The goal of this unit is for them to realize that Earth is only one of many planets but has special conditions and features that allow life as we know it.

To begin, have Student Teachers form small groups and compare and contrast Earth to another planet (in the solar system). Besides location, size, and neighbouring objects, the comparison should include a description of physical features, such as the presence/composition of an atmosphere, climate, and gravity. Based on that comparison, they should decide whether they think humans could survive on that other planet and, if so, what kind of protection they might require.

Also, if your Student Teachers have not built a model of the solar system that this is to scale, you might want to take the time to do it now. (For step-by-step instructions, refer to the Additional resources.)

Suggested activities for sessions 5–6

How it all began

There are many different ways to introduce the history of space. The topics in sessions 5 and 6 are just two ways of parsing the content and providing Student Teachers with a brief overview. Regardless of how you proceed or which topic you choose, for the purpose of this course, it is important that Student Teachers make connections to what they have already learned. Make sure they reaffirm their ideas of how vast space is and how scientists use technologies to gather data of places and time we cannot access otherwise.

The beginning of Earth

One possibility to introduce Student Teachers to the history of planet Earth is by providing them with the following information: Earth is approximately 4.6 billion years old, but the first life forms didn't begin until another billion years later.

Ask Student Teachers what they think the young planet Earth might have looked like at the beginning. (If they struggle to come up with ideas, show them some drawings of Earth at the beginning (see Additional resources).)

Ask Student Teachers: what kinds of changes needed to happen so life could begin? For this question, have them work in small groups. Remind them that they should focus on the first one billion years *before* the first life forms began. After a few minutes of brainstorming, to guide them, provide Student Teachers with additional materials (text or video—for instance, 'Earth: Making of a Planet' by National Geographic) that illustrate the changes that occurred on Earth. Have them focus on the most important factors, such as the formation of Earth's atmosphere, the arrival of water, and the formation of land.

After Student Teachers have gathered their information, discuss those changes that occurred and why they were so relevant for life to begin. Ask them to speculate what would have happened to Earth as we know it if those conditions hadn't formed.

In addition, ask Student Teachers how scientists know what happened so many millions, even billions, of years ago. What kind of evidence is used? What kind of tools and technologies do scientists use to obtain historical information?

In a closing discussion, make sure Student Teachers connect back to the previous unit on climatology and how we know about the climate of the past, plate tectonics, and the study of rocks.

The life cycle of a star: Our Sun

In the following suggested activity, the focus is on the Sun as our nearest star. But you could also choose another planet in the solar system. However, it is recommended to stay within the solar system because more information is available and Student Teachers have more prior knowledge; thus, they should be able to grasp the dimensions better.

If possible, provide Student Teachers with access to the Internet (or textbooks) so they can research what scientists have learned about the Sun. For example, they should read about its composition, its structure, and how stars evolve and change through a lifespan of millions or even billions of years before they eventually burn out. (Suns with a very high mass 'die' in a supernova that can result in the formation of new stars or even solar systems.)

There is evidence of the constant changes that occur in the Sun, resulting in the generation of sunspot cycles and solar flares. Have Student Teachers explore how solar activity, such as flares, can affect life on Earth and spacecraft. For example, solar activity can interfere with communications and create radiation hazards. For more advanced Student Teachers, you could explore the nature of stars. Perhaps introduce the process of nuclear fusion that occurs within the Sun's core and generates vast amounts of energy, creating new elements.

If there is still time, have Student Teachers look into space and begin an inquiry about the stars that make up most of the visible mass of the universe. They could compare the Sun to other stars. Examine evidence that stars vary greatly in size, temperature, and age but are made up of many of the same elements found on Earth. They could explore the techniques used by scientists to study stars—for example, methods to measure their size, composition, and temperature (for instance, the spectrometer that analyses light from stars).

Each of these topics is very complex and rather abstract. In this course, you can only briefly introduce these topics to inspire Student Teachers to learn more on their own time. However, make sure you make the connections to what has already been discussed in Science I and II. This session connects with many different science topics. But it is also another way to teach them how 'science works' and how ongoing research provides us with new insights. Science as a discipline is constantly changing—just like everything around us.

Unit 5/week 13: Teaching the solar system in elementary grades

(**Sessions** 7–9)

Dedicate this week to preparing Student Teachers for their teaching of science in elementary school. It is essential to support them in making the transfer from their own study of science to becoming a teacher of science in the elementary grades. Many teaching strategies and pedagogies learned in this course are transferable to teaching at elementary grades. However, the content, activities, and learning objectives must be adjusted to reflect the difference in age and prior knowledge.

Suggested activity for session 7

Establishing content for elementary grade science

Start this session by explaining to your Student Teachers that this week you will switch from teaching them content that enhances *their* science understanding to discussing how they can foster the science learning of young pupils in elementary school.

Ask your Student Teachers to reflect on the past two weeks and the content covered. Have them work in pairs and jot down ideas about how they could teach sections of the topic 'solar system' to children. What topics would be appropriate? What science topics would be relevant to teach in grades 1–8? Which principles and concepts do they need to establish as a foundation for learning science in high school and beyond regarding:

- the planets and stars in our solar system?
- deep space and time?
- the birth and death of stars?
- the tools and technologies space scientists use to gain a better understanding of Earth and the universe?

What main ideas or concepts should be covered with these young children? Possible answers are almost endless. This is not the time to approve or judge their ideas. Have your Student Teachers discuss the ideas with each other first. Have them explain their reasoning. Only interject if the discussion wanders too far off the topic. Record their ideas on the board or on a poster so that you can refer to them in the next session.

Also, have your Student Teachers consult Pakistan's National Curriculum for General Science in grades 1–8. Have them analyse whether they have missed any relevant topics that they want to add now. You might want to form groups for different grade levels, for instance, grades 1–3, 4–6, and 7–8.

If possible, establish a 'content progression chart' on the board. List all your Student Teachers' content ideas for each grade level. Ask them to step back and take a critical look at how the content is building from one grade level to the next. Ask if they would like to make any changes.

This exercise raises awareness that content cannot be viewed in isolation. Learning is a progression. Each topic builds on content learned before and becomes the basis for new content learned in the future. Student Teachers must learn to scaffold content and allow for such meaningful progressions.

A sample learning progression for 'solar system'

A child in grades 1–3:

- Recognizes that the Sun is the major source of light and warmth on Earth
- Monitors the apparent path of the Sun across the sky and compares it to that of the Moon
- Builds awareness that our Sun is a star among other stars in the universe
- Investigates the appearance of stars in the night sky

A child in grades 4–6:

- Examines components and relationships in the solar system (i.e. Sun, planets, moons—observes and records data of seasonal change in length of day/night, etc.)
- Develops an understanding of the Sun as a source of energy (i.e. observes sunspots and flares and makes the connection between the surface and angle of sunrays on a surface and their intensity)
- Investigates the apparent motion of the stars

A young adult in grades 7–8:

- Applies concepts of rotation, revolution, and alignment to explain the predictable patterns of phasing, eclipses, and seasons
- Compares and contrasts motion, properties, and characteristics of objects in the solar system
- Recognizes that gravity is the force that pulls all things on or near a planet towards the centre of the planet and governs the motions of objects in the solar system

In the following two sessions, it is important that the Student Teachers understand the expectations for children in elementary grades. Science content can and should be taught to young learners. However, it needs to happen in an age-appropriate, concrete, and hands-on inquiry way.

Suggested activities for sessions 8–9

Designing activities for elementary grade science

In grades 1–3, the National Curriculum covers several of the mentioned concepts in age-appropriate themes. For instance, in grade 1, 'Objects in the sky' is a listed theme. In grade 3, 'The Earth as a living planet' and 'Sun' are listed themes. In addition, exploring light and shadows is an essential foundation to understand how light travels and illuminates different objects.

Grades 4–8 increase the complexity and difficulty levels and include the following themes:

- 'Movement of the Earth' (grade 4)
- 'Properties and behaviour of light: Phases of the Moon' and 'Solar system' (grade 5)
- 'Space and satellites' (grade 6)
- 'Investigating space' (grade 7)
- 'Exploring space' (grade 8)

Developing intriguing activities: Teaching solar system in elementary grades

Solar system: Scale in earth science

Earth science is full of concepts that require a good understanding of scale. In particular, concepts in earth and space science require an understanding of time periods that span millions or even billions of years and distances that are so vast they are measured in light years. These numbers are almost incomprehensible for humans. They certainly present a big challenge when they are included in topics taught to young children. To conceptually understand the solar system (universe) or what causes the seasons or the phases of the Moon, children require a better understanding of scale and three-dimensional thinking. In order for young children to comprehend these topics, activities need to help children develop an appreciation for the distances, sizes, and times they are dealing with. One way to accomplish this in elementary grades is to build a model of the solar system to scale. Often, models of the Earth and the Moon are used, but they are hardly ever built to scale. The distances are so vast that in order to truly build a model of the solar system to scale, it requires at least the school campus—or, even better, the entire town—to accurately capture the dimensions of the solar system.

For example, if the Sun is represented by a bowling ball, the Earth is the size of a peppercorn. The peppercorn must be placed 26 metres away from the bowling ball to accurately reflect the dimensions. Continuing with this scale, Neptune, the planet farthest from the Sun, will be almost 1 kilometre away. Establishing this model hands-on requires time and space. However, it will leave a lasting impression on children. In addition, children will have an easier time understanding the vast emptiness of space, its distances, and how these distances matter. A model built to scale will also explain simpler concepts, such as day and night, but also more complex ones, such as seasonal changes, solar eclipses, the phases of the Moon, characteristics of other planets, space travel, and so on.

> For step-by-step instructions on how to develop a model of the solar system that is to scale, refer to the Additional resources at the end of this unit.

Long-term explorations and science projects in elementary grades

Children need time to explore the natural things around them in an inquiry fashion. Therefore, it is often most suitable to design a project that continues for several days, weeks, or even months but that takes only a few minutes every day. For example, children could observe the weather and keep notes (data) of the temperature and precipitation each day (see also Science I, unit 4). Children could also keep a Moon journal (e.g. what did it look like? At what time was it visible in the sky?). They could research where the resources they need to live come from (food, water, housing materials, etc.). Or, they could map their town and compare it to what it used to look like 100 years earlier.

These kinds of projects allow children to spend more time on a topic that they can then explore in depth. Allowing time for careful observation and teaching them how to collect and record their observations and data leads to natural inquiry questions. Such questions can become the heart of further investigations and learning of science. For instance, children might notice that the shape of the Moon changes. Depending on their age, you might just focus on the fact that roughly every month, the moon goes through the same cycle. Children could also keep a Sun journal that tracks where and when the Sun rises and sets. Then you could discuss, on a very basic level, Earth and its place in the solar system. With older children, you can explore why the Moon looks different at different times of the month. Why is it that the Sun sets earlier or later in different months of the year? Why do we have seasons?

Long-term studies help children develop their observational skills and expand their descriptive language as they observe, make measurements, record, and analyse their data. This project can also be tied in with biology investigations, such as those discussed in unit 2 of a local habitat or ecosystem. Combining the two studies allows for a more holistic picture. As a result, children can study in more depth the interdependence between the living and nonliving components of Earth.

Open-ended questions that require higher thinking skills are the key to this teaching approach. All activities should consist of opportunities for children to ask questions that they can then explore and for them to discover patterns in their data that allow them to make inferences. In a nutshell, provide them with opportunities to do research like a scientist, just on a smaller scale with guidance from the teacher.

Additional resources

National Optical Astronomy Observatory. *The Thousand-Yard Model, or the Earth as a Peppercorn* (by Guy Ottewell). Instructions on developing a model of the solar system at scale.
- http://www.noao.edu/education/peppercorn/pcmain.html

Public Broadcasting Service (PBS): What causes the tides?
- http://www.pbs.org/wgbh/nova/earth/what-causes-the-tides.html

Agan, L. and C. Sneider. 'Learning about the Earth's shape and gravity: A guide for teachers and curriculum developers'. *Astronomy Education Review,* 2(2) (2004): 90. Online version can be found at:
- http://aer.noao.edu/cgi-bin/article.pl?id=65

Kavanagh, C. and C. Sneider. 'Learning about gravity I: Free fall: A guide for teachers and curriculum developers'. *Astronomy Education Review*, 5(2) (2007): 21. Online version can be found at:
- http://aer.noao.edu/cgi-bin/article.pl?id=220

NASA: *Eyes on the Solar System*. Provides detailed information about the Solar System, current research, and space missions, and includes interactive multimedia for Student Teachers.
- http://eyes.nasa.gov/index.html

NASA: *From Earth to the Solar System*. This site is home to a collection of high-resolution images that showcase the discoveries and excitement of planetary exploration, with a focus on the origin and evolution of the Solar System and the search for life.
➢ http://fettss.arc.nasa.gov/

National Geographic. *Earth: Making of a Planet* (Video by National Geographic of the formation of Earth and the beginning of life). Video can be obtained from National Geographic and is also streamed from some servers, such as the following:
➢ http://www.moviesdatacenter.com/Movies/National-Geographic-Earth-Making-Of-A-Planet-2011.html

National Geographic. *Early Earth*. Article with images about infant Earth and how it developed.
➢ http://ngm.nationalgeographic.com/2006/12/early-earth/appenzeller-text

Agan, L. and C. Sneider. 'Learning about the Earth's shape and gravity: A guide for teachers and curriculum developers'. *Astronomy Education Review*, 2(2), (2004): 90.
➢ http://aer.noao.edu/cgi-bin/article.pl?id=65

Driver, R., Squires, A., Rushworth, P. and Wood-Robinson, V. *Making sense of secondary science.* New York: Routledge, 1994.

Duschl, R. A., Schweingruber, H. A., and Shouse, A. W. (eds.). *Taking science to school: Learning and teaching science in grades K–8*. Washington, DC: National Academies Press, 2007.

Kavanagh, C. and C. Sneider. 'Learning about gravity II: Trajectories and orbits: A guide for teacher and curriculum developers'. *Astronomy Education Review*, 5(2), (2007): 53.
➢ http://aer.noao.edu/cgi-bin/article.pl?id=221

Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART) Project K–4 and 5–8 Astronomy/Space Science tests:
➢ http://www.cfa.harvard.edu/smgphp/mosart/index.html

UNIT 6

HUMAN BODY AS A SYSTEM

Unit Overview

Unit 6 is an introduction to the human body and its components. Within the next two weeks, Student Teachers review what they know about the human body. They then apply their knowledge to better understand two key aspects of the human body:

1) the energy flow from food to the cells via the circulatory and digestive systems
2) the body's immune system.

The human body is another complex and vast topic that could be taught in many different ways. Because the course dedicates only two weeks to this topic, not everything can be taught, and choices have to be made. The following suggestions teach the concepts in a holistic way. As a result, Student Teachers get a better sense of how different systems (circulatory, respiratory, digestive, and immune systems) work together within the human body. At the end of the first week, Student Teachers should be able to apply their understanding to everyday situations. For example, they should realize the connection between food and physical work, and nutrition and health.

In the second week, Student Teachers study the immune system and make the connection between the human body and its response to diseases.

One of the shortcomings of many biology lessons on the human body is that people take a one-dimensional view of the different body systems. In doing so, they often fail to appreciate the necessary levels of interworking between systems that allow the body to function. Research studies have found that people's misconceptions about systems arise from their difficulty in recognizing that a natural phenomenon, such as the human body, exists due to systems working independently *and* together. People tend to interpret phenomena by noting the qualities of separate objects rather than by seeing the interactions between the parts of a system. To help with these misconceptions, make sure that Student Teachers view the entire body as a system and emphasize the interrelationships between the different parts of the body.

It is assumed that most Student Teachers have at least a basic understanding of the components and organization of the human body. They should know about the human cell and how cells divide and specialize to form tissue that forms organs.

In addition, Student Teachers should have a basic understanding of how the digestive, respiratory, and circulatory systems work. That is, they supply the body with the materials necessary for living and expel those not needed. They should also have a basic idea of what might happen if one part of a system fails to perform.

If this prior knowledge is not present, consider doing a quick refresher on these topics (15–20 minutes) before you continue to discuss the system of the human body in depth.

Learning outcomes for this unit

Student Teachers should be able to:

- Connect an organism's need for food with cells' need for food
- Explain how multiple body systems work together to meet cells' energy needs
- Examine and describe the flow of matter and energy in living systems
- Demonstrate through investigations that food is a source of energy (fuel) and building materials for cells
- Relate cellular respiration to the functions of body systems (e.g. how body systems function to provide cells with the necessary raw materials)

Unit 6/week 14: Food equals energy for the human body

(Sessions 1–3)

This week, Student Teachers develop an understanding of how cells get energy from food to power cellular work. The concepts included require them to build on their understandings of physical and chemical change, energy and matter transformation, and cells as basic units of function.

Throughout the week, Student Teachers investigate cellular respiration in a human context, even though all multicellular and many unicellular organisms release energy from food in the same way. The focus on the human context enables them to explore how body systems (e.g. digestive, respiratory, and circulatory) work together to provide for cells' energy needs. It also allows them to use their own bodies to collect data (e.g. measuring carbon dioxide in exhaled air). As a result, they are able to address persistent misconceptions about cellular respiration that are often rooted in personal understandings of how their bodies work (e.g. the misconception that breathing and respiration are the same).

Suggested activity for session 1

Why do we need food?

Begin this session with a very simple open-ended question: why do we need food? Have Student Teachers share their ideas first in pairs before you open the discussion to the class.

Student Teachers should know that food provides necessary energy and materials for growth and repair. For this discussion, challenge them to go deeper and to think from a cellular perspective. We need to eat because our cells need food. Food is a source of energy for cellular respiration. Cellular respiration is the process by which cells release the chemical potential energy stored in food by combining it with oxygen.

Make sure Student Teachers recall the science terminology of the key words. Also, make sure that they try to explain the connection between energy and growth through the process of cellular respiration as they understand it. At this point, do not try to teach them all the necessary details at once. Give them time to voice their ideas, even if some ideas are wrong or there are gaps in the process.

Next, focus on the question of how food actually gets into a cell. From their prior knowledge, Student Teachers should have some ideas about how food is processed in the digestive system. They should be able to develop a basic picture of the processes involved.

The key idea is that Student Teachers realize that the food we eat needs to be transformed so that the body can absorb it. Digestion involves mixing food with digestive juices, moving it through the digestive tract, and breaking down large molecules of food into smaller molecules. Digestion begins in the mouth, when food is chewed and swallowed. It is then completed in the small intestine, where the small molecules can be absorbed.

Student Teachers might recall that food is broken down in the mouth, oesophagus, stomach, and small and large intestines. They should know that different food groups—carbohydrates (starches and sugars), proteins, and fats—are digested at different parts of the process. They might even name some organs (such as the kidney, liver, and gall bladder) that play a crucial role. But most likely, they won't be able to explain the connections that make up the entire process. Instead of focusing this session on every detail of how starches, fats, and proteins are digested and absorbed, focus on the overall process and the reason it occurs.

To help Student Teachers better visualize how food gets from a plate into a cell, give them an opportunity to explore any of the following in a hands-on way.

First, review with Student Teachers that all food can be grouped into three main categories: carbohydrates, proteins, and fats. Each of those food groups contains energy in the form of nutrients. All of the nutrients are composed of simpler building blocks that are small enough to be absorbed and be used by the cell.

Second, have Student Teachers chew a starch (for instance, bread). Then have them test for starch and sugar afterwards to demonstrate that some food is broken down in the mouth. They should recall from Science I that chewing is a mechanical process resulting in a physical change (smaller piece of starch) but that a chemical change also occurs. The outcome of that chemical reaction is sugar.

Student Teachers do not need to know the specifics of those chemical changes. However, you should tell them that enzymes in the mouth, stomach, and small intestines trigger those chemical reactions. In the process, nutrients, such as complex starches, are broken down into smaller molecules (simple sugars). The starch test was only one of many processes that happen when food is digested in the digestive system.

As a hands-on activity, have them test different common foods to identify whether they are carbohydrates, proteins, or fats. For example, they can test for simple sugars using Benedict's solution or use other solutions for other foods:

- Benedict's solution turns bright orange in the presence of simple sugars
- Iodine turns dark purple in the presence of complex sugars (starch)
- Biuret solution is an indicator for protein
- Sudan IV solution is an indicator for fats

If you choose to demonstrate any of these indicators, quickly review how indicators use the physical and chemical properties of a substance.

Third, have Student Teachers answer the question of how food gets inside the cell. You can model this process by showing how the small building blocks get absorbed through the wall of the small intestine into the bloodstream and from there into every cell. Walk Student Teachers through this process: provide them with pictures of a cell membrane, through which small building blocks like simple sugars can pass, but bigger ones such as starch cannot. If possible, provide them with the opportunity to observe this critical process themselves. All you need is some dialysis tubing (to model the membrane of a cell) that you place inside a beaker of cornstarch or corn syrup (symbolizing the bloodstream). The following day, Student Teachers use indicators to test for the presence of sugar and starch inside the cell. As they discover only sugar molecules inside the cell, they can conclude that smaller molecules can move across the cell membrane, but larger molecules cannot. Thus, the digestion of food is only completed when the big molecules are broken down into small building blocks that can pass into the cells.

Suggested activity for session 2

What happens inside the cell?

When Student Teachers have a good idea of how food is broken down into the small building blocks (nutrients) that can get into the cells, ask them what happens next.

To help Student Teachers understand cell respiration, have them imagine the cell as a tiny motor. They should know that a motor produces energy through combustion (simply put: fuel and oxygen combine in an exothermic chemical reaction). They should also know that in order for a motor to run, it needs fuel and oxygen. The chemical reaction that occurs produces energy (heat) and other by-products, such as carbon dioxide. Combustion and cellular respiration are similar processes. However, the former occurs only in machines and the latter in human beings. Both processes produce energy, which is then used in other parts of the system, and carbon dioxide.

Because of time constraints, it is best not to go further into cellular respiration and the metabolic processes that happen inside the cell.

Ask Student Teachers what kind of evidence they have for such a reaction to happen in their cells. Answers could include that we inhale oxygen and exhale carbon dioxide (you could have Student Teachers do hands-on tests to prove that we exhale carbon dioxide).

Use a model, a graphic, or an online simulation to remind Student Teachers how the blood transports oxygen. The blood carries oxygen from the lungs to body cells and carries carbon dioxide from body cells back to the lungs. The main goal for these sessions is for Student Teachers to recognize that the digestive, circulatory, and respiratory systems all work together. These systems provide cells with the materials they need to get energy and remove waste materials that cells produce.

Often, Student Teachers do not make the connection between the respiratory and circulatory systems in the human body. They see them as disconnected. They might, for instance, think that carbon dioxide is a by-product produced in the lungs. They might not realize that it is a by-product of cellular respiration happening throughout the body. They might be able to explain the individual role of the lungs, the heart, the stomach, and so on. But most fail when they are asked to make the connection by answering the simple question of why we need food to survive.

Suggested activities for session 3

Nutrition and health

In this session, Student Teachers should apply their theoretical knowledge from the past two sessions to daily life situations. Most likely, you will not be able to cover all three suggested activities in one session. You could choose the one that seems most relevant for your Student Teachers. You could also assign sections of those activities as tasks to be done at home or as a final course assignment.

Effects of (hard) physical work on the human body

Student Teachers have experienced that as they exert themselves, their breathing rate goes up and their heart beats faster. What's the reason for this?

Have Student Teachers verify these observations with data that they collect themselves in a hands-on activity. They can take their pulse at rest and then again while they are doing physical work (for instance, climbing up and down stairs, running a distance, lifting heavy objects, etc.). They could even measure their breathing rates and/or the level of carbon dioxide in the exhaled air during rest and after physical work.

Have Student Teachers look at their data, compare the data of a body at rest versus a body doing physical work, and then answer the following questions:

- Why does physical work change pulse rate?
- Why does physical work change breathing rate?
- Why does physical work make your body produce more carbon dioxide?

Looking at physical work from a cellular point of view, Student Teachers should be able to explain why exercise prompts:

- faster breathing (the need for more oxygen for respiration)
- faster pulse (the need for efficient supply of oxygen to cells)
- greater carbon dioxide production (the production of more respiration waste products).

Food calories: What are they?

The human body needs energy (food) just to support all the bodily functions, such as the heartbeat, breathing, digestion, and organ support.

Research studies on adults have shown that the basal, or resting, metabolic rate (BMR) lies between 1,027 kcal per day (4,301 kJ) and 2,499 kcal (10,455 kJ); the average is about 1,500 kcal (6,279 kJ).

Refresh Student Teachers' memories by explaining that a calorie is a unit measurement for heat or energy and that they will explore the exact meaning shortly.

In the meantime, ask them why they think there is such a span between the low number of 1,027 kcal and 2,499 kcal.

What could be the reason? Student Teachers should realize that some of the difference can be explained by body composition (male, female, large body / small body, overweight, very muscular). They should mention as many contributing factors as possible. Then have them explain how these factors connect back to what they learned about the respiratory, circulatory, and digestive systems and the energy consumption required to keep them all going.

In a final hands-on activity, introduce Student Teachers to a calorimeter. Explain that a calorie is the amount of energy or heat needed to increase the temperature of 1 gram of water by 1 degree Celsius (a kcal is the energy or heat needed to increase the temperature of 1 kg (1,000g) of water by 1 degree Celsius).

With the help of a calorimeter, Student Teachers can analyse how many calories are contained in food items that they consume. To simplify the experiment, have them choose food items that easily burn. For instance, nuts contain a lot of fat, so they burn easily. Have them burn the item as completely as they can in the calorimeter. Then have them measure the amount of heat given off by monitoring temperature change in the water that surrounds the combustion chamber of the calorimeter. Even with a self-made calorimeter, they should recognize that food items with different proportions of protein, fats, and carbohydrates have different energy potentials.

Student Teachers should be able to apply what they have learned and discuss under which circumstances a person gains or loses weight. They should also know what kind of a diet plan people should follow if they wanted to gain or lose weight.

Make sure Student Teachers understand that these recommendations are just based on calories. They do not take into consideration the nutritional value of the chosen food, which is another important factor to consider when talking about food, nutrition, and health.

Cellular respiration in animals vs. photosynthesis in plants

This week focused on cellular respiration in a human context; however, all organisms get energy through cellular respiration, except some single-celled organisms can extract energy from food without oxygen (by using fermentation processes). As time allows, have Student Teachers examine evidence for cellular respiration in other organisms. They can also explore the mitochondria as the site for cellular respiration. As a result, they can make the connection between the number of mitochondria cells have and their energy needs (e.g. muscle cells have large numbers).

Begin this session by having Student Teachers examine the connection between photosynthesis and cellular respiration. The basic equations for photosynthesis and cellular respiration are as follows:

carbon dioxide + water + energy (from sunlight) → glucose + oxygen
glucose (food) + oxygen → energy + carbon dioxide + water

Student Teachers should conclude that photosynthesis *stores energy* in food, whereas respiration *releases energy* from food. Through photosynthesis, producers transform solar energy into the chemical bonds of complex molecules; through respiration, energy is released by breaking chemical bonds.

This is a good opportunity to revisit food webs introduced in Science I, unit 2. Student Teachers can then make the bigger connections and understand how energy is stored in producers through photosynthesis and is released through cellular respiration by producers or by consumers that eat the producers.

In addition, Student Teachers should recognize that at any point in the food web, the energy released from chemical bonds during respiration originated as solar energy. This will connect them back to the previous unit on the solar system.

Unit 6/week 15: Immune system
(**Sessions 4–6**)

Building on their knowledge of blood and the circulatory system that transports resources to the cell, Student Teachers explore the lymphatic system and its processes. The processes of the lymphatic system allow the immune system to recognize and react to microbes and foreign substances. Student Teachers learn how infectious agents can disrupt system, organ, tissue, and cell function in various ways. They compare the causes of a variety of diseases and model how viruses, bacteria, and parasites can interfere with normal body structures and functions.

But first, Student Teachers determine that the lymphatic system helps keep blood continuously circulating through the body by returning excess tissue fluid to the bloodstream. They examine the structure of the lymph nodes and their relationship to the immune system. They investigate how foreign material is removed from the lymphatic stream and how white blood cells are produced that function in the immune response. They also explore the role of special cells called macrophages, which are found within lymph nodes. Macrophages destroy bacteria, viruses, and other foreign substances in the lymph before it is returned to the blood.

Suggested activity for session 4

Lymphatic system

If available, have Student Teachers use microscopes to look at blood and lymph. From the previous week, they should already know that blood transports nutrients and oxygen (via red blood cells) to the cells and removes waste products, such as carbon dioxide. When they study blood through a microscope, they should detect the white blood cells. At this point, begin a discussion about the function of these cells using their prior knowledge.

If microscopes are not available, you could use images or simulations to guide the discussion. Be sure to introduce the idea of the white blood cells working together to ward off infections.

Through pictures or simulations, Student Teachers review the structures and function of the lymphatic system and its interrelationship with the circulatory system. They should learn that the lymphatic system helps keep blood continuously circulating through the body by returning excess tissue fluid to the bloodstream. At this point, they should take a closer look at the structure of the lymph nodes and their relationship to the immune system. Have them investigate how foreign material is removed from the lymphatic stream and how white blood cells are produced that function in the immune response.

The immune response varies depending on the different antigen. In the interest of time, in this session, Student Teachers focus only on the general processes that take place during the immune response. However, in the next two sessions, they can deepen the generic example when they research a disease of their choice.

At the end of this session, Student Teachers should be able to simulate the cooperative efforts of the cells in the immune system in warding off infection. They should also be able to follow the series of events that is called the immune response. They model the strategies the body uses to protect itself from microscopic organisms, foreign substances, and cancer cells. In addition, they analyse the roles of antibodies in the immune response and how they are produced.

Be aware that Student Teachers are often unclear about the meaning and use of the terms *microbe*, *pathogen*, *bacteria*, and *virus*. Also, they do not always realize that viruses and bacteria are different kinds of organisms and that only bacteria respond to antibiotic treatment.

Student Teachers with these misconceptions often use unscientific terms, such as *germ* or *bug*, to describe all of these organisms. It is important to emphasize the differences between these organisms and to encourage Student Teachers to use appropriate language.

Also, be aware that Student Teachers often confuse antibiotics with antibodies from both a language and conceptual perspective.

Suggested activities for sessions 5–6

Infectious and non-infectious diseases: Independent research project

In these two sessions, Student Teachers take the abstract processes of a general immune response and make it more concrete by studying a disease of their choice.

Begin by having Student Teachers create a list of diseases and what they know about them. As they share their lists with the class, have them try to group them into two categories:

1) *infectious* diseases (can be passed from one organism to another)
2) *non-infectious* diseases (cannot be passed from one organism to another).

Student Teachers reflect on what they have learned about healthy cell and system function in the previous week. They also learn to define disease as a breakdown in those healthy structures and/or functions.

You might provide some historic context on the battle against infectious diseases. Supply Student Teachers with data that compare the cause of death in the past century to the present day. Besides smaller outbreaks, especially in poorer countries, they should realize that the number of deaths based on infectious diseases has declined worldwide. The reasons are twofold: better medication and, in particular, vaccination.

Because this is the last week of the science courses, allow Student Teachers to conduct some independent research on a disease of their choice. As part of their research, they should address the following points:

- What causes the disease (what's the mechanism)?
- How does the disease affect the body?
- What forms of treatment are available?
- Why/how does this treatment work?

Student Teachers who are interested in infectious diseases (e.g. dengue fever, cholera, influenza, tuberculosis, chicken pox, AIDS) should choose a disease that is caused by bacteria or viruses (note that malaria is caused by a parasite). Infectious diseases are also caused by other pathogens (e.g. protists, fungi, parasitic worms), but due to time constraints, viral and bacterial infections will be the focus this week.

Student Teachers' research should show them how pathogens are passed from one organism to another, how they disrupt normal body function, and how treatments (such as antibiotics) disable them. Student Teachers who are interested in non-infectious diseases (e.g. cancer, diabetes, cardiovascular disease, cystic fibrosis, sickle-cell anemia) must explain how normal cell and body functions break down. They should also link those failures (if possible) to hereditary and/or environmental triggers and discuss how treatments target the cell/system failures.

As needs for instruction emerge throughout the research process, be prepared to provide short lessons to Student Teacher groups to help them clearly understand fundamental concepts. For example, short discussions about the key differences between viruses and bacteria as well as how antibiotics generally work may be useful to the infectious disease research group. Similarly, the non-infectious group may benefit from mini-lessons linking cancer to the process of cell division and connecting faulty genes with malfunctioning proteins.

Unit 6/week 16: Teaching the human body in elementary grades

(**Sessions** 7–9)

Dedicate this week to preparing Student Teachers for their teaching of science in elementary school. It is essential to support them in making the transfer from their own study of science to becoming a teacher of science in the elementary grades. Many teaching strategies and pedagogies learned in this course are transferable to teaching at elementary grades. However, the content, activities, and learning objectives must be adjusted to reflect the difference in age and prior knowledge.

Suggested activity for session 7

Establishing content for elementary grade science

Start this session by explaining to your Student Teachers that this week you will switch from teaching them content that enhances *their* science understanding to discussing how they can foster the science learning of young pupils in elementary school.

Ask your Student Teachers to reflect on the past two weeks and the content covered. Have them work in pairs and jot down ideas about how they could teach the topic of ‘the human body’ to children. What science topics would be relevant to teach in grades 1–8? Which principles and concepts do they need to establish as a foundation for learning science in high school and beyond regarding the human body? What main ideas or concepts should they cover with these young children?

Possible answers are almost endless. This is not the time to approve or judge their ideas. Have your Student Teachers discuss the ideas with each other first. Have them explain their reasoning. Only interject if the discussion wanders too far off. Record their ideas on the board or on a poster so that you can refer back to them in the next session.

Next, have your Student Teachers consult Pakistan’s National Curriculum for General Science in grades 1–8. Have them analyse whether they have missed any relevant topics that they want to add now. You might want to form groups for different grade levels, for instance, grades 1–3, 4–6, and 7–8. Again, focus the discussion on only science concepts that relate to the human body.

If possible, establish a ‘content progression chart’ on the board. List all your Student Teachers’ content ideas for each grade level. Ask them to step back and take a critical look at how the content is building from one grade level to the next. Ask if they would like to make any changes.

This exercise raises awareness that content cannot be viewed in isolation. Learning is a progression. Each topic builds on content learned before and becomes the basis for new content learned in the future. Student Teachers must learn to scaffold content and to allow for such meaningful progressions.

A sample learning progression for 'human body'

A child in grades 1–3:

- Recognizes similarities, differences, and variation in physical characteristics
- Explores the human senses: seeing, touching, hearing, smelling, and tasting
- Uses tools that can extend some of the senses
- Explains the difference between feeling healthy and sick

A child in grades 4–6:

- Investigates how structures in organisms coordinate to carry out essential functions
- Gains an understanding that the cell is the fundamental unit of life
- Examines and describes the flow of matter and energy in living systems
- Explains that reproduction is a characteristic of life and essential to the continuance of a species

A young adult in grades 7–8:

- Compares and contrasts structure and function in unicellular and multicellular organisms
- Communicates an understanding of the specialized structures and functions found in multicellular organisms, including humans
- Describes growth processes
- Assesses similarities and differences among internal structures in diverse organisms

In the following two sessions, it is important that the Student Teachers understand the expectations for children in elementary grades. Science content can and should be taught to young learners. However, it needs to happen in an age-appropriate, concrete, and hands-on inquiry way.

Suggested activities for sessions 8–9

Establishing content for elementary grade science

Although grades 1–3 do not explicitly specify 'the human body' as learning content, the foundation for this larger topic is laid in themes, such as the following:

- 'The food I eat' and 'Health care' (grade 1)
- 'Water' (grade 2)
- 'Food and feeding' (grade 3)

After the general knowledge is covered in grades 1–3, the topics become more specific and scientific. Examples are the following:

- ‘Characteristics of living things’ and ‘Food and health’ (grade 4)
- ‘Classification of living things’ (grade 5)
- ‘Cellular organization of plants and animals’ and ‘Photosynthesis and respiration in plants’ (grade 6)
- ‘Transport system in humans and plants’ and ‘Environment and feeding relationships’ (grade 7)
- ‘Human organ system’ in grade 8

Student Teachers should take the opportunity to finalize their knowledge and skills in lesson planning. Have them work one more time with their peers under your guidance to plan a lesson or even unit for an elementary grade of their choice. The larger context to address is the human body.

Sample activity: Introducing cells

One possible way to begin teaching about cells in the lower elementary grades (2–3) is through the world of unicellular organisms. In this context, young children can be introduced to the majority of organisms that live in various ecosystems. They learn that most organisms are actually single-celled. They learn to appreciate the world’s vast array of tiny life forms that can easily go unseen but that play vital roles.

Later in their studies, children learn that they have much in common with these microscopic creatures. For instance, their own cells carry out the same basic functions as a single-celled organism, which they could even observe first-hand.

In later elementary grades, children learn how diverse organisms are interconnected within ecosystems. They also learn that all life forms are tied together by the same functional unit, the cell. As children will later understand, this cellular connection is what allows matter and energy to flow among and through diverse organisms.

Children in elementary grades could compare the ways humans obtain and use materials for life processes with those of other organisms. As they consider these differences, they also examine the commonalities of all living things. Through microscopic imaging (or images), children identify and describe the common characteristics of living things.

Without going into too much detail, children in elementary grades can begin to think about the following questions:

- How might organisms in the schoolyard obtain and use the materials necessary for life? How about the earthworm? The fungi? The plant?
- What are the characteristics all living things share?

They can conduct experiments with materials that organisms need for survival—for instance, what plants need to survive. They can speculate how the materials needed for survival are obtained in different species. They can also think about what might happen with those materials so the species can use it for growth, repair, and energy.

In later grades, children observe how single-celled organisms carry on all functions. Conversely, they observe that multicellular organisms are organized in more complex ways with cells as the building blocks of all structures. They could make these discoveries in a hands-on manner. Using microscopes, if they are available, children could examine the cells of onions and elodea plants and cheek cells from their own bodies.

In addition to learning about the different kinds of cells and their function, children should also recognize that various schemes are used to make sense out of the diversity of living things. They begin to understand how classification systems help us:

- group similarities in form and function
- explain how organisms carry out life processes
- identify relationships between and among organisms.

They answer questions, such as: what are the similarities and differences between cells from different organisms? How could these characteristics be used to sort and classify all living things?

For a more holistic picture, they consider where the materials come from that all living things need for growth and repair. They also consider how specific adaptations or strategies might help the organisms obtain and use materials, forming an interconnected food web.

Sample activity: Immune system

In order to teach the specifics of the complex immune system, it is essential to build stepping stones. Start by introducing children to the other less abstract systems in the human body first. It is suggested to begin with the basics of eating, breathing, the heartbeat, and the role of some organs, such as the heart, the lungs, and the skin. In parallel, children learn about what it means to be healthy versus sick and what causes diseases.

Driver et al. has done extensive research on children's misconceptions, among them the understanding of diseases. According to her findings, it is common for children to confuse which diseases can be attributed to 'germs' and which are linked to other causes (Driver et. al., 1994). Robust but unproven 'folk beliefs' about environmental causes (you catch a cold by getting cold and wet) are widespread and persistent. Also, many children are unaware that every infectious disease has a specific pathogen; they have difficulty distinguishing between pathogens, especially bacteria and viruses. Additionally, children are not aware of how pathogens disrupt function ('they walk about and eat us') or realize how antibiotics work (antibiotics work only on bacteria, not on viruses). In addition, children do not view some conditions as diseases ('if I just have a cold, I am not sick'). For more information, refer to the Additional resources.

Knowing about such perceptions and misconceptions is crucial for a Student Teacher. Try to keep an eye and ear open when teaching any child. But basic understanding and vocabulary can begin in the early grades. Consequently, more complex and abstract topics can be built on a strong foundation that was built during the early grades in elementary school.

Additional resources

Your Digestive System and How It Works. Website provided by the U.S. Department of Health and Human Development.

- http://digestive.niddk.nih.gov/ddiseases/pubs/yrdd/.

Driver, R., Squires, A., Rushworth, P., and Wood-Robinson, V. *Making sense of secondary science: Research into children's ideas*. New York: Routledge, 1994.

Approaches to Biology Teaching and Learning: Understanding the Wrong Answers—Teaching Toward Conceptual Change. Online article on teaching strategies and common misconceptions. Second paragraph is specifically on the role of misconception research in teaching towards conceptual change using examples of cell biology.

- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1103711/.

To learn more about nutrients and energy potential, access:

- http://www.merck.com/mmhe/sec12/ch152/ch152b.html
- http://www.merck.com/mmhe/sec12/ch152/ch152e.html
- http://www.npr.org/templates/story/story.php?storyId=6700905

To learn more about how the human digestive system processes food into forms that cells can use, access:

- http://digestive.niddk.nih.gov/ddiseases/pubs/yrdd/
- http://yucky.discovery.com/flash/body/pg000126.html
- http://training.seer.cancer.gov/module_anatomy/unit10_1_dige_functions.html
- http://www.innerbody.com/image/digeov.html

To learn more about cellular respiration and combustion, access:

- http://www.angelfire.com/ga2/nestsite2/webunit8.html
- http://www.angelfire.com/ga2/nestsite2/webunit8.html

To learn more about how the respiratory and circulatory systems work together, access:

- http://www.fi.edu/learn/heart/systems/respiration.html
- http://www.pbs.org/wgbh/nova/heart/heartmap.html
- http://www.innerbody.com/image/cardov.html
- http://www.kidshealth.org/parent/general/body_basics/heart.html

Deadly Diseases: Rx for Survival (website and video). Tells the story of some of the world's most lethal and feared diseases. The diseases profiled on the website explore the nature and origin of many of the diseases covered in the series; their impact on the past, present, and future; and the battle to tame and eradicate them.

- http://www.pbs.org/wgbh/rxforsurvival/series/diseases/index.html

Appendix

Professional Standards for Teaching Science

In 2009, the Ministry of Education passed into policy a set of National Professional Standards for Teachers in Pakistan (NPSTP). The 10 standards describe what a teacher should know, be able to do and be like (with regard to knowledge, skills, and dispositions).

The following is a list of standards specific to the teaching of science. They were developed to be used in conjunction with the three science courses in the B.Ed. (Hons) Elementary/ADE. They provide a description of the knowledge, skills, and dispositions a teacher requires to teach science.

This set of standards for teaching science is linked to the NPSTP. The first standard in the NPSTP concerns Subject Matter Knowledge – the knowledge, skills, and dispositions a teacher requires to teach the content of the National Curriculum. In the NPSTP, knowledge, skills, and dispositions are described in general terms for all subjects. Here, they are described specifically for teaching science.

The standards for teaching science may be used by Instructors and Student Teachers in a variety of ways, including for assessment (including self-assessment) and planning instruction. The standards may also be used as part of instruction. Helping Student Teachers deconstruct and understand the standards (and what they 'look like' in the classroom) will help them learn about teaching science.

Subject Matter Knowledge (Teaching Science)

Knowledge and understanding

Teachers know and understand the following:

- the national curriculum framework for science
- the science domain; basic science concepts and theories; the history and nature of science; how to conduct experiments, collect, and analyse data; how to represent data visually; and the structure and process of acquiring additional knowledge and skills in science
- the evolving nature of science, its content, and the need for keeping abreast of new ideas in particular as they relate to teaching science
- the findings of latest science research and the latest trends at the national and international levels as they relate to teaching science
- in-depth knowledge of the subject matter and its relationship to other content areas
- the relationship between science and other disciplines and subjects, and science's usability and applications in everyday life.
- the relationship between reading, writing, and arithmetic principles and science

- that science is more than the accumulation of established scientific knowledge – it is an ongoing process
- that science content and science pedagogy cannot be separated and an effective lesson plan makes best use of both in a synergistic manner.

Dispositions

Teachers value and are committed to doing the following:

- facilitating learning in a variety of ways to help learners to construct knowl edge and understanding in science and to develop the skills required to do science
- providing meaningful learning experiences that lead to deep understanding of the topic, not just memorization of facts
- creating a challenging but non-threatening learning environment
- recognizing the diverse talents of all students and helping them to develop self-confidence and science literacy
- believing that *all* children and adolescents can learn science at high levels and achieve success
- identifying learner-relevant science content and teaching it in ways that connect to learners' daily lives
- teaching students how to think critically about information and how to make informed decisions that will affect their personal lives, careers, and society
- believing that the scope of science content is unlimited and can change
- believing in life-long science learning and in being part of a learning community.

Performance and skills

Teachers demonstrate their knowledge and understanding by doing the following:

- designing and teaching science lessons that take into account the learner's biological maturation, prior knowledge and experience, *and* present challenges and opportunities for new learning
- using tools and methodology of inquiry appropriate to the nature of science and the content being taught
- effectively explaining concepts and ideas in science from multiple perspectives and in multiple ways appropriate to the students being taught
- giving examples of how content can be applied in daily life
- encouraging 'scientific habits of mind' by asking relevant, open-ended questions and by creating opportunities for students to ask questions, analyse situations, and solve problems
- asking challenging, open-ended questions (rather than questions that depend on memorization of facts) to help students construct conceptual scientific understanding
- modelling skills and dispositions for scientific inquiry, including curiosity and openness to new ideas and data
- using teaching strategies that help learners to become aware of inconsistencies in their own or others' thinking and, thus, to construct new understanding
- facilitating laboratory work and hands-on activities to develop skills and techniques as well as to construct new scientific ideas

- arranging opportunities for discourse about scientific ideas to help learners develop evidence-based reasoning skills
- adapting available curricula, materials, and teaching strategies to fit the diverse needs of all learners
- promoting deep scientific understanding by applying the nature of science and inquiry in conjunction with core science concepts and ideas.

Adapted from National Professional Standards for Teachers in Pakistan. Policy and Planning Wing Ministry of Education Government of Pakistan. Islamabad, February 2009. Available from:

➢ http://unesco.org.pk/education/teachereducation/files/National%20Professional%20Standards%20for%20Teachers.pdf

References

National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Washington, DC: National Academy Press, 2011).

National Research Council, *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (Washington, DC: National Academy Press, 2000).

National Research Council, *National Science Education Standards* (Washington, DC: National Academy Press, 1996).

Higher Education Commission