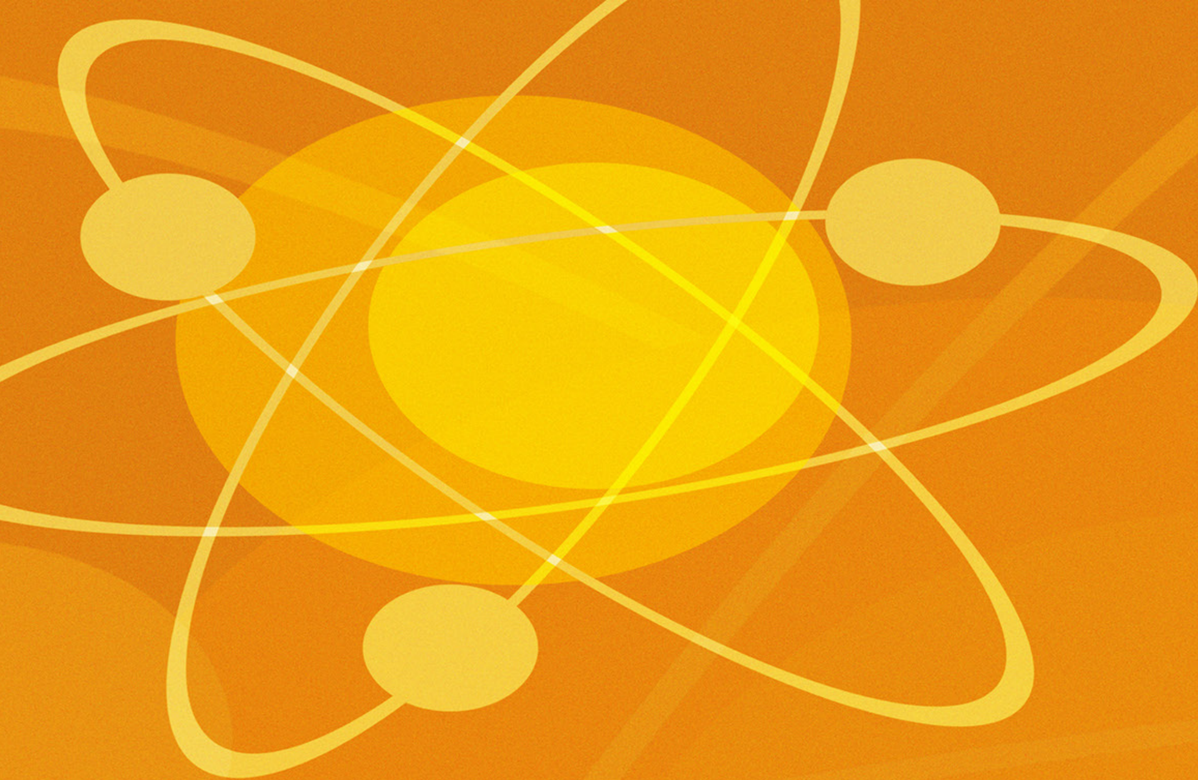

QUARKS AND LEPTONS

Lesson Sample for Science, Grade 8

by Stacey Joyce

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The new BC Curriculum reflects a shift towards a concept-based, competency-driven curriculum. The new curriculum is less prescriptive than before, allowing educators to be creative and innovative in their design of learning experiences, and offering flexibility and choice for teachers and students.

The new curriculum promotes higher-order thinking and deeper learning centred on the 'Big Ideas' in each discipline. Core Competencies related to Thinking and Communication are explicit, and First Peoples' Principles of Learning are integrated throughout.

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Overview

The purpose of this lesson is to further explore the building blocks of matter. Before this lesson, students would have explored the kinetic molecular theory and early models of the atom. Students should be comfortable with the concept that the atom is made up of three subatomic particles: protons, neutrons, and electrons. This lesson deepens their knowledge and understanding by introducing them to the concept of fundamental (indivisible) particles. Following this lesson, students would continue to explore the nature of the atom and how fundamental forces keep the atom held together. Many possible extensions or inquiries focused on the particle model and fundamental forces (e.g., exploring force carrier particles or the other types of quarks) could be further pursued by students and/or the teacher.

“When developing this lesson, I first chose the concept that I wanted to explore with students. The concept dictates the Big Idea and learning standards.

Big Idea

The behaviour of matter can be explained by the kinetic molecular and atomic theory.

Learning standards (Content)

Atomic theory and models:

- protons, neutrons, and quarks
- electrons and leptons

“After choosing the content, I asked myself, “Why is this content important?” My answer focused on the importance of fundamental particles as the building blocks of matter. This helped me formulate the essential question to help guide student learning.

Essential question

What are all the things in our world made of?

Learning standards (Curricular Competencies)

Questioning and predicting

- Make observations aimed at identifying their own questions about the natural world

Processing and analyzing data and information

- Construct and use a range of methods to represent patterns or relationships in data, including tables, graphs, keys, models, and digital technologies as appropriate
- Seek patterns and connections in data from their own investigations and secondary sources

Applying and innovating

- Transfer and apply learning to new situations

Core Competencies

Communication

- Connect and engage with others
- Acquire, interpret, and present information

Critical Thinking

- Analyze and critique
- Question and investigate

First Peoples Principles of Learning

- Learning takes patience and time.
- Learning is holistic, reflexive, reflective, experiential, and relational.

> “I chose the Curricular Competencies after I had a sketched out a framework for the lesson. I made a rough outline of the activities and strategies I felt would be most effective with students — in this case, the foundational idea is modelling. Knowing that this lesson was focused on analogies and models, I selected the Curricular Competencies that could be assessed in a naturalistic way throughout this lesson both formatively and summatively at the end.

> “The Core Competencies are embedded within the Curricular Competencies and naturally presented themselves as the lesson took shape. Choosing the formal list of Core Competencies was one of the last things that I did for this lesson. Once the lesson was complete, I looked for the Core Competencies that stood out as clear and significant opportunities for students to develop their profiles. Depending on the teacher's teaching style, other competencies may be a better fit.

> “Because this lesson is predominately focused on Western science understandings and research, I knew that First Peoples content would be integrated through the First Peoples Principles of Learning instead of through direct knowledge and understandings of First Peoples.

Quarks and Leptons Lesson Flow Chart

Big Idea

Core Competencies

Introduction

Students discuss the essential question and share their thinking.

Core Competencies

Curricular Competencies

Cookie Exploration

Students dismantle and categorize the parts of a cookie. Transition to the card sort activity.

Cookie Dough Modelling

Students mix and match card ingredients to investigate possible combinations.

Chocolate Chip Modelling

Students investigate difference in chocolate chips. Transition to card sort activity.

Core Competencies

Curricular Competencies

Content

The Atom as a Cookie

Students use the card sort activity to compare and relate the patterns in cookie ingredients to the patterns in atoms with subatomic particles.

Core Competencies

Curricular Competencies

Content

Summative Assessment

Students create an infographic or presentation of their choice that communicates their understanding of the essential question.

> “Once I had the topic, Big Idea, and Content and Curricular Competencies, I sketched out the framework for this lesson (see flow chart, page 6). In each step of the lesson, I considered how I would integrate formative assessment strategies to provide a solid foundation for the summative assessment at the end. The lesson flow chart maps out both the activities of the lesson and the new curriculum underpinnings (Big Ideas, Core and Curricular Competencies, and Content learning standards). The flow chart is intended to help the teacher visualize the lesson through the various lenses when considering their delivery and formative assessment strategies. Very different from previous curriculums, the Content learning standards are no longer the dominant factor in the lesson plan and don't appear in the flow chart until the end.

Lesson Framework

Introduction

The essential question, "What are all the things in our world made of?" is intended to serve as the hook to engage students' creative and critical thinking skills. The question can be posed in a variety of ways (e.g., to the class at large, in small groups, through journal entry). Students should have an opportunity to discuss their answers and to share ideas. Depending on the class, the teacher may need to guide the discussion to encourage students to question on a deeper level and incorporate their knowledge of elements and atoms. The teacher may choose to break this lesson into two class periods: the cookie modelling on day one and the content transition on day two.

As an extension, the teacher may wish to introduce historical ideas of what comprises matter such as the concept of earth, wind, air, and water as the four fundamental elements.

Students should not try to definitively answer the essential question at this stage. The intention of the introduction is to place students in an inquiry mindset and have them generate questions to explore as they proceed through the lesson.

Cookie exploration

The atom is too small to be seen and explored. The foundation of this lesson is to provide students with a concrete analogy of atoms through the exploration of a chocolate chip cookie. The intention is that students will find patterns in the building blocks of the cookies and then transfer and expand their learning to the atom.

To facilitate development of the interpersonal and communication Core Competencies, students should work in pairs or small groups. The teacher provides a chocolate chip cookie (a soft cookie is easier to dismantle) to each group. This activity is predominately exploratory, and the teacher should focus on asking questions rather than directing actions.

Sample questions

- What is a cookie made of?
- Can you see the parts?
- How do you make a cookie?
- How can you change the flavour of a cookie?
- Does it matter what you use to make a cookie?
- Do all cookie recipes turn out well?
- Does combining any set of ingredients always produce edible food?

The learning intention of this activity is to have students collaboratively develop and communicate their understanding that large things (i.e., the cookie) are made up of smaller parts. Students should have sufficient background knowledge to generate a list of simple ingredients.

There are a variety of implementation strategies for this activity. The cookie can be physically separated into the simple parts of chocolate chips and cookie dough. This is an engaging hands-on activity that should spark student interest. Students then consider the dough and the chocolate chips separately.

Dough exploration

The dough can be further separated into its constituent parts, but not mechanically as they cannot be seen or touched. A set of cookie ingredient cards (i.e. card sort) facilitates students' understanding of how building blocks combine to make up matter. The teacher may choose to use guided steps or a more open-ended inquiry for this activity depending on their specific class make-up and learning intentions.

As an extension, students can sort the ingredients into "wet" and "dry" categories. This extra classification of building blocks can be mirrored with the division of fundamental particles as quarks and leptons.

Chocolate chips exploration (optional)

The chocolate chips can be further broken down as well. The exploration of the chocolate chips is specific to the modelling of protons and neutrons. Different types of chocolate chips are used to simulate different types of subatomic particles. Chocolate chips are easily identified as "one type of thing," but there is great variety. Students will explore the foundational building blocks that are combined in different ways to produce different results (i.e., dark chocolate, white chocolate).

The teacher provides students with a variety of chocolate samples (e.g., high percent cocoa, low percent cocoa, white chocolate [no cocoa]). Students should make observations about the chocolate samples and be able to share their thinking with what makes them the same and different. Depending on which Curricular and Core Competencies the teacher is focusing on, students could be asked to record, chart, document, or discuss their observations. (A set of chocolate chip ingredient cards facilitate this exploration.) It is likely that many students will not be familiar with the ingredients of chocolate, so the cards are simplified.

The key understanding from this activity is for students to be able to communicate how the ratio of base ingredients can alter the final product. This concrete model will be the basis for understanding how the different combinations of quarks form different particles.

Sample questions:

- What is chocolate made of?
- Can you see the parts?
- How do you make chocolate?
- How can you change the flavour of chocolate?
- Does it matter what you use to make chocolate?
- How is it possible for different types of chocolate to be made from the same basic ingredients but still taste differently?
- What are other examples where you can see this pattern?

The atom as a cookie

After cookie activities have been completed, students should have a strong understanding that the type and amount of a base ingredient results in the properties of the final product. The teacher may choose to link back to the introductory discussion based on the essential question as a segue from the concrete to the abstract. Students should be familiar with the three subatomic particles (proton, neutron, electron) and the basic structure of the atom. There are a variety of decisions to be made regarding the teaching of the content (quarks and leptons). The teacher may choose to have the formal content before the modelling activity, or after. As well, the teacher may wish to formally present the information, or they may prefer to have students independently research or discover the information in another way.

The intention of this lesson is to introduce students to the idea of fundamental (indivisible) particles – quarks and leptons – as the basic building blocks of all matter. (Force carrier particles are not considered at this level). This lesson has students explore only two types of quarks — up and down — and only one type of lepton — electrons. The particle model of matter is significantly larger and more encompassing than the quarks and leptons. The teacher and/or students may choose to delve into the topic in much more detail, past the intentions of this lesson (some suggested resources are included at the end of this lesson).

A set of particle cards facilitate the modelling and understanding of the basic building blocks of matter by students. The cards can be used by themselves or in conjunction with the chocolate chip and cookie cards. The teacher may also provide students with a word list to sort as well, including any additional terms they deem applicable. The cookie to atomic model is not an exact 1:1 model, but the cards can be used to effectively model aspects. Some teachers and/or students may find the concept easier to understand when the cards are used in parallel as in the example below.

Example:

Atom	
Nucleus	Electron

Cookie	
Chocolate Chips	Dough

Example:

Nucleus	
Protons	Neutrons
Up Quark	Up Quark
Up Quark	Down Quark
Down Quark	Down Quark

Chocolate Chips	
Dark Chocolate	White Chocolate
Cocoa Powder	Cocoa Butter
Cocoa Butter	

Example:

Fundamental Particles	
Quarks	Leptons
Up Quark	Electron
Down Quark	Neutrino
Charm Quark	Muon
Strange Quark	Tau
Top Quark	
Bottom Quark	

Cookie Ingredients	
Wet Ingredients	Dry Ingredients
Eggs	Flour
Vanilla Extract	Sugar

As an extension, the teacher may want to include the charge of the quarks on the cards. Students should already know and be familiar with the charge of electrons, protons, and neutrons. The simple addition and subtraction of quark charge can be used to reinforce the idea that quarks are the fundamental building blocks that stack together to form protons and neutrons.

Formative assessment through questioning and observation by the teacher should play a large role in ensuring that students have developed an understanding of the building blocks of matter. The teacher should pay close attention to the correct use of the hierarchy of the cards or terms used by students. The goal of this lesson is for students to understand that the matter we see around us — from the stars to seaweed — is all made from different combinations of the same fundamental particles. The teacher should be able to both observe (card placement) and hear students (discussions, questions) clearly communicating their knowledge and understandings. The framework of this lesson provides a solid foundation for a large variation in the depth of content that would be dictated by the needs and desires of the class.

Formative Assessment Opportunities

CURRICULAR COMPETENCY	POSSIBLE ASSESSMENTS
Make observations aimed at identifying their own questions about the natural world	• Student-generated questions during the opening discussion • Student observations made during the opening discussion • Students explain their thinking when dividing up the cookie parts • Observations of chocolate chip differences • Questions and observations about how chocolate chips can be different and similar at the same time
Construct and use a range of methods to represent patterns or relationships in data, including tables, graphs, keys, models, and digital technologies as appropriate	• Observations of card sort layouts • Informal questioning of students as they work in pairs with the card sort idea • Suggestions of other analogies or models that could be used to model building blocks
Seek patterns and connections in data from their own investigations and secondary sources	• Observations of card sort layouts • Informal questioning of students as they work in pairs with the card sort idea • Student connections to background knowledge
Transfer and apply learning to new situations	• Observations of card sort layouts • Informal questioning of students as they work in pairs with the card sort idea • Generation of new analogies and/or models

CONTENT	POSSIBLE ASSESSMENTS
Atomic theory and models: • protons, neutrons, and quarks • electrons and leptons	• Informal questioning of students as they work in pairs with the card sort idea • Listening to discussions between students • Use of concept-based "clicker" questions • Think-Pair-Share responses based on specific and focused questions by the teacher • Observations of card sort layouts

Reflection Opportunities

Students may reflect formally (e.g., science journal, edublog, freshgrade) or informally (e.g., discussion) on the content and activities in this lesson. The teacher or students may choose to:

- Compare and contrast the idea of "fire, wind, earth, water" to "quarks and leptons" as building blocks of matter
- Comment on how this new information fits in with understanding the world
- Consider the validity of this information knowing quarks and leptons have never been seen or touched

Summative Assessment Options

Formal assessment of the Curricular Competencies and Content learning standards is through a student-created infographic. Students are tasked with the creation of an infographic that clearly communicates their learning and understanding of the fundamental particles and a rudimentary knowledge of the standard model (particle physics). The instructions should be very open-ended to encourage creative and critical thinking Core Competencies. Teachers can provide, or co-create with students, the criteria that will be assessed and allow them maximum creative freedom.

Possible assessed learning outcomes

- Model of the atom including representation of protons, neutrons, and electrons
- Understanding of the term "fundamental"
- Representation of quarks and leptons
- Modelling of protons as two up quarks and a down
- Modelling of neutrons as two down quarks and an up
- Connections to prior content
- Connections to the cookie (or other) analogy

Possible student choice alternatives to an infographic

- Screen cast
- Poster
- Digital video
- TV or radio interview
- Press Release presentation

Possible extensions

For students wanting to challenge themselves, the teacher can have them create their own analogy to compare with the building blocks of matter. Students can then present their analogies to their classmates.

Possible adaptations

For students with higher learning needs, the teacher can provide an infographic template or framework that guides and prompts them for the required information.

Resources

http://particleadventure.org/

https://www.youtube.com/watch?v=nlv06lSAC7c&list=PLAPjAbosOdYgTeS2L4XiKvirlaKD_ODdv

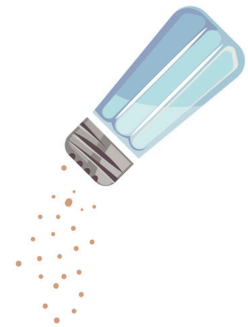
https://www.youtube.com/watch?v=SMgi2j9Ks9k&index=2&list=PLAPjAbosOdYgTeS2L4XiKvirlaKD_ODdv

https://www.youtube.com/watch?v=V0KjXsGRvoA&index=3&list=PLAPjAbosOdYgTeS2L4XiKvirlaKD_ODdv

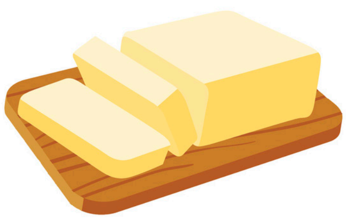
FLOUR

BAKING SODA

SALT



BUTTER



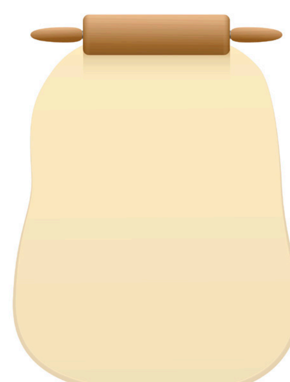
SUGAR

EGGS

VANILLA EXTRACT

COOKIES

COOKIE DOUGH



Card Sort Activity Cards – Chocolate Chips

COCOA POWDER

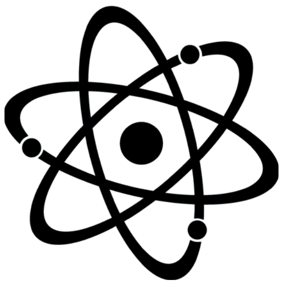
COCOA BUTTER

SUGAR

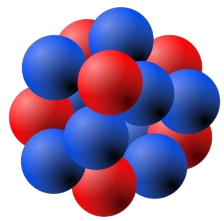
CHOCOLATE CHIPS

Card Sort Activity Cards – Atom Model

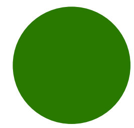
ATOM



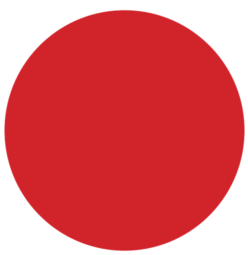
NUCLEUS



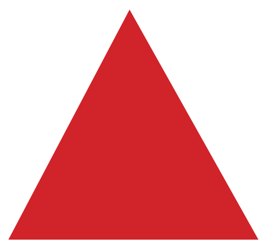
ELECTRON



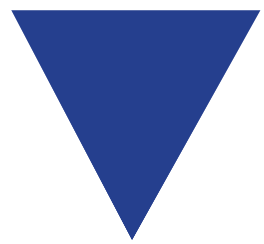
PROTON



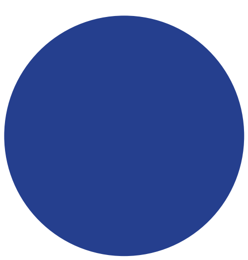
UP QUARK



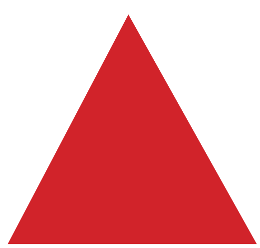
DOWN QUARK



NEUTRON



UP QUARK



DOWN QUARK