Earth and Environmental Science Module 6 - magma viscosity tasks

## Magma viscosity and volcanic eruptions

### Teacher Notes:

**Task outline**: The following set of activities based on an inquiry based learning model emphasise the development and formative assessment of the Working Scientifically outcomes and content. This series of demonstrations and/or practical activities lead students to developing their own first-hand investigation to modelling the relationship between magma viscosity and volcanic explosivity using laboratory equipment. Student handouts, rubrics and self-reflection are included should teachers wish to use them to assess student achievement and progress. Teacher monitoring and support is required.

**Background:** The explosivity of any given volcanic eruption is determined by the features of its magma, such as viscosity, temperature, and the amount of dissolved gases in the magma. Viscosity is a measure of a fluid’s resistance to flow or fluid motion. Viscosity can be thought of as a fluid’s thickness, for example, syrup is more viscous than water, and water is more viscous than air. More viscous magma has the ability to trap gases from escaping over longer periods of time, allowing for the build-up of pressure and therefore resulting in more explosive eruptions. The relationship between magma viscosity and gas content can be more deeply investigated through demonstrations and experiments.

**Diagnostic/discussion questions**: can be used to engage students and test their prior understanding of the concept and also to address any misconceptions. Students may work in a group, discuss the questions and feedback to the class or they may complete a diagnostic quiz or form.

* What do you already know about different types of volcanoes? Describe as much as you know about each type, such as features, how, where and why do volcanoes form in this way?
* What do you already know about plate boundaries the relationship to volcanic eruptions? Is there a relationship between type of boundary and type of volcanic eruptions?
* What do you already know about different types of magma? For example basaltic, andesitic, rhyolitic. Do these differ in viscosity? Would certain types “flow” easier than others?

Outcomes in this document are from [Earth and Environmental Science Stage 6 Syllabus](https://educationstandards.nsw.edu.au/wps/portal/nesa/11-12/stage-6-learning-areas/stage-6-science/earth-and-environmental-science-2017)© 2017 NSW Education Standards Authority (NESA) for and on behalf of the Crown in right of the State of New South Wales.

### Task 1 - Secondary source investigation: What fluids are the most viscous?

**Outcomes assessed:**

* WS12-3 Conducting Investigations
* WS12-4 Processing Data

**Question**: What are some examples of fluids of different viscosities? Which fluids might be available to use in the lab in first hand investigations? Samples may be provided if available. Students complete the table below using secondary sources and rank each fluid from least to most viscous.

|  |  |  |
| --- | --- | --- |
| Substance | Relative Viscosity | Relative viscosity ranking (1 = lowest) |
| Glycerol |  |  |
| Ethanol |  |  |
| Air |  |  |
| Olive oil |  |  |
| Water | 1.00 |  |
| Peanut butter |  |  |
| Corn syrup |  |  |
| Honey |  |  |
| Detergent |  |  |

Some potential follow up **discussion** with students could include:

* Consider what factors could affect the data? Temperature? Brand of food? Concentration of solute?
* Consider why it may be very difficult to plot this information on a graph. You could discuss the type of graph and also the units and a logarithmic scale
* How may these values relate to volcanic eruptions?

### Task 2 - Experiment: measuring viscosity

**Outcomes assessed:**

* WS12-2 Planning Investigations
* WS12-3 Conducting Investigations

**Question**: How is viscosity measured? Students investigate the concept of viscosity by comparing different fluids (for example: water, corn syrup, glycerol, detergent and vegetable oil). Possible activities include:

* [drop a marble or paperclip](https://www.teachengineering.org/activities/view/rice_erruption_activity1) into a beaker containing samples of these fluids and observe the rate at which they fall
* [compare the flow rates of fluids](https://www-tc.pbs.org/wgbh/nova/teachers/activities/pdf/3215_volcanoc.pdf) of different viscosities

**Discussion** from the activities:

* Identify the independent, dependent and controlled variables
* Evaluate the accuracy of the measurements of variables
* Discuss the validity and reproducibility of the experiment
* What other factors could influence the viscosity of these liquids?
* How does viscosity of a fluid affect its rate of flow or the movement of the marble?
* What are the implications for volcanic eruptions, lava flow and the behaviour of magma?

### Task 3 - Experiment: how does viscosity affect the behaviour of magma and volcanic eruptions?

**Outcomes assessed:**

* WS 12-1 Questioning and Predicting
* WS 12-4 Processing data and information
* WS 12-5 Analysing data and information

**Question**: How does viscosity affect the behaviour of magma and volcanic eruptions? Students model the behaviour of escaping gas from magma of different viscosities, in order to gather data and propose a hypothesis regarding eruptions and the viscosity of magma.

[Testing how viscosity affects volcanic eruptions](https://www.youtube.com/watch?v=9p74IovY0-M) (duration 0:27) with different fluids. Risk assessment is necessary prior to any experimentation.

**Discussion** from the activity:

* How did you collect and record data?
* Compare the difference between collecting qualitative and quantitative data
* Assess the validity of your model
* Assess the accuracy and reliability of your data
* What pattern or relationship was observed in the model and how did the “bubbling” relate to explosivity of eruptions (how “real-life” is this activity?). Students could watch video of volcanic eruptions, such as Kilauea.
* What were some of the benefits and limitations of this model?
* How well did the different fluids relate to “types” of magma?

### Task 4 - Test the hypothesis linking viscosity to explosivity of eruptions.

**Outcomes assessed**

* WS12-2 Planning investigations
* WS12-6 Problem Solving

**Task**: Students construct a specific inquiry question and hypothesis in order to plan and/or conduct a first-hand investigation that could model the link between volcanic eruptions and viscosity of magma. A valid and reliable investigation which gathers quantitative data may then be carried out as an option, or the task may only include the planning component.

**Sample response**:

**Inquiry question:** Does the viscosity of fluids affect the release of pressure in a super soaker water pistol?

**Hypothesis**: the more viscous the fluid, the further it will travel when ejected, due to a greater build-up of pressure.

**Investigation method:**

* Prepare 5 fluids which vary in their viscosity, including:
	+ 100ml water (least viscous)
	+ 75ml water + 25ml glycerol/corn syrup
	+ 50ml water + 50ml glycerol/corn syrup
	+ 25ml water + 75ml glycerol/corn syrup
	+ 100ml glycerol/corn syrup (most viscous)
* Using a measuring cylinder, pour equal amounts of each liquid separately into the chamber of 5 equal sized super soaker water pistols.
* One student will give exactly 10 full pumps to the first pistol to build pressure, then press the trigger and measure the point on the ground where the stream finishes with a trundle wheel or measuring tape (this provides quantitative data).
* The procedure is then repeated 5 more times with averages of all results to be obtained and analysed
* The same procedure is then followed with the 4 other pistols that contain the fluids of different viscosities.

**Risk Assessment must be completed prior to any experimentation**

**Notes**: This is a sample only, if this procedure is to be followed the MSDS safety sheet for glycerol (glycerine) must be reviewed and appropriate safety precautions and disposal protocols followed. This particular investigation allows for deep discussion about the benefits and limitations of the model in demonstrating the link between viscosity of magma and explosivity of eruptions. It is also a good opportunity to delve into many of the Working Scientifically skills in regard to fair testing principles.

## Magma viscosity and volcanic eruptions

### Student Handouts

**Background**: The explosivity of any given volcanic eruption is determined by the features of its magma, such as viscosity, temperature, and the amount of dissolved gases in the magma. Viscosity is a measure of a fluid’s resistance to flow or fluid motion. Viscosity can be thought of as a fluid’s thickness, for example, syrup is more viscous than water, and water is more viscous than air. More viscous magma has the ability to trap gases from escaping over longer periods of time, allowing for the build-up of pressure and therefore resulting in more explosive eruptions. [Magma Viscosity, Gas Content & Milkshakes](https://www.youtube.com/watch?v=2iaqE0xmsHI) (duration 5:15) shows the relationship between magma viscosity and gas content.

**Working in a group, discuss these questions and feedback to the class:**

* What do you already know about different types of volcanoes? Describe as much as you know about each type, such as features, how, where and why do volcanoes form in this way?
* What do you already know about plate boundaries the relationship to volcanic eruptions? Is there a relationship between type of boundary and type of volcanic eruptions?
* What do you already know about different types of magma? E.g. basaltic, andesitic, rhyolitic. Do these differ in viscosity? Would certain types “flow” easier than others?

### Resources

* [TeachEngineering STEM Curriculum for K-12](https://www.teachengineering.org/activities/view/rice_erruption_activity1), University of Colorado. [What makes an eruption explosive?](https://www.teachengineering.org/activities/view/rice_erruption_activity1) Presentation, worksheet and activities about volcanic eruptions, including measuring lava flow and viscous fluids.
* [pbs.org/wgbh/nova/volcanocity](https://www-tc.pbs.org/wgbh/nova/teachers/activities/pdf/3215_volcanoc.pdf)/ This website supports [activities](https://www.pbs.org/wgbh/nova/teachers/activities/3215_volcanoc.html), interactives and worksheets that accompany the [NOVA Volcano under the city](https://youtu.be/XWhkvrwtOmQ) video program about Nyiragongo.

### Student task 1 - Investigation: what fluids are the most viscous?

**Question**: What are some more examples of fluids of different viscosities? The teacher may be able to provide samples for you to look at. Samples could include: glycerol, ethanol, water, honey, peanut butter, tomato sauce, liquid detergent, corn syrup, olive oil and air.

**Results**: Determine the viscosity of various fluids using secondary sources, organise information and then rank each fluid from least to most viscous.

**References**:

**Discussion**

* Consider what factors could affect the data
* Consider why it may be very difficult to plot this information on a graph.
* How may these values relate to volcanic eruptions?

### Student task 2 - Experiment: measuring viscosity

Investigate the concept of viscosity by comparing different fluids. Possible procedures could include:

* [drop a marble or paperclip](https://www.teachengineering.org/activities/view/rice_erruption_activity1) into a beaker containing samples of these fluids and observe the rate at which they fall
* [compare the flow rates of fluids](https://www-tc.pbs.org/wgbh/nova/teachers/activities/pdf/3215_volcanoc.pdf) of different viscosities

Fluids may include those listed in Task 1. Consider carefully the variables involved and their measurement.

**Format of report:**

**Question**: How can viscosity be measured?

**Procedure**:

**Risk assessment:**

|  |  |  |
| --- | --- | --- |
| Identify hazard | Evaluate risk | Control measure used |
|  |  |  |
|  |  |  |
|  |  |  |

**Results**:

|  |
| --- |

 **Discussion**:

* Identify the independent, dependent and controlled variables
* Evaluate the accuracy of the measurements of variables
* Discuss the validity and reproducibility of the experiment
* What other factors could influence the viscosity of these liquids?
* How does viscosity of a fluid affect its rate of flow or the movement of the marble?
* What are the implications for volcanic eruptions, lava flow and the behaviour of magma?

### Student task 3 - Experiment: how does viscosity affect the behaviour of magma and volcanic eruptions?

Model the behaviour of escaping gas from magma of different viscosities, in order to gather data to propose a hypothesis regarding eruptions and the viscosity of magma.

**Format of report**:

**Question**:

**Prediction of model behaviour:**

**Procedure**: Hint: view the video of [Testing how viscosity affects volcanic eruptions](https://www.youtube.com/watch?v=9p74IovY0-M) (duration 0:27) with different fluids.

**Risk assessment:**

|  |  |  |
| --- | --- | --- |
| Identify hazard | Evaluate risk | Control measure used |
|  |  |  |
|  |  |  |
|  |  |  |

**Results**:

|  |
| --- |

**Discussion**:

* How did you collect and record data?
* Compare the difference between collecting qualitative and quantitative data and assess the accuracy and reliability of your data
* What pattern or relationship was observed in the model and how did the “bubbling” relate to explosivity of eruptions (how “real-life” is this activity?). Make a hypothesis linking viscosity to explosivity of eruptions
* What were some of the benefits and limitations of the model?
* How well did the different fluids relate to “types” of magma?
* Assess the validity of your model by considering what factors involved in volcanic eruptions were not considered

### Student task 4 - Plan an experiment to test your hypothesis

Plan an experiment to test your hypothesis linking viscosity to the explosivity of eruptions. Construct a specific inquiry question based on the hypothesis in order to plan a first-hand investigation that could model the link between volcanic eruptions and viscosity of magma. Consideration of the build-up of gas pressure within magma/fluids of differing viscosities is necessary to ensure a valid and reliable investigation. The plan should outline the process of gathering of quantitative data.

**Option**: The experiment designed in task 4 may be conducted following risk assessment, including disposal recommendations and approval from the teacher

### Marking rubric

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Criteria | A | B | C | D | E |
| **Task 1****WS12-3 Conducting Investigations**Select and extract information form a wide range of reliable secondary sources and acknowledge them using an accepted referencing styleWS12-4 Processing DataSelect qualitative and quantitative data and info and represent them using a range of formats, digital tech and appropriate media | Selectively sources reliable secondary data and acknowledges data sources in a recognisable formatSelects and represents qualitative and quantitative data in an effective and appropriate format to show patterns | Selectively sources reliable secondary data and acknowledges data in a recognisable formatSelects and represents quantitative data in an appropriate format | Extracts secondary data and acknowledges a data sourceSelects and represents quantitative data in an appropriate format | Extracts some data from secondary source/sRepresents some quantitative data in an appropriate format | Extracts some data from secondary source/s**or**Attempts to use a recognised data type or presentation |
| ****Task 2******WS12-2 Planning investigations**Assesses risks, consider ethical issues, and select appropriate materials and technologies when designing and planning an investigationJustify and evaluate the use of variables and experimental controls to ensure that a valid procedure is developed that allows for the reliable collection of dataEvaluate and modify an investigation in response to new evidence**WS12-3 Conducting Investigations**employs and evaluates safe work practices and manages risksuse appropriate technology to ensure and evaluate accuracy | Selectively sources reliable secondary data and acknowledges data sources in a recognisable formatSelects and represents qualitative and quantitative data in an effective and appropriate format to show patternsEvaluates safe work practices to manage risks | Selectively sources reliable secondary data and acknowledges data in a recognisable formatSelects and represents quantitative data in an appropriate formatEmploys safe practices and Manages risks | Extracts secondary data and acknowledges a data sourceSelects and represents quantitative data in an appropriate formatConducts a safe procedure to collect data  | Extracts some data from secondary source/sRepresents some quantitative data in an appropriate formatIdentifies and risk and/or mitigation strategy | Extracts some data from secondary source/s**or**Attempts to use a recognised data type or presentationIdentifies risk |
| **Task 3****WS12-1 Questioning and Predicting**Develop and evaluate inquiry questions and hypotheses by identifying concepts that can be investigated scientifically.Modify questions and hypotheses, to reflect new evidence**WS 12-4 Processing data and information**Select qualitative and quantitative data and information and represent them using a range of formats, digital tech and appropriate mediaEvaluate and improve the quality of the data **WS12-5 Analysing data and information**assess the relevance, accuracy, validity and reliability of data and suggest improvements to investigations | Applies knowledge and information to unfamiliar situations to propose comprehensive solutions or explanations for scientific issues or scenarios Utilises technology to evaluate the accuracy of investigationsEvaluates and improves the quality of the data by considering limitations as well as validity, accuracy and reliability | Applies knowledge and information to unfamiliar situations to designs solutions to scientific problems, questions, hypotheses or explanations for scientific issues or scenarios Utilises technology to evaluate the accuracy of investigationsApplies processes and formats and considers the quality of both qualitative and quantitative data to suggest improvements | Applies knowledge and information relevant to scientific issues or scenarios and identifies scientific problems, questions, or hypotheses and applies processes, and formats to primary or secondary dataselects appropriate formats and technology to represent data and identifies trends in dataIdentifies errors, limitations accuracy, validity or reliability of data  | Responds to scientific problems, questions, or hypothesesFollows a procedure and records resultsRecords qualitative data and/or qualitative data in an appropriate format or Identifies a trend in data | Provides simple descriptions of scientific phenomenaFollows a procedure **or**Records some data in an appropriate format |
| **Task 4** **WS12-2 Planning investigations**Assesses risks, consider ethical issues, and select appropriate materials and technologies when designing and planning an investigationJustify and evaluate the use of variables and experimental controls to ensure that a valid procedure is developed that allows for the reliable collection of dataEvaluate and modify an investigation in response to new evidence**WS12-6 Problem Solving**Use modelling (including mathematical models) to explain phenomena, make predictions and solve problems form primary and secondary sourcesUse scientific evidence and critical thinking skills to solve problems | Designs solutions to scientific problems, questions, or hypotheses using selected accurate, reliable, valid, and relevant primary and secondary data, and scientific evidence, by applying processes, modelling and formatsWith reference to evidence from secondary data, justifies or uses reasoning to solve problems criticallyEvaluates the use of model to explain phenomena and make predictions.Proposes possible alternatives to explanation and/or model. | Designs solutions to scientific problems, questions, or hypotheses using selected accurate, reliable, and valid secondary data, and scientific evidence, by applying processes, and modelsApplies secondary data and information to unfamiliar situations to propose a model and/or fist hand investigationsIdentifies possible alternative explanations/modelsUses reasoning to make predictions | Identifies scientific problems, questions, or hypotheses and applies models and formats to secondary data and informationMakes a generalisation about the model that is supported by the secondary information or evidence**or**applies knowledge and information relevant to scientific issues or scenarios | Outlines an investigation that is able to obtain data and identifies risksResponds to scientific problems or questions and relates the proposal/model to the prediction  | partially outlines investigation that is able to obtain data and/or informationMakes a prediction or a conclusion regarding scientific phenomena |
| EES12-13: describes and evaluates the causes of the Earth’s hazards and the ways in which they affect, and are affected by, the Earth’s systems**Inquiry question:** How and why do geological disasters occur? account for the types of magma in each of the above types of volcanoes, and analyse how this affects the explosivity of their eruptions | Demonstrates an extensive knowledge and understanding of scientific concepts, including complex and abstract ideas | Demonstrates thorough knowledge of content and understanding of course concepts, and applies well-developed skills and processes in a variety of contexts. | Demonstrates sound knowledge of content and understanding of course concepts, and applies skills and processes in a range of familiar contexts. | Demonstrates a basic knowledge and applies skills and processes in some familiar contexts. | Demonstrates a limited knowledge and applies some skills and processes with guidance. |