

Evaluating experiments

Help students to successfully evaluate their practicals with the *Education in Chemistry* article **Help students to successfully evaluate their practicals**, which is part of the **Teaching science skills series**, available from: rsc.li/3RXdtbu.

Learning objectives

- 1 Understand what is required when evaluating an experiment or investigation.
- 2 Identify the aspects of a named investigation that are relevant to its evaluation.
- 3 Evaluate the aspects identified and use them to write an overall evaluation, if required.

The points on the student sheets list the different aspects of evaluation that your learners need to be aware of. Not all of these points will apply to every investigation so learners need to be able to identify what is relevant to them. Completing the table at suitable intervals during an investigation will help your learners evaluate their work.

Introduction

Being able to evaluate a practical procedure, the data collected and the conclusion made is an important part of most 14–16 and 16–18 chemistry courses. This resource includes a student sheet, with a scaffolded version available, to take learners step-by-step through the evaluation process. The *Education in Chemistry* article outlines the rationale for evaluating an investigation at suitable intervals as it is carried out, rather than tagging it on as an afterthought at the end.

The questions in the table aim to focus learners' attention on the points they need to consider when evaluating an investigation. The list of questions is not exhaustive and can be adapted to suit different investigations. You can find an experiment specific example for a rates of reaction investigation at the end of this document.

How to use the resource

Use the resource with a few selected investigations during a course to guide your learners through the evaluation process. You can find suitable suggested investigations in the accompanying *Education in Chemistry* article, available at rsc.li/3L6aLPD.

Ask your learners to complete the 'Evaluating the planning' and 'Evaluating the apparatus' sections before they carry out the experiment. The 'Evaluating the method' section can either be done while the experiment is carried out or directly after. If learners complete this section during the experiment, make sure that they are observing safety precautions and are not introducing additional errors. Learners should answer the 'Evaluating the conclusion' and 'Improvements' sections while processing their results. Alternatively, practical groups can be organised with one learner responsible for evaluating the investigation. They can share their evaluation with the rest of the group when appropriate.

The lists of points on the sheets are not exhaustive and can be adapted as required.

Scaffolding

Evaluation is a higher order thinking skill that many learners find difficult. The terminology required will be new to many of your learners. The scaffolded version (indicated with an 'S' icon in the header) includes prompts in simple, everyday language as far as possible and sentence starters to support your learners.

The ideal outcome is that learners will develop the skills to evaluate their practical work without prompts from this resource.

Answers

Evaluating the planning stage	Answer comments
What is the independent variable?	Learners should only list one independent variable.
What is the dependent variable?	Learners should only list one dependent variable.

Which variables are you controlling?	There may be several control variables. These should include the same learner taking measurements, detecting colour changes and end points in titrations.
Are there any variables you cannot control? If so, name them.	Learners will usually name factors like room temperature, but bias, when a person influences the results, is also a variable. It is usually unintentional. We tend to look for specific things, find what we expect to find and overlook other things.
Will your method provide valid data relevant to your hypothesis?	The method should aim to provide evidence for the hypothesis.
Evaluating the apparatus	
Which pieces of apparatus that you are using have uncertainties? (errors) Hint: look at the apparatus. Uncertainties are usually printed on them.	These are pieces of apparatus for measuring, such as pipettes, burettes, thermometers, balances, etc.
What are you doing to limit errors from apparatus?	Measuring apparatus with the smallest possible maximum measurement will give the smallest errors.
Evaluating the method	
List any errors due to the method you are using.	This may help learners suggest improvements that can be made.
List any errors due to the way you carried out the investigation.	As learners' practical skills improve, human error in investigations should decrease.
What is your biggest source of error?	Since learners cannot measure human error, this is an informed guess. For example, in calorimetry investigations, heat loss is usually the greatest source of error and not errors associated with measuring apparatus.
Evaluating the conclusion	
Have you identified and dismissed any anomalous results?	If these are the results of random errors, then they can be dismissed, but it is better practice to repeat the measurement if time allows.

Have you used a suitable range of values for the independent variable?	The range of values must allow for safe working.
Have you done enough repeats?	Repeating a measurement many times and taking an average is one way of minimising random errors.
What are the limitations of your investigation and conclusion?	Learners need to carefully consider whether their conclusion can be applied to a wider situation.
Is your conclusion reproducible?	It may be possible for learners to compare data and conclusions with others in the class.
You have now completed your evaluation. What improvements can be made?	
What changes can be made to the apparatus and procedure to improve the validity of the results?	This will depend on the errors learners have previously identified.

Experiment specific example

Experiment: To investigate the effect of changing temperature on the rate of reaction between sodium thiosulfate and dilute hydrochloric acid. See rsc.li/3J0q8HI for the equipment, method and health, safety and technical notes.

This investigation asks learners to measure the time taken for a cloudy precipitate of sulfur to form when dilute hydrochloric acid is added to sodium thiosulfate solution. Learners place a cross on a piece of paper under the reaction flask and measure the reaction time when the cross is no longer visible through the cloudy sulfur precipitate. They carry out the reaction at different temperatures.

The completed table provides suggested responses.

Experiment: To investigate the effect of changing temperature on the rate of reaction between sodium thiosulfate and dilute hydrochloric acid.	
Evaluating the planning stage	Answer comments
What is the independent variable?	The temperature.
What is the dependent variable?	The time taken for an amount of sulfur precipitate to be produced.
Which variables are you controlling?	The concentration of sodium thiosulfate solution. The volume of sodium thiosulfate solution. The concentration of the dilute hydrochloric acid. The volume of dilute hydrochloric acid. The same person measuring the reaction time.
Are there any variables you cannot control? If so, name them.	The room temperature. The accuracy of the apparatus.
Will your method provide valid data relevant to your hypothesis? Explain your answer.	Yes, because we are investigating a range of temperatures and controlling variables.
Evaluating the apparatus	
Which pieces of apparatus that you are using have uncertainties? (errors) Hint: look at the labels on the apparatus.	50 cm ³ measuring cylinder. 10 cm ³ measuring cylinder. Thermometer.
What are you doing to limit errors from apparatus?	Using the smallest possible measuring cylinders available to measure volumes of solutions. Using a -10°C to 110°C thermometer.
Evaluating the method	
List any errors due to the method you are using.	Deciding when the cross is no longer visible is not precise. There was no way to maintain the temperatures of the reaction mixtures.

List any errors due to the way you carried out the investigation.	Learner dependent. Example: there were delays between adding the reactants and starting the stopwatch. Deciding when the cross was no longer visible was not precise.
What is your biggest source of error?	Deciding when the cross was no longer visible.
Evaluating the conclusion	
Have you identified and dismissed any anomalous results?	Learner dependent. Example: the result at 10°C did not fit the curve when we plotted our results, so we dismissed it.
Have you used a suitable range of values for the independent variable?	We used approximately 10-degree intervals from 10°C to 50°C.
Have you done enough repeats? Have you taken an average of repeat values, excluding any anomalous results?	There was only one result for each temperature. More repeats would make our results more reliable.
What are the limitations of your investigation and conclusion?	The conclusion only applies to this reaction and the temperatures investigated.
Is your conclusion reproducible?	Other groups in the class obtained different reaction times for the same temperature, but overall conclusions were the same.
You have now completed your evaluation. What improvements can be made?	
What changes can be made to the apparatus and procedure to improve the validity of the results?	A device (a photometer) for measuring the amount of light that passes through the sulfur precipitate would be more accurate. A method of maintaining the temperature would be more accurate. More accurate apparatus to measure volumes of liquid, such as a pipette or burette.