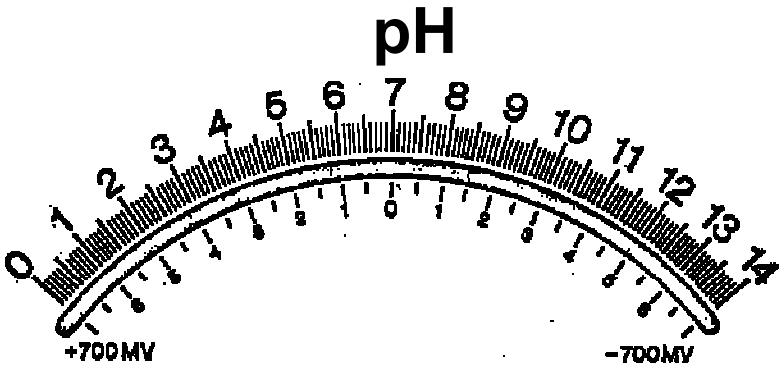

Cola and Teeth

Ontwikkeld voor scholen binnen Bètapartners

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Bewerkt door: Lisette van Rens

Klas: 5 vwo
Vak: Scheikunde

Explanation of the used icons:

 Observation

 Inquiry Question

 Theory formation

 Experiment

 Execution

 Conclusion

Name:

Cooperated with:

Mark:

Content

1. Introduction

Nowadays chemistry forms an integral part of daily life. Whether it is clothes, food, body care, cars, computers or drugs, everything people produce involves chemistry. Without inventions and chemical research the world would be very different. Chemists conduct research to acquire directly applicable knowledge, but sometimes also to understand things better. Most of the time they build on research done by other chemists. Building on knowledge of others can be advantageous because you do not need to examine things yourself. On the other hand previous research causes problems of its own. When results are not reliable, invalid conclusions may be drawn. Other research can be distorted by invalid information and this may have serious consequences. That's why accurate and reliable research is important.

One of the aims of this inquiry project is to understand how to measure **'fair'** and **accurate** in your inquiry. This accuracy is necessary to get **reliable results** in your inquiry. The only way to draw **valid conclusions** is to get reliable results.

Only when 'fair' and accurate measurements are taken, research results will be reliable and valid conclusions can be drawn. Research should also be designed in such a way that other researchers can repeat it. This does not mean, however, that knowledge based on research results in itself is justified. Further investigations or other research can yield results that are slightly different or even undermine acquired knowledge. Researchers communicate about their research methods and their conclusions in professional magazines, journals and on the Internet. Another way of informing the public and politicians is by means of papers and television.

The researchers Drabe, Niste & Axel (2003) investigated the neutralizing effect of saliva on carbonated drinks and its role in dental erosion. We take their article as a starting point in your inquiry project. How 'fair' and accurate is their research? Do you think their research results are trustworthy? Are their conclusions valid? These are questions that you will answer by critically analysing the article written by the three researchers. Following this we expect you – in a team of two – to perform a better inquiry. As a team you will write a first report on your inquiry. You mail this first report to your teacher. All of the first reports will be published on a website or *elo*. In this way you can discuss your results with peers in your class, giving and receiving suggestions. You have to use these suggestions to improve your report, when you write your final article.
A professional jury will judge all incoming final articles and will select the best inquiry. Those students whose inquiry is considered the best will win a *chemistry inquiry award*.

Below you find a time schedule for the inquiry project, 'Cola and Teeth. The first three parts (1-3) are integrated in the chemistry lessons and the others (4-8) will be done outside the chemistry lessons. Your first task is to become familiar with the inquiry. Therefore your teacher will give you a demonstration and you will do a guide experiment. After this you will analyse and judge research done by Drabe, Niste & Li (2003). Then you can start with your own inquiry.

Schedule for the procedure of the 'Cola and Teeth inquiry project (10-20 hours):

Procedure	**Part of the project**
Start with the task	*1. Understand aim and nature of the inquiry project* *2. Understand the research of Drabe, Niste & Li:* • Predict, observe, explain • Conduct guide experiment • Judge accuracy, reliability and validity
Conduct research	*3. Own inquiry in teams*
Write report	*4. Report*
Send first report	*5. Report* to: teacher All reports on a website/*elo*
Peer discussion	*6. Peer discussion* The peer discussion on: • Accuracy in the inquiry plan • Accuracy in performing the inquiry • Reliability of the results • Validity of the conclusions
Process comments	*7. Teamwork*: Processing the comments received, improve report
Send final article	*8. Report* to: teacher All final articles on a website/*elo*
Receive prize	Jury selects the best inquiry

2. Demonstration: a raw egg in vinegar

A raw egg is placed in a jar with vinegar (acetic acid)

2.1. Prediction

What do you expect to happen when a raw egg is placed in vinegar?

I expect that

Why?

2.2. Write down your observations, conclusion and explanation.

Write observations immediately after the egg is put in vinegar and after approximately 72 hours.

Observations

Conclusion

Explanation

Explain the kind of reaction that took place. Use a reaction equation in your explanation.

Do you still agree with your expectations as written in "prediction" [2.1.]?
Yes / No, because

2.3. Browse the Internet for information on the composition of a chicken bone. Search also for hydroxyapatite.

Write down your findings.

3. Guide experiment: cola and chicken bones

In this guide experiment you will find out what the effect is of cola on chicken bones. Work in groups of two.

3.1. Prediction

(i) What do you think the pH of cola is? Explain.

(ii) Describe the composition of chicken bone. Use your Internet findings.

(ii) What do you expect to happen when cola is added to a chicken bone?

(ii) Why do you expect this?

3.2. Experiment

Materials: two 25 mL beakers, a measuring cylinder, a forceps, chicken bone (see picture left), one bottle or can of cola and a pH measuring device.

Procedure:

- Measure the pH of a 10 mL sample of cola.
- Place a number of pieces of chicken bone in a beaker with 10 mL of cola.
- Measure the pH.
- Measure the pH again after 15 minutes.

3.3. Observations

Write down your observations.

3.4 Explanation

Write down your explanation.

4. Judging the research of Drabe, Niste & Li

"Carbonated drinks and neutralizing saliva: dental erosion"

Before analyzing Drabe, Niste & Li's research on 'fairness', accuracy, reliability and validity you will first answer some questions concerning accurate and reliable measurements.

4.1. Orientation on accurate and reliable measurements

Remember the guide experiment with a piece of chicken bone in cola.

(i) What would determine the accuracy of measuring the pH? Explain.

Assume that a measured pH is 3.75.

(ii) What would you do to find out if this measurement is reliable? Explain.

(iii) When is a series of measurements reliable? Explain.

4.2. The research of Drabe, Niste & Li: accuracy, reliability, validity

The research question of Drabe, Niste & Li (2003) was: *"to what extent does saliva neutralize carbonated drinks?"*

From the guide experiment you can conclude that bone tissue reacts with cola. You have thought about how to measure pH values accurately. In order to be capable of measuring accurately, experiments need to be designed in a 'fair' way. You need accurate measurements to come to reliable results. Only when results are reliable can one draw valid conclusions. So the question is how to design your experiments as 'fair' as possible to measure most accurate.

To achieve accurate measurements researchers have to follow certain procedures. You will practice this procedure using the Drabe et al.'s article:

How 'fair' is the design of the research of Drabe et al.?

How accurate are the measurements of Drabe et al.?

How reliable are the measurements or results of Drabe et al.?

How valid is the conclusion drawn by Drabe et al.?

By practicing these steps you will be able to critically judge other research and be capable of doing an accurate inquiry yourself.

A. How 'fair' is the design of the research of Drabe et al.?

To judge a research design, you need to identify all of the variables that play a role in the experiment. To take accurate measurements researchers want to know which variable they will measure. Variables are quantities (e.g. temperature), which can be measured as a number. Usually variables also have a unit (e.g. degree Celsius). Researchers should also carefully take into account other factors (e.g. when measuring the height of a person the floor on which the person stands should be straight), which can interfere with the variable to be measured. When taking variables into account:

1 **List** all of the variables;
2 Choose **one** of the variables
3 **Change** this variable;
4 **Measure the effect** of this change; and at the same time
5 Keep all other variables and factors **constant**.

Researchers distinguish three types of variables:
Independent variable: This is the variable to be **changed**
Dependent variable: This is the variable to be **measured**
Control variables: These are the variables to be kept **constant**

By using distinct variables it is easier for researchers (and other interested people) to understand the research and follow its progress. 'Fair' handling of variables is a difficult aspect of research design. For researchers it is difficult both to recognize 'all' of the variables and to exclude those variables and factors that they do not want to measure or to change. In other words: to keep all interfering variables and factors constant.
Now it's up to you (in groups) to recognize the different variables in the experimental procedure of the research of Drabe et al. and to find out whether they handled the variables carefully.

B. Recognizing variables in the research of Drabe et al. (2003)

Use the part on 'Experimental procedure' in the article of Drabe et al.; see page b. List all variables and factors that influence the measurements in the experiment as done by Drabe et al.

(i) Variables:

(ii) Factors:

(iii) What is the independent variable in the experiment done by Drabe et al.?

(iv) What is the dependent variable in the experiment done by Drabe et al.?

(v) What are the control variables in the experiment done by Drabe et al.?

(vi) Did Drabe et al. forget any control variables?
If yes, which one(s)?

(vii) Compare your answer in (vi) to these of the other groups in your class.

(viii) We think that Drabe et al. – in relation to their research question – measured the incorrect / correct variable. Explain.

(ix) We think that Drabe et al. – in relation to their research question – changed the incorrect / correct variable. Explain.

(x) We think that Drabe et al. – in relation to their research question – kept the incorrect / correct variables and factors constant. Explain.

(xi) Is the dependent variable visible in the research question of Drabe et al? Is the independent variable visible in the research question of Drabe et al.?

Therefore, the question has a high / low quality. Explain.

C. How accurately did Drabe et al. measure?

When the variables – related to the question under research – are known, the next step is to think about the design and set-up of the experiments. It is important to decide carefully, in advance how to conduct the actual experiment, both the set-up and the measurements. Drabe et al. had to make decisions about:

i. Which cola or drink to use?
ii. How much saliva, cola or drink to use?
iii. How many samples to measure?
iv. How often should every measurement be repeated?
v. What instrument should be used to measure?
vi. To what significant figure can the measuring instrument be read off?

With a well-developed research you will be less likely to encounter unpleasant surprises while the experiment is being conducted.
To find out whether Drabe et al. did collect accurate measurements, you judge the decisions made by them in their experimental procedure, see their article, page b. Discuss and answer in your group the following questions:

C. 1. Decisions regarding the experimental set-up

(i) Did Drabe et al. choose the right drinks with respect to their research question? Explain.

(ii) Did Drabe et al. choose appropriate amounts of saliva or drink? Explain.

C.2. Decisions regarding the measuring instrument

(i) Is the instrument used by Drabe et al. accurate enough? Explain.

(ii) Did they read the pH values to a correct significant figure? Explain.

C.3. Decisions regarding the number of measurements

Drabe et al. measured the effect of saliva on the pH several times. Did they measure enough times, according to you? Explain.

C.4. Decisions regarding the number of saliva drink mixtures used

(i) In vitro:

Drabe et al. measured pH values for 4 different mixtures of saliva and drink. Is this, according to you, accurate enough to show a reliable relationship between mixtures and pH values? Explain.

(ii) In situ

Drabe et al. measured pH values of mixtures at the start and after 15 seconds. Is this, according to you, accurate enough to get reliable pH values? Explain.

D. How reliable are the measurements or results of Drabe et al. 's research?

Before collecting measurements researchers think about how to collect their observations and data, how to present and analyze their results. Collected measurements are presented in tables and graphs. Furthermore, researchers always need to check whether their results are reliable. When measurements show too much deviation, they need to be repeated. Repetition of measurements enhances the reliability. You are now to judge whether Drabe et al. presented their measurements in a correct manner and whether their measurements are reliable.

D.1. Presentation of measurements

(i) Did Drabe et al. present their measurements (in Table 2 and 3) in a correct manner? Explain.

(ii) Drabe et al. used a graph (see Fig. 3) to find a relationship between the pH and the amount of drink added to a fixed amount of saliva. Did DNL use the correct variables on the x-axis and y-axis? Explain.

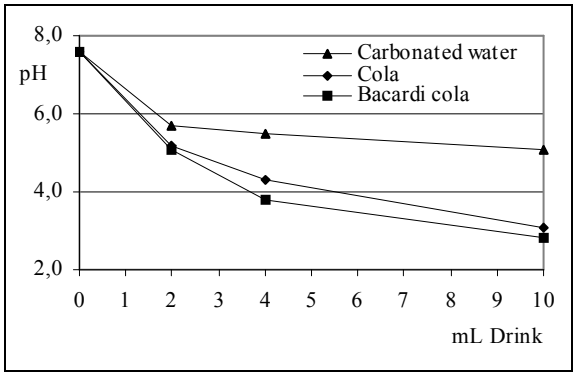

Fig. 3**:** In vitro pH after mL added drink

D.2. Reliability of measurements

Drabe et al. presented part of their measurements or results in Table 2 as:

	pH After 2.0 mL drink is added	pH After another 2.0 mL drink is added	pH After another 6.0 mL drink is added
Carbonated water	5.7 ± 0.1	5.5 ± 0.1	5.1 ± 0.2
Cola	5.4 ± 0.2	4.3 ± 0.4	3.1 ± 0.1
Bacardi -cola	5.1 ± 0.2	3.8 ± 0.2	2.8 ± 0.3

Table 2: pH values for various drinks

When looking at a series of measurements, e.g. carbonated water (the left upper field of Table 2), we see:

	pH After 2.0 mL drink is added
Carbonated water	5.7 ± 0.1

With 5.7 ± 0.1 Drabe et al. state that the measured pH values lie between

5.7 – 0.1 = 5.6 and 5.7 + 0.1 = 5.8

Their measurements deviate 0.1 from the mean pH value, which is 5.7.

Suppose that pH values are allowed to deviate **within** 5% of the mean result.

Which of the pH values in Table 2 are accurate enough to be reliable?

(i) Encircle them.

(ii) What possible causes of inaccuracy in Drabe et al. measurements occur:

(1) Low significance of pH values. Yes / No Explain.

(2) Low number of measurements. Yes / No Explain.

(3) Lack of keeping control variables and factors constant. Yes / No Explain.

(4) Other causes. Yes / No Explain.

D.3. Validity of the conclusion drawn by Drabe et al.

A conclusion can be considered as valid when experiments are accurately designed and carefully executed. Of course, experiments should be designed in such a way that answering the research question is possible. Drabe et al. 's research question is: *"To what extent does saliva neutralize carbonated drinks?".* To answer this question experiments were designed for measuring pH values of

various mixtures of drinks and saliva, in vitro as well as in situ.
The results were presented in tables and graphs. From the graphs Drabe et al. concluded that in situ cola will be more neutralized than bacardi cola whereas in vitro the two behave the same.

(i) Which of the measurements did you conclude to be reliable? Explain.

(ii) Do you agree with the conclusions Drabe et al. inferred from their results? Explain.

(iii) Is their conclusion an answer to their research question? Explain.

5. Inquiry in teams

Drabe et al. asked to what extent saliva neutralizes carbonated drinks. They concluded from their experiments that the pH value in a mouth drastically decreases after drinking cola or bacardi cola whereas carbonated water does not have this effect. They also found that cola in a mouth is neutralized to a higher extent than bacardi cola. Possible causes for this effect were stated in the discussion in their article. To better understand what happens to teeth in contact

with drinks and saliva, you are going to design and conduct your own inquiry. You will do research and write a report in a 'fair', accurate, reliable and a step-by-step manner.

As mentioned in the article use of artificial saliva (see appendix) could be of help for further investigations. You may use other drinks in your inquiry. As a model for teeth chicken bones could be used, for example. It is all up to you!

Before starting your own inquiry answer the part in 5.1

5.1. Formulate your own inquiry question

An inquiry question can be investigated when this question has an independent (what are you going to change?) and a dependent (what are you going to measure?) variable.

Write down:

(i) inquiry question:

(ii) our hypothesis:

(iii) based on which theory:

Now write your own inquiry plan as a team.

5.2. Inquiry plan

5.2.1 Variables

Dependent variable

What variable are you going to measure? Explain why.

Independent variable

What variable are you going to change? Explain why.

Control variables

Which variables and factors do you need to control - keep constant - in your experiment? Explain why.

5.2.2. Decisions on the experiment, the experimental set-up and the measurements

How to make accurate measurements?

(i) What instrument for measurement are you going to use? Explain.

(ii) What is the accuracy of the instrument?

(iii) Up to what significant figure can you read the instrument?

(iv) Are repeated measurements needed? Explain.

(v) Which materials do you need? List these materials below.

(vi) Make a drawing of your experimental set-up.

(vii) What results do you expect? Explain why.

(viii) Check whether your inquiry plan is really answering your inquiry question. If not, change your question into a question that fits to your plan.

Discuss your plan with your teacher. If she / he agrees, you can start your experiments.

Good luck!

5.3 Keep a record of the inquiry

Inquiry dairy

Date	Work done	Remarks / Observations

6. First and final report, peer discussion: guidelines

This booklet needs to be handed in to the teacher. As a team you will get a mark for your inquiry plan, your final article and for your participation in the peer discussion.

6.1 Writing a report: guidelines

The layout of a report depends on the journal you are writing for. A report will be published when it satisfies criteria posed by the journal. This will also be the case for your article. After publishing the reports on the website/*elo* the peer discussion starts. You can use the comments to improve your first report as you write a final article. These articles will also be published on the website/*elo*. Then a professional jury will compare all articles and nominate the best research for Chemistry inquiry award.

Take Drabe et al.'s article as an example. Your report should contain the following:

- **Snappy** but relevant title
- Names of the authors and submission date
- **Summary** of the inquiry
- **Introduction** with the reason of or problem in the inquiry guided by theory on the problem, with the **inquiry question** and with a **hypothesis** and the **theoretical assumptions** concerning the answer on the inquiry question.
- **Experimental design** with a description of the method of investigation, of the way of handling the different **variables** and of the way of handling the **accuracy** in the experimental set-up and the measuring itself.
- **Results** with a description of the **relevant observations**/ **measurements** that are correctly put into **tables and graphs**.
- **Discussion and conclusion** with a critical interpretation of your results and with a valid answer to your inquiry question.
- **Evaluation** with a critical description of the experimental set-up, with suggestions for improvements and further inquiry questions.
- **Bibliography** with relevant resources like textbooks, websites, magazines, articles.

Further guidelines:

- Use correct **English** and use a layout in **2 columns**.
- Enclose a **picture** or **drawing** of the experimental set-up (max. **100 kb**).
- The report should not exceed **1500 words** (max. **500 kb**).
- **Label** your document with **teamnumber_first name_first name**.
- Add **separately the email addresses of all team members.**

6.2. The peer discussion in the Cola and Teeth symposium

To have a meaningful and fruitful discussion with another inquiry team in your class, you first need to read their report. Then judge their inquiry report by using the following questions:

- Are the dependent and independent variable visible in their inquiry question?
- Are their assumptions and theory about their hypothesis relevant?
- Did they manage the control variables well?
- Did they measure accurately?
- Are their results well presented?
- Did they track the reliability of their results?
- Can you approve of their discussion and conclusions?
- Did they write a critical evaluation?
- Did they come up with relevant bibliography?

Halfway the discussion you will be checked to see how well you have participated in the symposium. This will be part of the jury's judgement.

7. Study guide

- Read the planning
- Choose your inquiry partner

Lesson 1. Understand what Drabe, Niste & Li (2003) investigated:

- Read the introduction
- Follow the demonstration: Predict, observe and explain
- Find information on the Internet

Homework:

Read the article of Drabe, Niste & Li (2003)

Lesson 2. Judge the research of Drabe, Niste & Li:

- Conduct the guide experiment: cola and chicken bones
- Orientation on accurate and reliable measurements
- Read about variables
- Judge Drabe, Niste & Li's article on handling variables
- Judge Drabe, Niste & Li's article on accuracy

Lesson 3. Judge the accuracy and reliability in Drabe et al. 's research:

- Judge Drabe, Niste & Li's experimental set-up
- Judge the reliability of Drabe, Niste & Li's measurements
- Judge the presentation of Drabe, Niste & Li's results
- Judge the validity of Drabe, Niste & Li's conclusion

Lesson 4. Your own inquiry project: question and plan:

- Formulate an inquiry question
- Design an inquiry plan
- Hand in your inquiry plan to the teacher

Lesson 5-6. Your own inquiry project:

- Conduct your planned experiments and collect measurements
- Write a first report as a team (see **Planning**)
- Send your first report **with the right code** to your teacher
- Discuss the report of another team in the Cola and Teeth symposium
- Improve your report and write a final report
- Send your final report **with the right code** to your teacher

The jury only **judges final reports of teams that participated in the peer discussion**.

8. List of concepts

Complete the list of concepts. Work gradually on this list as the project proceeds.

Write the definition of:

pH

NEUTRALIZING

INDEPENDENT VARIABLE

DEPENDENT VARIABLE

CONTROL VARIABLES

ACCURACY

RELIABILITY

VALIDITY

9. Appendix

Ingredients for artificial saliva:

Salts		Even more realistic; salts and:	
5.208 g	$NaHCO_3$	2.16 g	Mucin
1.369 g	$K_2HPO_4 \bullet 3H_2O$	200 000 units	α-Amylase
0.877 g	NaCl		
0.5 g	NaN_3		
0.477 g	KCl		
0.441 g	$CaCl_2 \bullet 2H_2O$		

Added to 1 L distilled water

10. Some words explained

accuracy	nauwkeurigheid
advantageous	voordelig
artificial	kunstmatig
cause	oorzaak
to cause	veroorzaken
to chew	kauwen
comparable to	vergelijkbaar met
to conduct	uitvoeren
control variables	controlevariabelen
dependent variable	afhankelijke variabele
enamel	tandglazuur
to encircle	omcirkelen
extent	mate
forceps	pincet
gland	klier
harmful	schadelijk
to increase	toenemen
to infer from	afleiden uit
independent variable	onafhankelijke variabele

integral	wezenlijk
inquiry	onderzoek
a jar	een pot, fles
justified	gerechtvaardigd
knowledge	kennis
mean	gemiddelde
on the contrary	in tegenstelling tot
reliability	betrouwbaarheid
saliva	speeksel
snappy	pakkend
to submit	insturen
a swallow	een teugje, slokje
to tackle	aanpakken
validity	geldigheid