Project 4

Research and analysis

The sunshine factor

- Themed lesson guide for teachers
- Teacher's project guide
- Class project instructions
- Student project portfolio

This project is extracted from Analytical Chemistry in Ireland
More projects and resources available from https://rsc.li/3P00Lfl

THEMED LESSON GUIDE FOR TEACHERS

The sunshine factor

Focus: **research and analysis.** Two lesson plan

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Task

Investigating how sunscreens are effective.

Background

This investigation provides a summative task for the understanding and skills gained in the previous projects, observation and inference, accuracy and precision, graph skills and culminates in 'analysis', allowing the students to consolidate and demonstrate their knowledge so far. It can also be used as a standalone project to inform students about ultraviolet (UV) rays and how sunscreens are used to combat some of their detrimental effects.

Learning objectives

On completion of the project students will:

- relate UV rays, the sun and sunburn;
- recall what sun protection factor (SPF) is and describe how different sunscreens achieve this;
- plan and evaluate a a scientific investigation to test some of the features of sunscreen.

Pre-planning

- Ideally, students will have completed the previous projects to gain a solid understanding of the scientific method, accuracy and precision and drawing graphs, and have a basic understanding of spectroscopy.
- UV beads will need to be ordered in advance (at least eight per group of students).
- Best on a sunny day with little cloud cover.

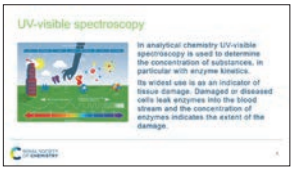
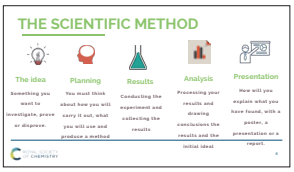
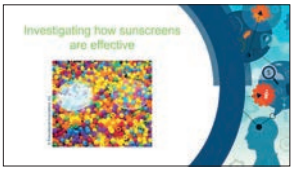
General equipment

- UV-sensitive beads
- A clear covering on which to apply the cream
- Suggestions: acetate/overhead projector sheets/microscope slides and lens covers. Plastic sandwich bags can also be used but it is much harder to evenly apply the cream to these.
- Three different SPF sunscreens
- Balance (optional)

Additional resources

- For use with the suggested lesson plan PowerPoints, the **teacher's project guide**, the **class project instructions** and the **student project portfolio**.
- Visit **edu.rsc.org/resources/outreach-sunscreen-and-uv-light/1212.article** for information and resources for teaching about spectroscopy.
- Ireland Science on Stage video comparing suncreams by UV absorption: **vimeo.com/91604126**
- Free resource from Stanford Solar Centre **solar-center.stanford.edu/activities/uv.html**
- Read more about the chemistry of UV-detecting beads at **teachersource.com**. You can also find the free activity used as inspiration for this project and resource from Educational Innovations **s3.amazonaws.com/cdn.teachersource.com/downloads/lesson_pdf/UV-AST.pdf**

THE SUNSHINE FACTOR: LESSON ONE
Planning the project and carrying out the investigation

STAGE/PURPOSE	RUNNING NOTES	
Engage Get students interested in planning an investigation and how they would do it.		Display slide 2 shows the question: How are sunscreens effective?
		Slide 3 opens up the discussion about how we could measure this.
Real world and careers link Get students interested in how this links to their career aspirations and industry in Ireland.		Display slides 4 and 5 show how this is relevant to the real and global world.
		
		Display slide 6 shows a condensed personalised version of two careers stories.
Scientific method This section allows teachers to introduce key concepts for undertaking the scientific method.		Display slide 7 shows the key stages of the scientific method. These overlap with key sections in the **class project instructions**.
Project instructions and investigation		Display slide 8 which gives the title of the investigation and some indication of the method. At this point the **class project instructions** should be given. The video link below provides some inspiration on the utility and creativity that these beads can invoke. **vimeo.com/36033383** During this section students should be able to explore the best method for their investigation. Finally, when the group is clear about their method, give each student an empty **student project portfolio**. Ask them to individually fill in the planning section of the report and collect their data.

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STAGE/PURPOSE	RUNNING NOTES
Project analysis This stage will allow students to apply their knowledge of UV and skills in the scientific method to explain some of its features of sunscreen.	Drawing graph and completing results analysis → The **class project instructions** section contains a comprehensive guide to conducting this analysis. There are research questions at the end of the **class project instructions** to be completed in advance or after students have completed the project. The answers can be found in the supporting **teacher's project guide**. 

Project 4

Teacher's project guide

The sunshine factor

Investigating how sunscreens are effective

Why are you doing this investigation?

What do you want to find out?

Whether it is possible to 'qualify' the effectiveness of a variety of sunscreens. The measurements will not be numerical, they will be of a qualitative nature.

Students should be encouraged to evaluate the method in terms of the previous foci, such as accuracy and precision.

There are options to compare it with UV apps and online indexes such as the Met Office Ireland, for a particular time and place (as referenced in **student instruction sheet one**.)

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Suggested method

1 Conduct this activity on a bright sunny day.

2 Using the acetate sheets draw on a table with space for two/three beads for each SPF, as shown right.

3 Place one drop of sunscreen on the first layer over each bead.

4 Repeat this for the sunscreens available.

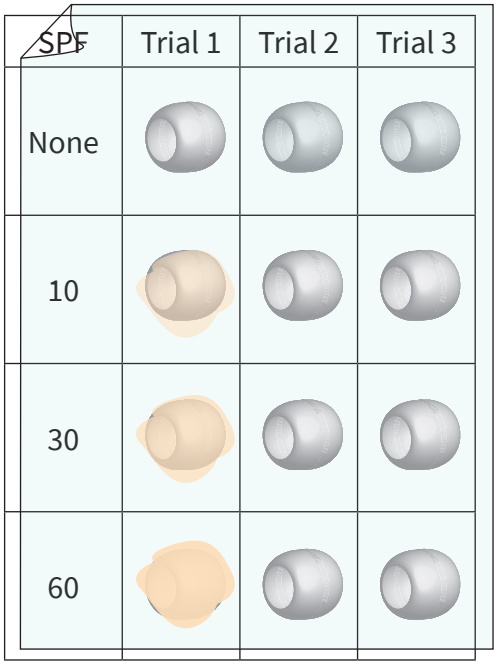
5 Then place another sheet over the top, gently pressing to give each bead an even coat.

6 Leave one row uncovered – this will act as a control so you can see the intensity of the colour change when no protection is offered.

7 Place the sheets in direct sunlight.

8 Wait 10 minutes to allow the detector beads to change colour. Record any colour change.

There are plenty of alternatives to this method, including simply spraying the beads an equal number of times, using plastic bags and trying to apply even coats, and microscope slides and covers.



Suggested set-up with acetate sheet over UV beads

Variables

Students should be encouraged to identify their own variables and design in how they will obtain the most accurate results.

Independent variable – the SPF of the sunscreen. Other variables could be the type or brand of sunscreen, although sufficient variation might not be measurable with such insensitive equipment.

Dependent variable – the intensity of colour on each bead.

Control variables – the amount of sunscreen will be difficult to control. Suggestions include one drop each or weighing the amount.

Other variables include the time in the sun and the colour of the surface behind the acetate sheets (where the beads sit, eg the ground, a white piece of paper) as greater reflection could influence the results.

Raw data

Trial 1	
Sunscreen SPF value	**UV bead detector colour intensity**
0 (no sunscreen)	
20	
30	
50	

Averaged results table

SPF	Colour intensity of bead	Intensity value
0	intense	4
20	medium intensity	3
40	light intensity	2
60	white	1

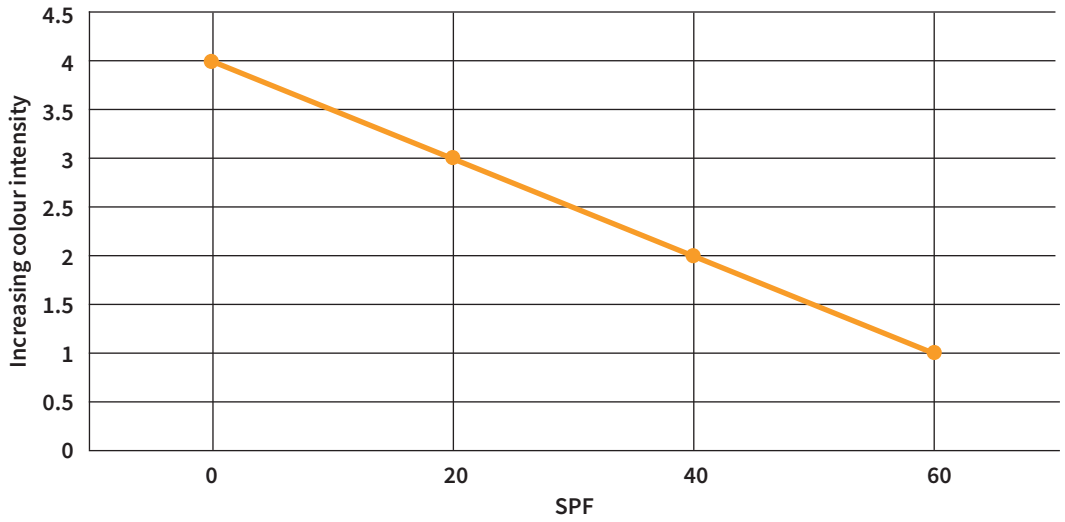
Graph

Students could be encouraged to draw a graph of the results, but often a table is sufficient for qualitative results, as the analysis remains the same.

Suggestions for transforming qualitative data include giving numbers to represent the intensity, eg white = 0 and intense = 4.

The advantages of this can be that it allows scientists to become less biased and often more precise (allowing for averages). It also allows patterns and trends to be realised more easily.

How the colour intensity of the UV bead changes with SPF



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Graph analysis

Describe the relationship that has been established between the independent and dependent variables and if possible link this back to the theory.

Checklist for analysing the graph

1 Make a statement describing what the graph shows, or the relationship between the two variables, eg 'As SPF increases, the intensity of the colour of the beads …'

2 Use the results, usually two as evidence, eg 'When the concentration was 1 ppm the absorbance was 0.5, when the concentration of the standard solution was 5 ppm the absorbance was …'

HL 3 Link this to the theory explaining what this model represents, eg 'These results would reflect what is to be expected, a higher SPF means more sun protection, therefore …'

Hint! Reference could also be made to the wavelength of the most intense light and which colour this corresponds to on the UV-Index (shown in **student instruction sheet one**.)

Conclusion

How could you improve your results next time? What would you change about your method, or the day/location/time to have obtained more accurate results, eg more accurate application of sunscreen?

Variables that affect the strength of the rays reaching the ground:

1 time of day – UV rays are strongest between 10.00 am and 4.00 pm;

2 season of the year – UV rays are stronger during spring and summer months;

3 altitude – more UV rays reach the ground at higher elevations;

4 clouds – the effect of clouds can vary, but what's important to know is that UV rays can get through to the ground, even on a cloudy day;

5 reflection off surfaces – UV rays can bounce off surfaces like water, sand, snow, pavements or even grass, leading to an increase in UV exposure;

6 contents of the air – ozone in the upper atmosphere, for example, filters out some UV radiation.

Make a concluding statement linking back to your hypothesis, suggesting whether your results confirmed or denied it, eg 'My results confirm that as SPF increases the intensity of the bead colour decreased.'

THE SUNSHINE FACTOR
Answers to research questions

1. Ultraviolet A (UVA) has a longer wavelength, and is associated with skin aging. Ultraviolet B (UVB) has a shorter wavelength and is associated with skin burning.
2. High intensities of UV can lead to persistent damage to cells and even burning, which can lead to skin damage and even blindness.
3. Broad-spectrum sunscreens are the best, meaning those that protect against both UVA and UVB. An SPF of 15 is usually the minimum, but SPF 30 is recommended.
4. The SPF number gives an indication of how long you have before the UVB rays cause reddening of the skin, eg SPF 30 means it will take 30 times longer for the reddening to occur than if you did not have any protection.
5. The SPF tells you how much it protects against UVB but not UVA.
6. Sunblock usually contains ingredients that physically block and scatter the rays before they penetrate your skin, such as the minerals titanium dioxide and zinc oxide. Sunscreens usually contain ingredients (like avobenzone and octisalate) that absorb UV rays before they can damage your skin.
7. Water, insect repellent and also rubbing in the sunscreen can all lead to reductions in its protective effects.
8. The greater the concentration the greater the ability to block or absorb the UV rays.
9. Too little sunscreen will mean it cannot protect to that SPF level – if more is applied it will improve the protection but only up to that level (and not higher). In addition most manufacturers suggest reapplying every two hours.

Project 4

Class project instructions

The sunshine factor

Investigation title

Prepared by:

Name

Class

Date

STUDENT INSTRUCTION SHEET ONE
Investigating how suncreens are effective

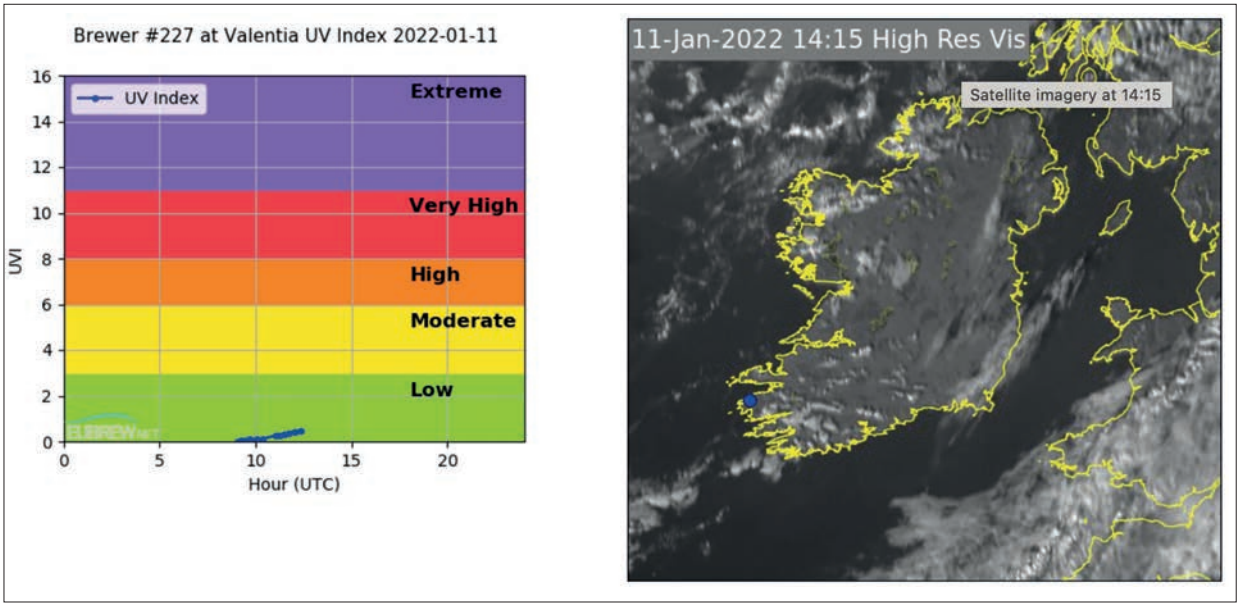
Background

The Earth's atmosphere prevents most ultraviolet (UV) radiation given off by the sun from reaching the ground. The radiation tends to be screened out by stratospheric ozone, which is about 35 km above the Earth's surface. UV radiation has both positive and negative effects.

Positive effects of UV radiation include warmth, light, photosynthesis in plants, and vitamin D synthesis in the human body. However, too much exposure to UV damages skin cells and can lead to wrinkled and patchy skin, cataracts and even skin cancer.

Sunscreens in the shops are labelled with an SPF (sunshine protection factor) number. This number tells you how good the cream is at absorbing UV radiation. The higher the SPF number the more absorption that takes place. Sunscreen contains molecules that can absorb UV radiation; this stops your skin absorbing the radiation and protects you from damage.

The Irish Meteorological Service (**met.ie)** and global weather stations often use the UV index when conveying information and advice on UV exposure to the public. It's the coloured index on the left-hand side. Unsurprisingly, on a cloudy evening in February the advice is that it's low. This might be something to think about in your investigation.



The UV index for Ireland on 11 January 2022

Your task

How it works

UV beads change colour when exposed to UV radiation. The greater the intensity of the colour the greater the exposure to UV light.

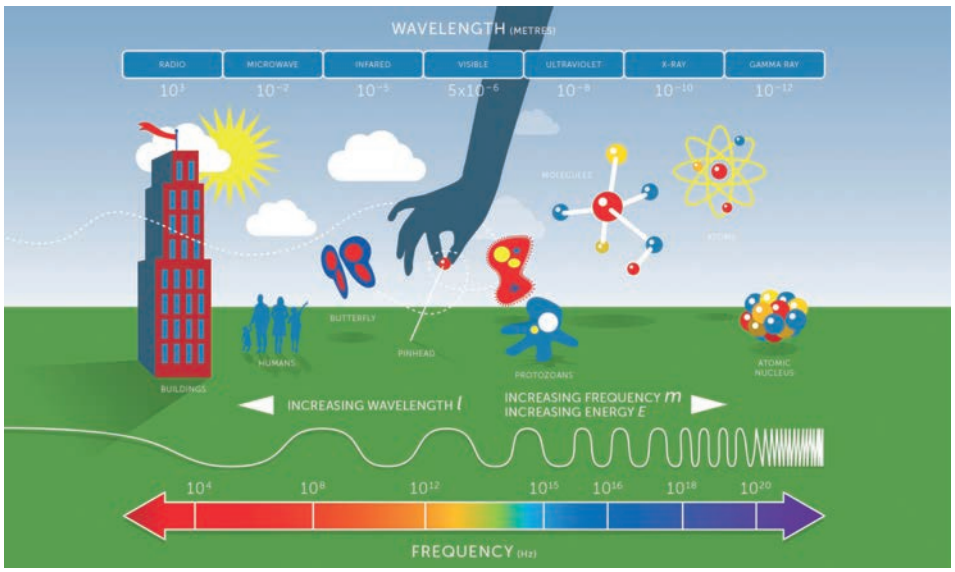
Your task is to test sunscreens to determine whether the higher the SPF number, the more UV light is being absorbed or reflected, offering better protection.

The electromagnetic radiation needed to cause a change in the colour of the beads is between 360 and 300 nm in wavelength. This includes the high-energy part of UV type A (320–400 nm) and the low-energy part of UV type B (280–320 nm).

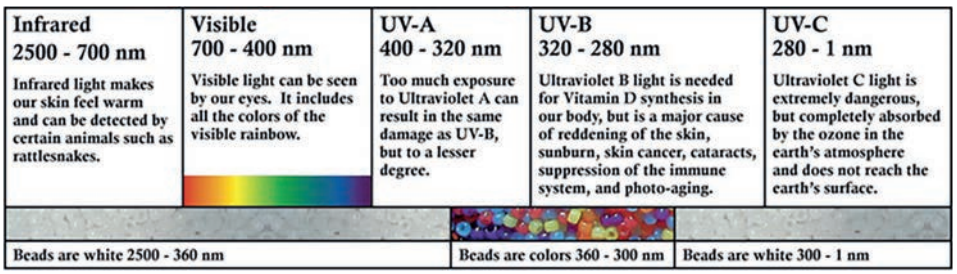
UV beads

Available from Educational Innovations, who offer a free activity resource for the beads at **cdn.teachersource.com/downloads/lesson_pdf/UV-AST.pdf**

The electro-magnetic spectrum and its corresponding wavelengths



Educational Innovations have provided this spectrum for their beads



You should design a method given the following equipment:

- UV-sensitive beads;
- a clear covering (eg acetate sheets) on which to apply the sunscreen;
- three different SPF sunscreens.

You could use: white, light intensity, medium intensity or intense when recording the UV bead colour intensity.

Planning sheet

Why are you doing this investigation?

What do you want to find out? This could be some type of hypothesis or idea you want to prove or disprove.

Include any inspiration for undertaking the project. The work of other scientists, weather warnings and sunscreen advertisements.

What do you think you might discover or find. This should link to the focus of research and analysis. How your results will prove or disprove your hypothesis or idea.

Deciding your method

Your equipment should give you an idea of how to set up your method – try to focus on achieving the most accurate results.

Variables

What are your project variables including control variables?

Are there any control variables that you will not be able to control, and what impact do you think this will have on your results?

Model

For the focus of 'research and analysis' you must include a hypothesis – this should be something you seek to prove or disprove, eg 'Paying more money means I get a better product'. You would then seek to prove or disprove this statement with your results.

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Include a photograph or a diagram of your equipment set-up

Results

For qualitative data, analysis of the data can usually be done from the table of results as this requires making observations and the inferences from the observations.

Raw data

Averages are used by scientists to get a more accurate result. It allows for random variation and human error to be absorbed into the total, so increasing the accuracy.

This should be a table of results you collected, without any processing.

Averaged results table

You should average your trials – usually you will have about three.

This means add them all together and divide by three (if you carried out three trials).

For quantitative data, analysis involves collecting numerical values, using these to perform calculations or presenting the numerical values in a graph to establish a relationship between independent and dependent variables or to find an unknown value.

Graph

Graphs should only be drawn from averaged results. You should draw a graph of intensity against SPF.

Draw your graph by hand or in Excel and paste it here.

Affix graph here

Marking criteria for the graph

- Axis drawn using a pencil and a ruler.
- Axis labelled with correct headings and includes units.
- An appropriate scale was used.
- Points plotted correctly.
- Line of best fit drawn.

Describe the relationship that has been established between the independent and dependent variables and if possible link this back to the theory.

Checklist for analysing the graph

1 Make a statement describing what the graph shows, or the relationship between the two variables, eg 'As SPF increases, the intensity of the colour of the beads …'

2 Use the results, usually two as evidence, eg 'When the concentration was 1 ppm the absorbance was 0.5, when the concentration of the standard solution was 5 ppm the absorbance was …'

HL 3 Link this to the theory explaining why this relationship exists, state whether the hypothesis or question posed at the beginning of the investigation is correct, eg 'These results would reflect what is to be expected, a higher SPF means more sun protection, therefore …'

Conclusion and evaluation

How could you improve your results next time? What would you change about your method, or the day/location/time to have obtained more accurate results?

What system could you use to help you grade the effectiveness of each sunscreen?

Hint! edu.rsc.org/resources/mission-starlight/2073.article

There is a similar exercise in the Royal Society of Chemistry Mission: Starlight resource. You can use the graded colour chart shown here to consistently measure the colour change of each bead and compare it to a UV index.

Make a concluding statement linking back to your hypothesis, suggesting whether your results confirmed or denied that. Also include what you have learned from the project and any suggestions you may have for improving the method used to verify your hypothesis.

THE SUNSHINE FACTOR
Research questions

1. What is the difference between ultraviolet A (UVA) and ultraviolet B (UVB) radiation?
2. Why is prolonged exposure to UV radiation (light) harmful to the eyes and skin?
3. What protection from UV radiation should an effective sunscreen offer?
4. What does a sunscreen's SPF rating mean?
5. Does SPF tell us how well a product blocks UVA or UVB?
6. What is the difference between suncreens and sunblock (chemically)?
7. What reduces the effectiveness of sunscreen?
8. How will the concentration of molecules used in your final product affect how the sunscreen works?
9. How will the amount of sunscreen applied affect how it works?

Futher research links

1 **edu.rsc.org/resources/spectroscopy-in-a-suitcase-students-resource-spectroscopy-introduction/281.article**

2 D Dondi, A Albini and N Serpone, *Photochem. Photobiol. Sci*., 2006, **5**, 835. Available online **pubs.rsc.org/en/content/articlehtml/2006/pp/b606768a**

3 M Lucas, R E Neale, S Madronich and R L McKenzie, *Photochem. Photobiol. Sci*., 2018, **17**, 1956. Available online: **pubs.rsc.org/en/content/articlehtml/2018/pp/c7pp00374a**

Project 4

Student project portfolio

The sunshine factor

Project title

Prepared by:

Name

Class

Date

THE SUNSHINE FACTOR
Planning sheet

Why are you doing this investigation?

Deciding your method

Variables

Model

Include a photograph or a diagram of your equipment set-up

Results

Raw data

Averaged results table

Graph

Affix graph here

Marking criteria for the graph

- Axis drawn using a pencil and a ruler.
- Axis labelled with correct headings and includes units.
- Appropriate scale used.
- Points plotted correctly.
- Line of best fit drawn.

Analysis

Conclusion

4

Research questions