



Physics & Astronomy
Education Research
Group @ UCT



DEPARTMENT OF
PHYSICS
UNIVERSITY OF CAPE TOWN

Using the **Smartphone** **Magnetometer** in a **(self-guided)** **physics learning activity**

PhD Candidate Mayhew Steyn

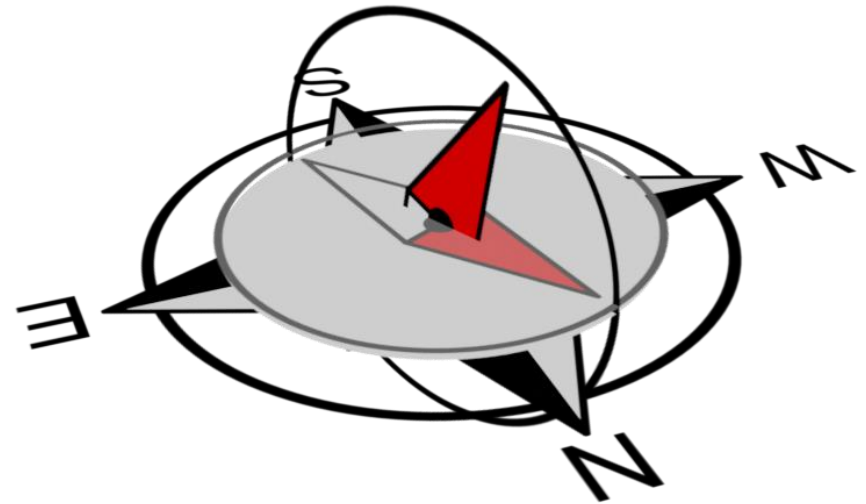
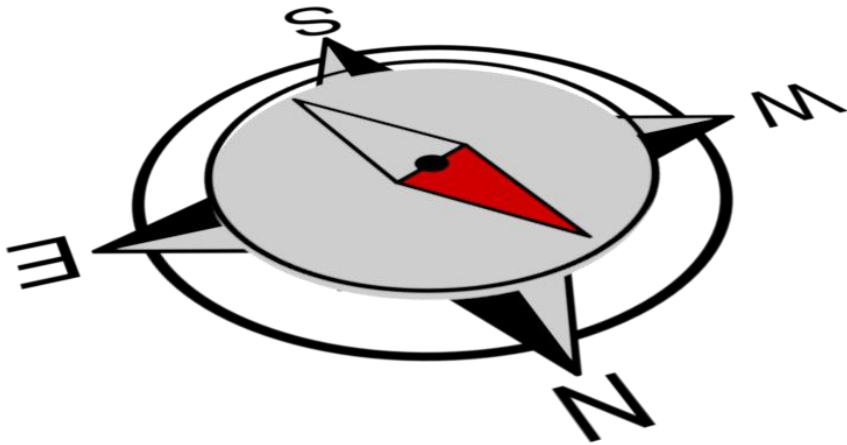
Supervised by: Saalih Allie and Dale Taylor

SAIP Conference 2026

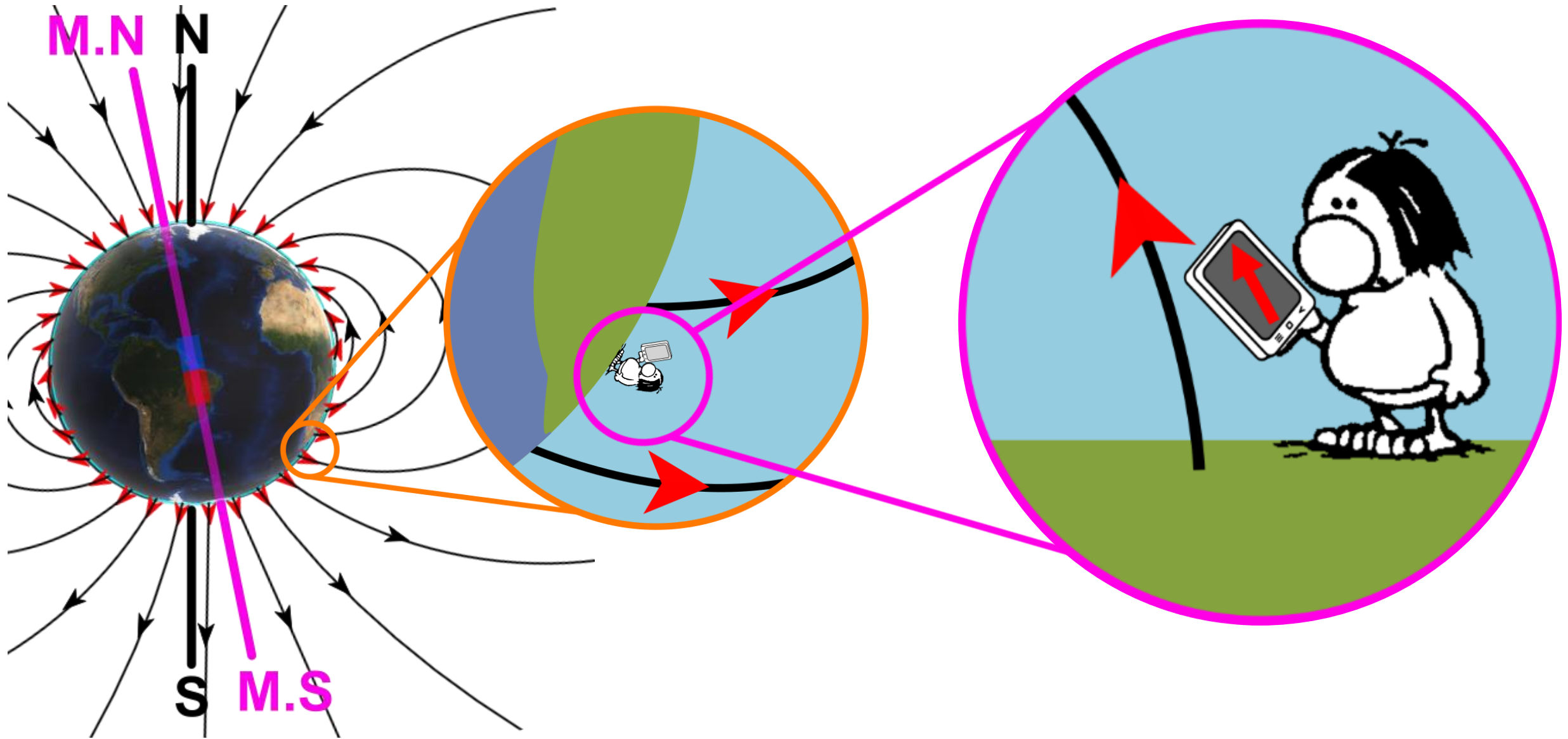


What direction is the Earth's Magnetic Field?

- In this room?
- How can we find it for ourselves?
- Is a compass enough? What about the vertical component?



Earth's Magnetic Field: Global $\leftrightarrow$ Local



Problem

Students have difficulty understanding 3D fields – for example in electromagnetism

Solution?

Smartphones contain sensors that can measure fields (gravity, magnetic fields)

Aims

Design and test educational activities that

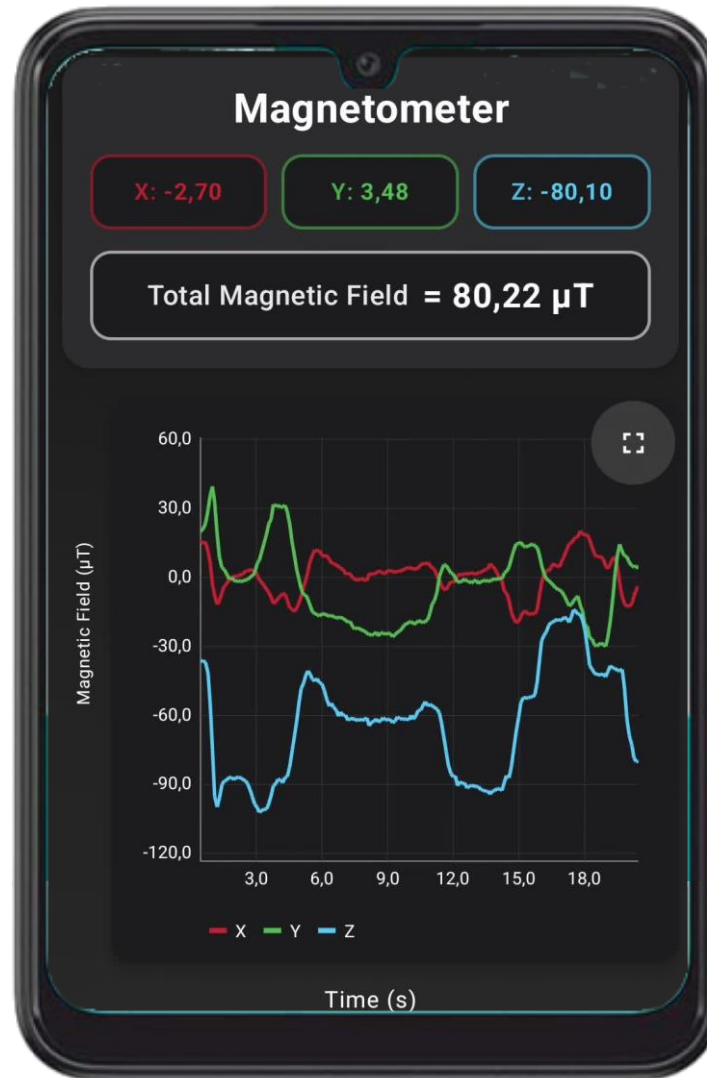
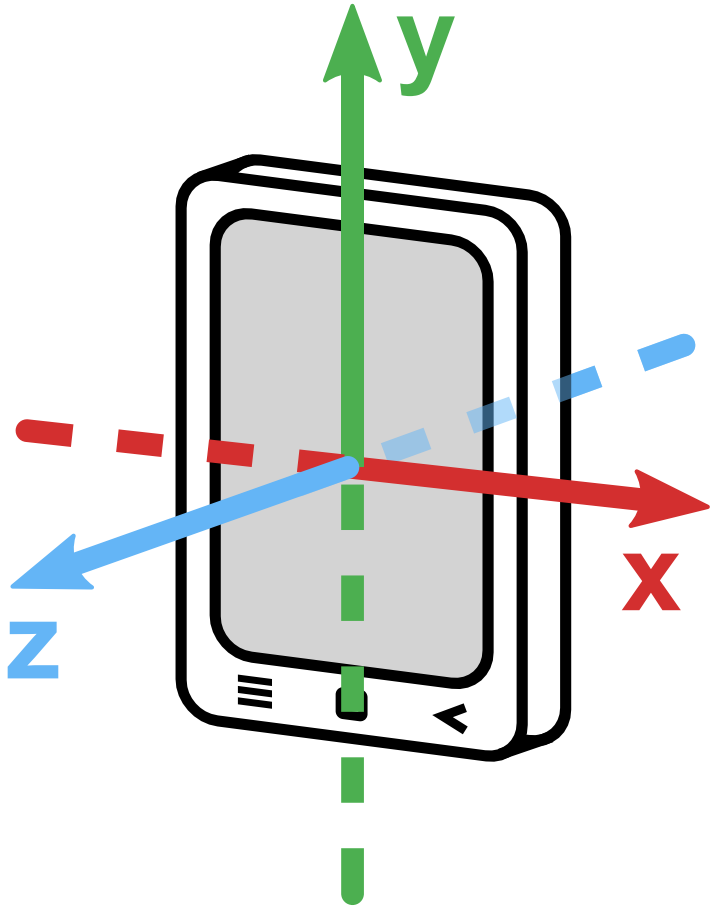
- Make use of smartphone sensors
- Use students' own smartphones
- Are suitable for self-guided learning
- Are aimed at a first-year level

Produce guides for

- Designing these activities
- Running these activities

Smartphone Sensor: + Application to use it

Magnetometer (3D)



Physics Toolbox
Sensor Suite



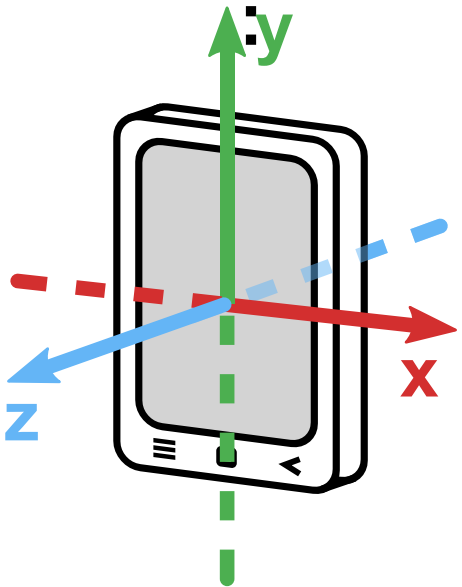
phyphox



Systematically Finding the Direction of the Earth's Magnetic Field

Goal: Point **y** axis in magnetic field direction

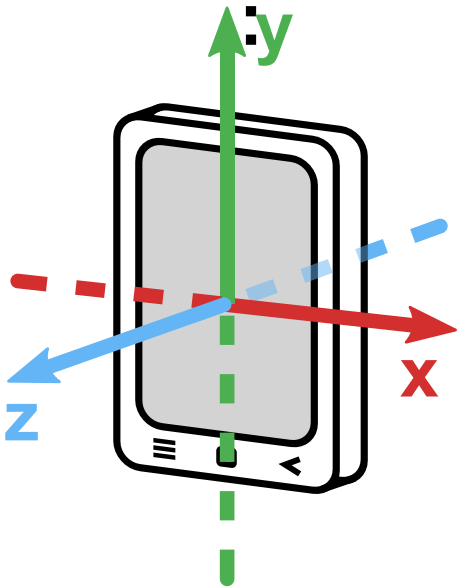
Method Zero-out **other** axes



Systematically Finding the Direction of the Earth's Magnetic Field

Goal: Point **y** axis in magnetic field direction

Method Zero-out **other** axes



M Field Direction
(Horizontal Component)

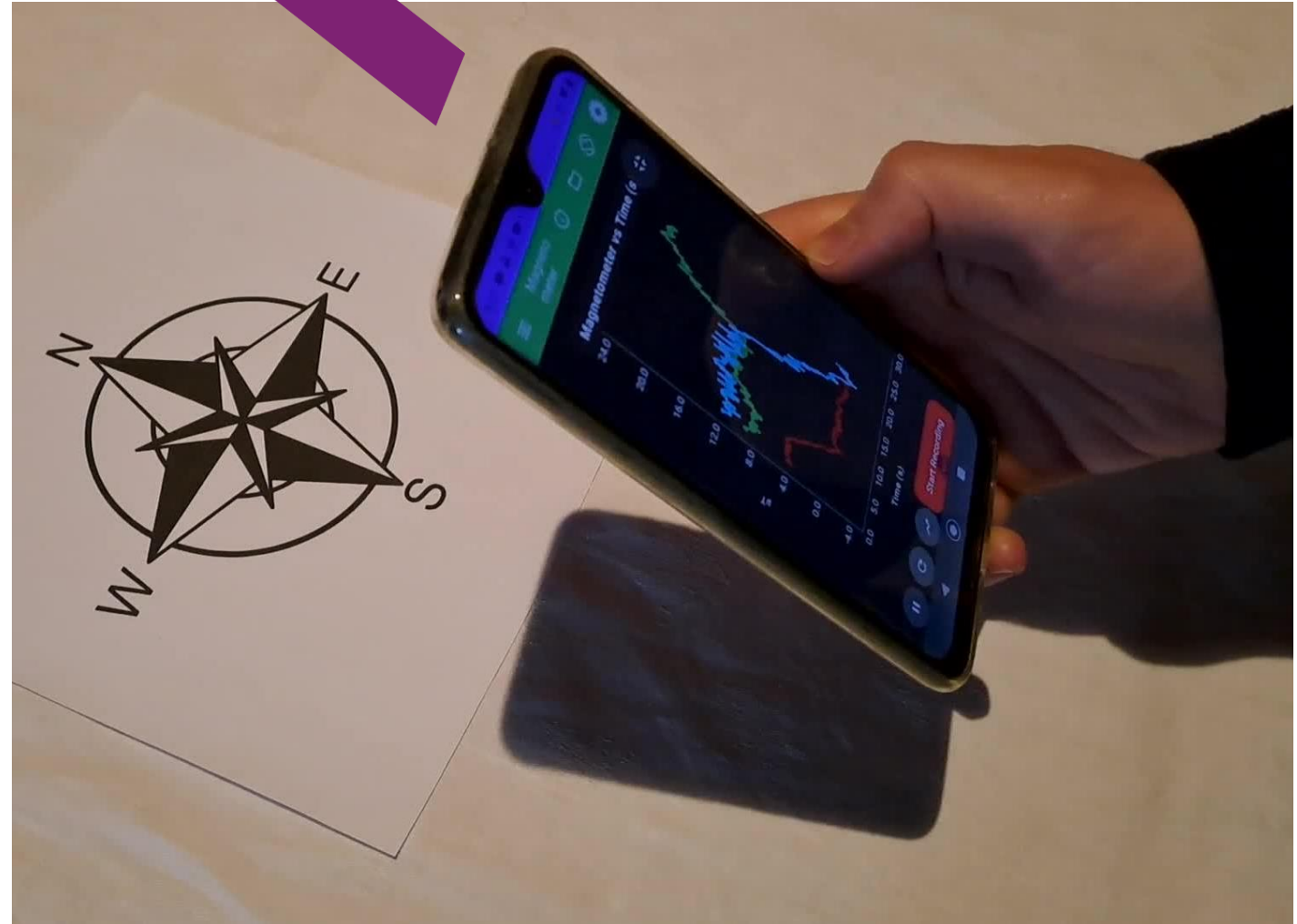
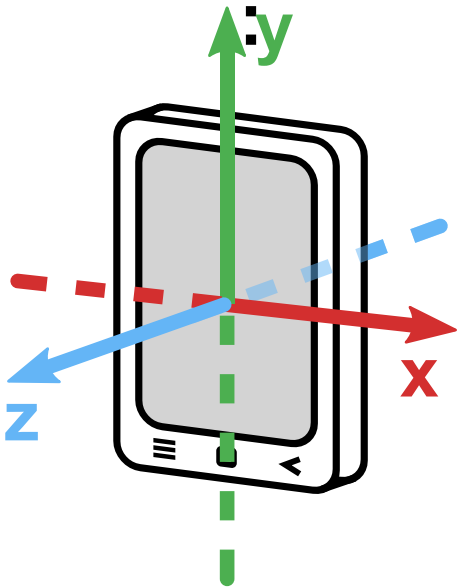


Systematically Finding the Direction of the Earth's Magnetic Field

M Field Direction

Goal: Point **y** axis in magnetic field direction

Method Zero-out **other** axes



In the beginning...

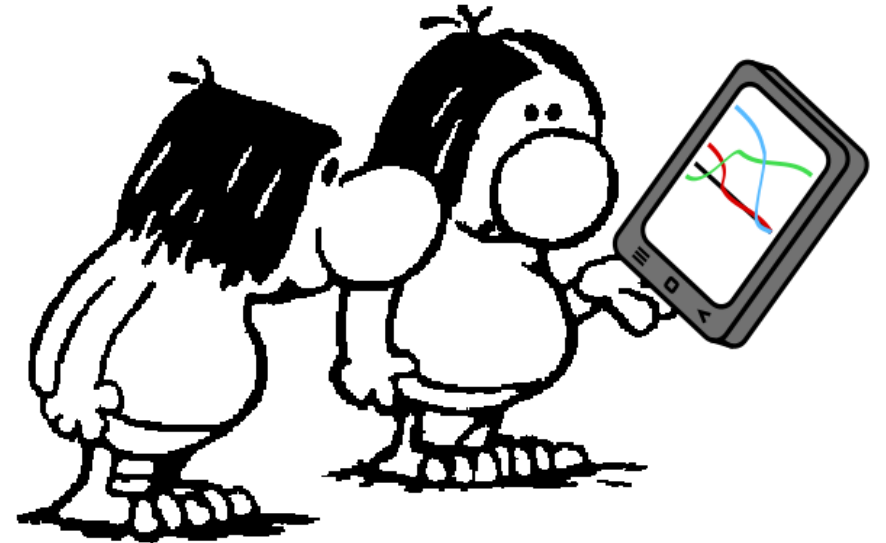
Previous work:
Dedicated device

(Volkwyn, Airey et al. 2019)



VS

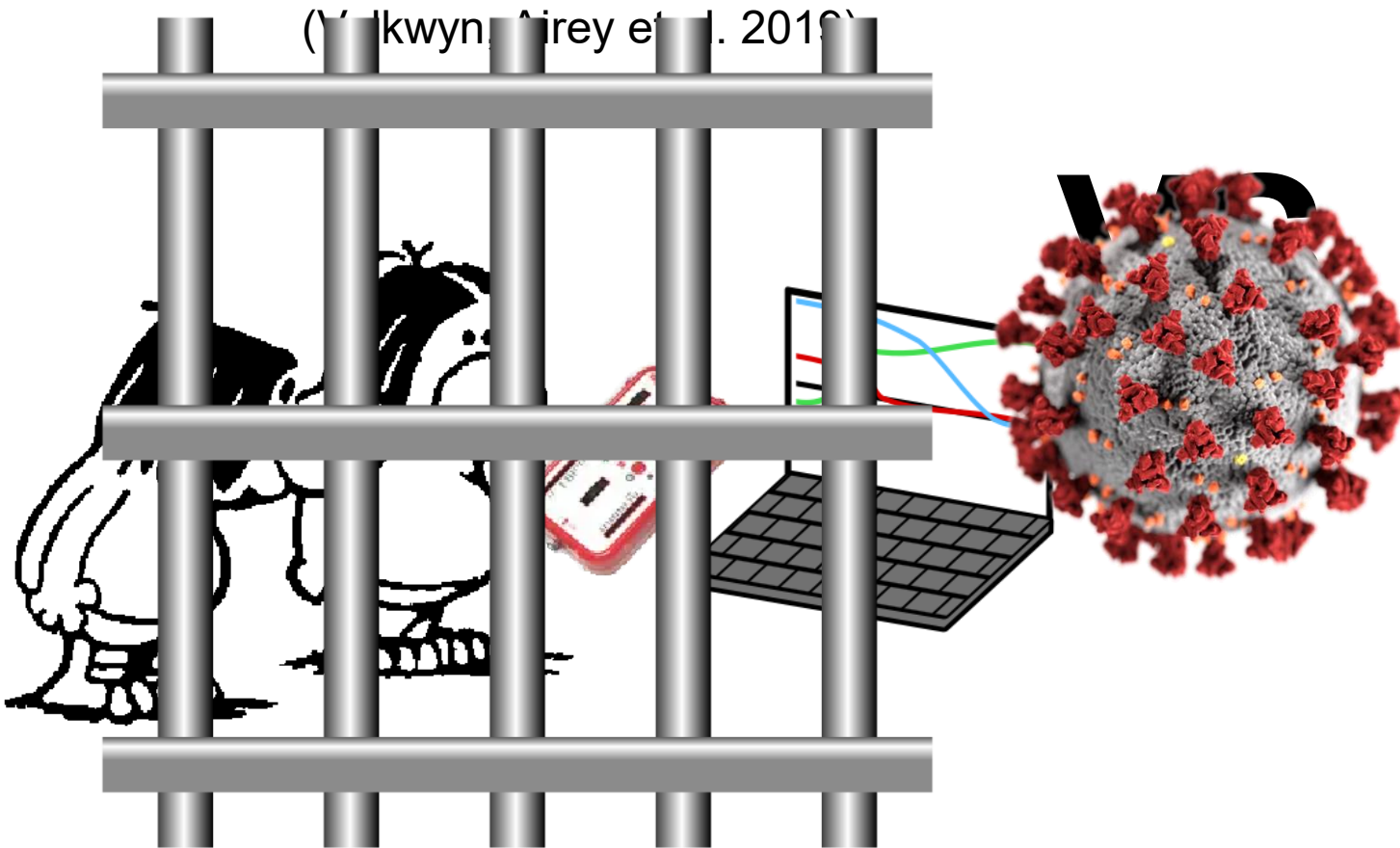
Compared to:
Students' smartphones



... but then ...

Previous work:
Dedicated device

(Volkwyn, Airey et al. 2016)



Compared to:
Students' smartphones



... but then ...

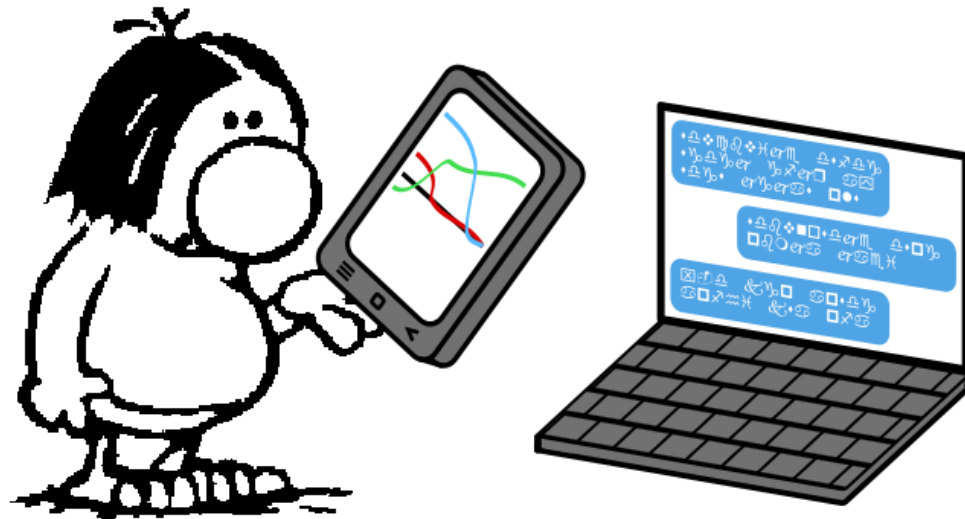
Previous work:

Dedicated

(Y. Kwyn, Firey)



Pivot: Students' smartphones
and work **self-guided at home**



Compared to:

' smartphones



It started with

Masters

Previous work:

Dedicated

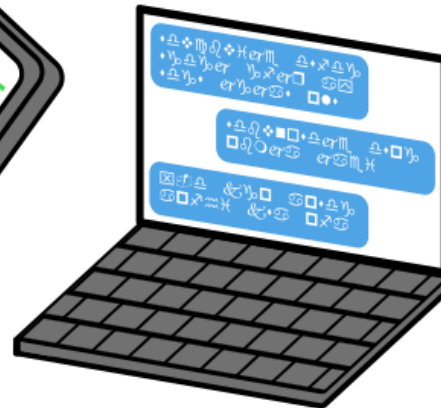
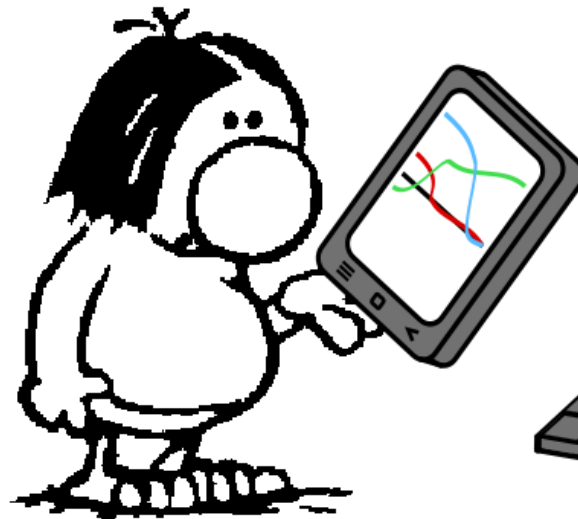
(Yolkwyn Airey)

Pivot: Students' smartphones
and work **at home** (self-
guided)

Compared to:

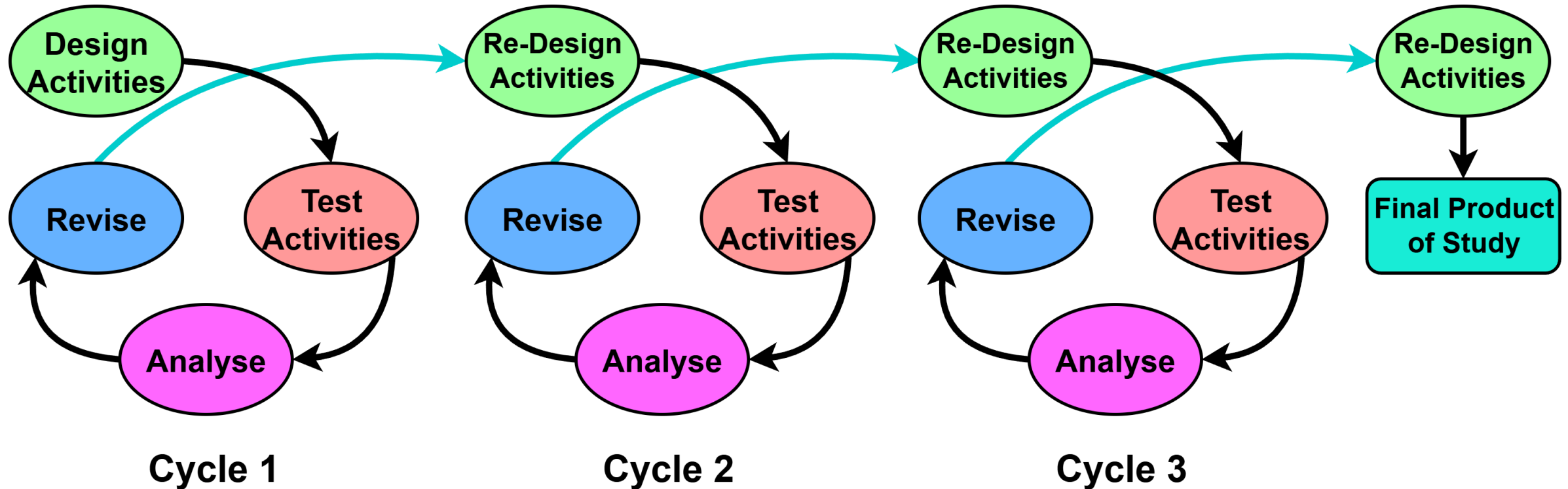
' smartphones

PhD



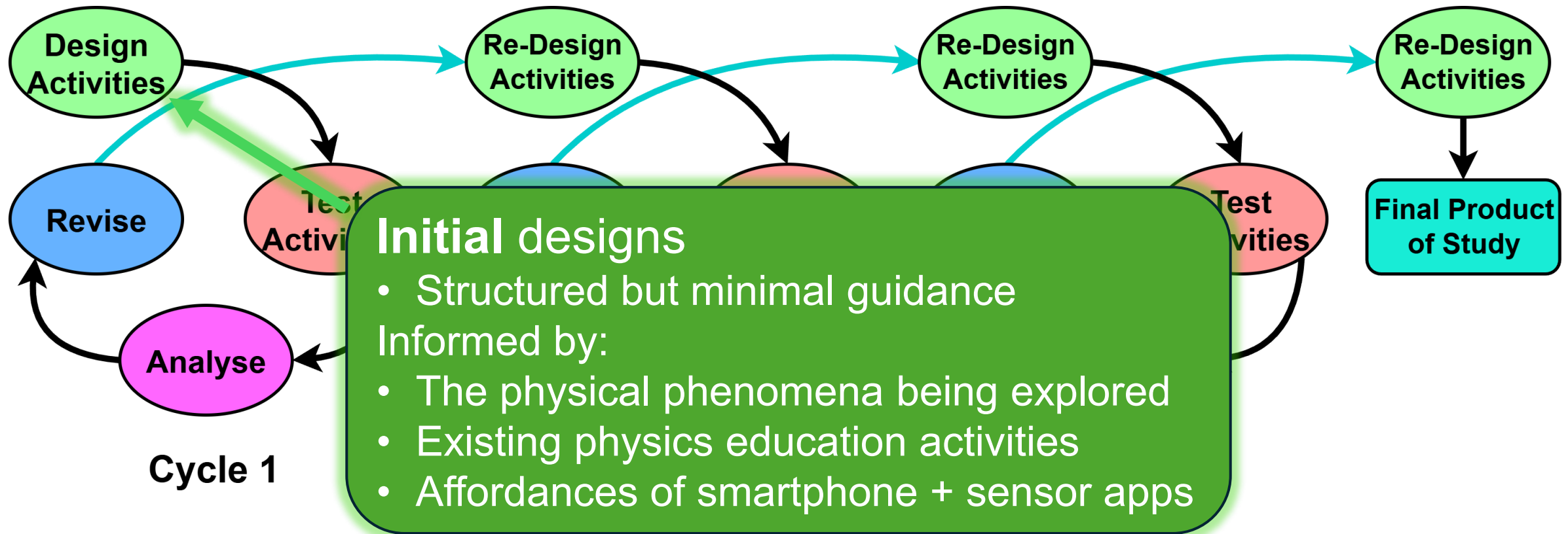
Design-Based Research Methodology

(Prediger,
Gravemeijer
et al. 2015)



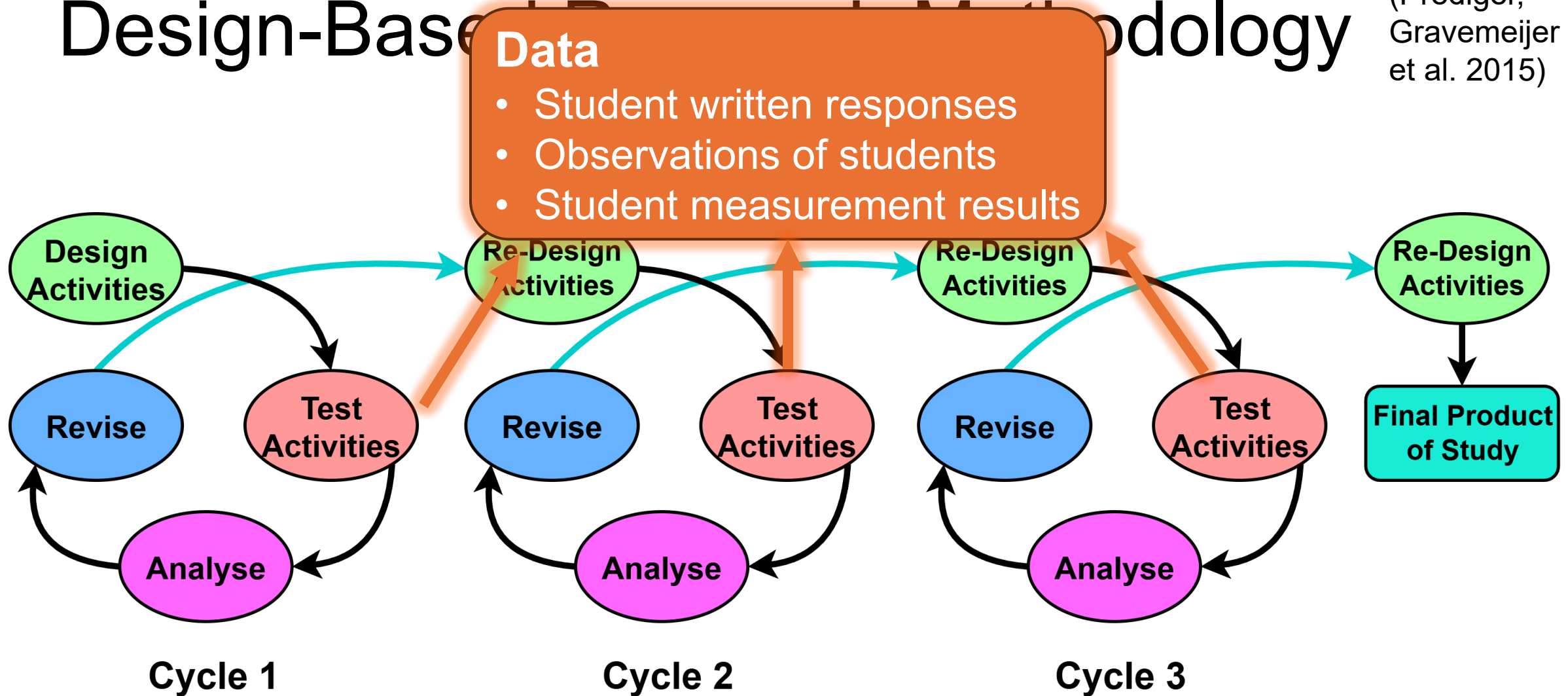
Design-Based Research Methodology

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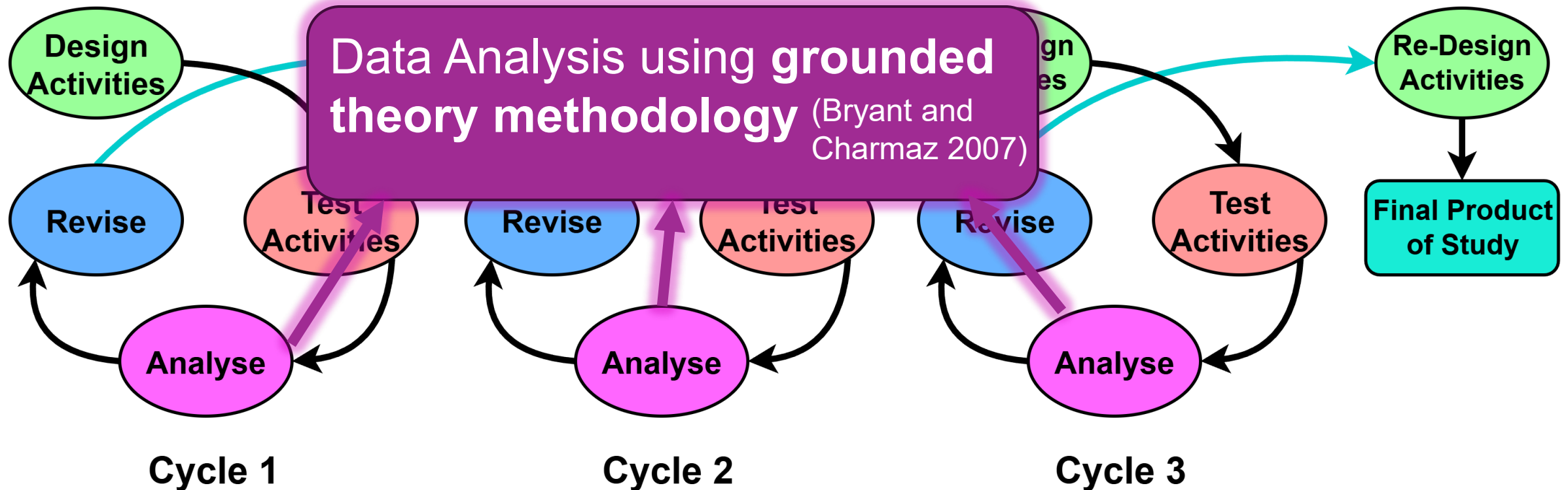
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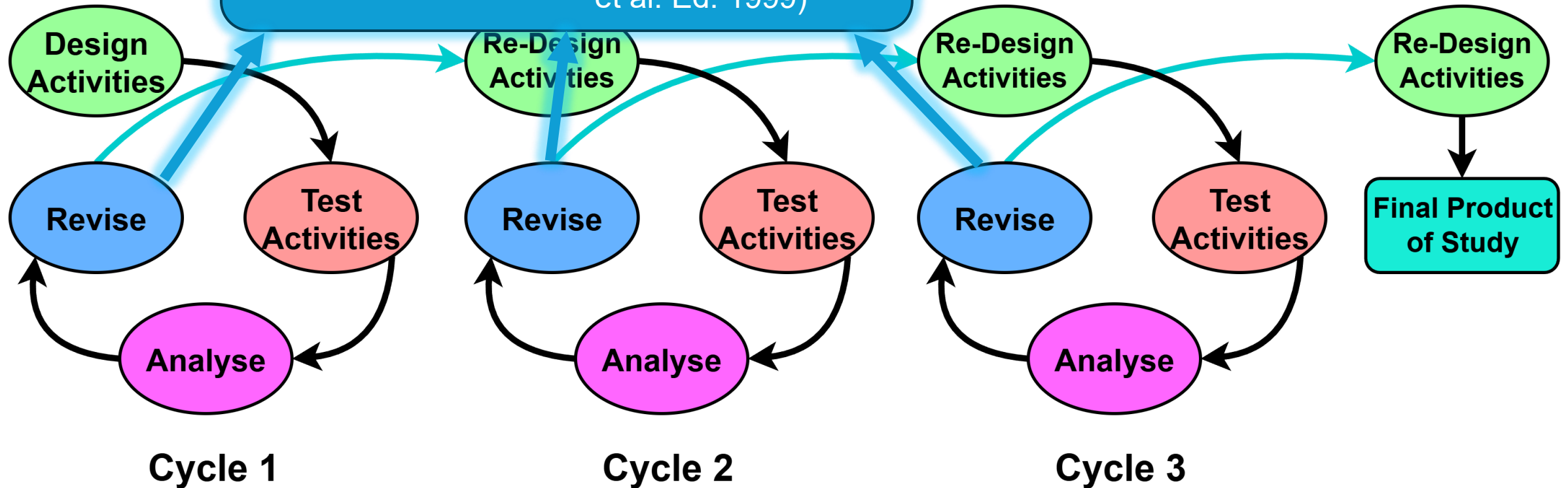
Design-Based Research Methodology

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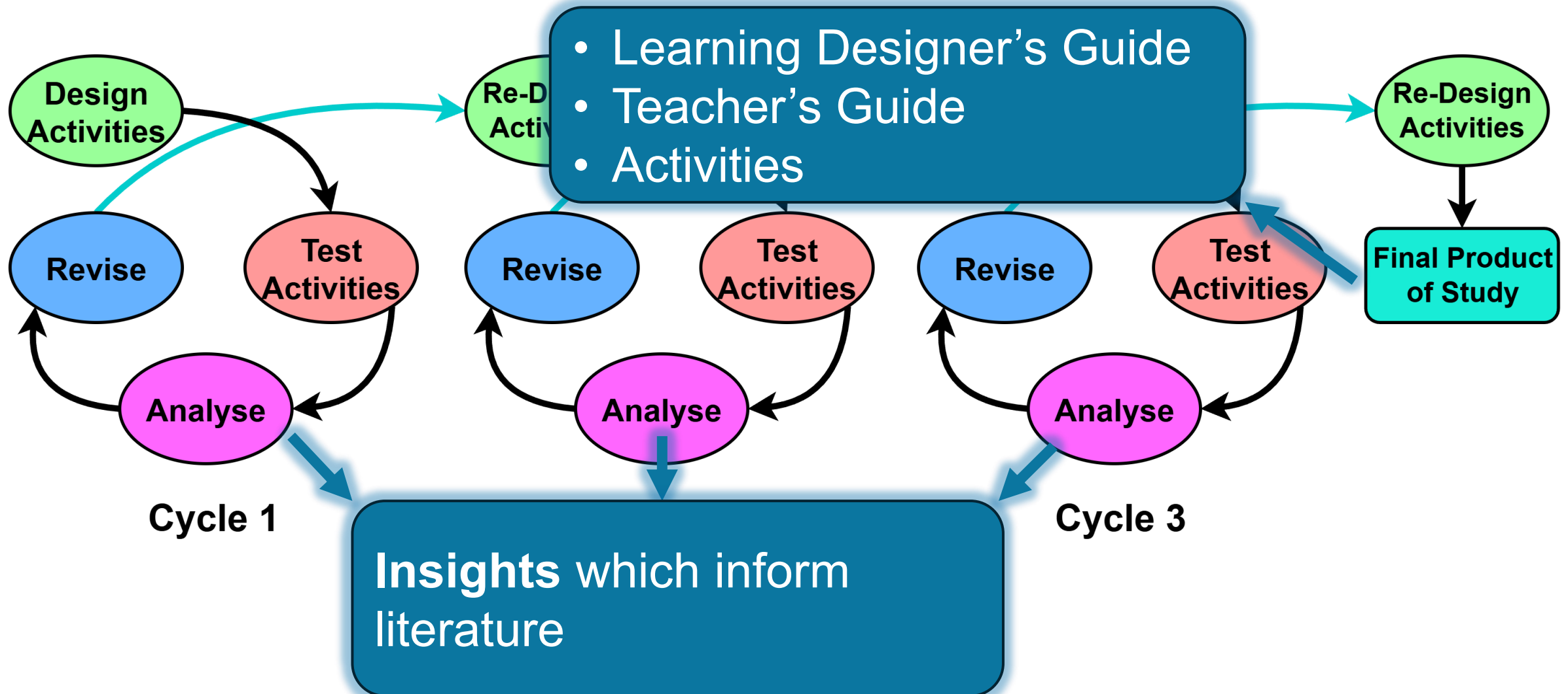
(Prediger,
Gravemeijer
et al. 2015)

(Engestrom, Miettinen
et al. Ed. 1999)



Design-Based Research Methodology

(Prediger,
Gravemeijer
et al. 2015)



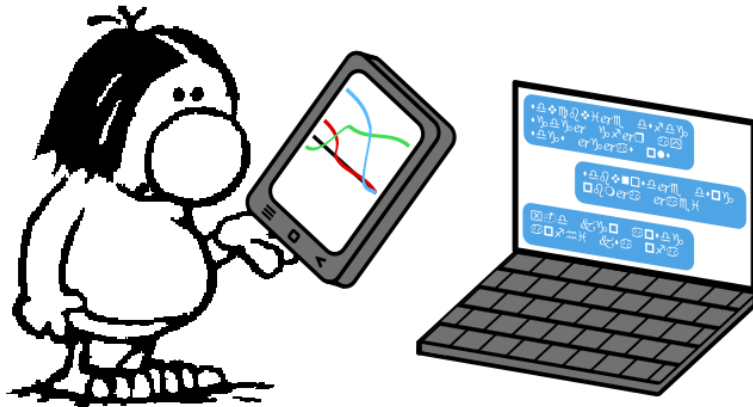
Design Cycle 1

App (Physics Toolbox)
used out-the-box

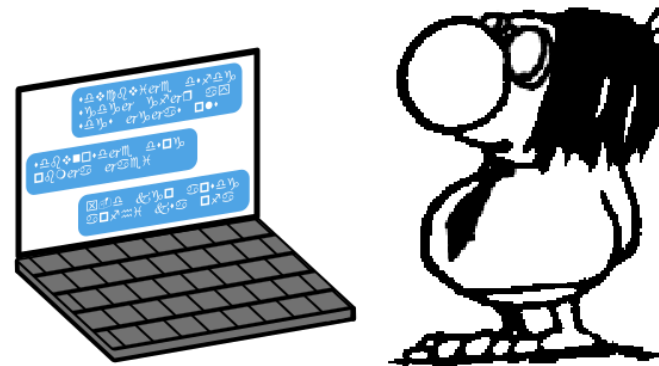
6 Honours students
(PER module)

Activity instructions open-ended

- Magnetometer sensor not explained (rely on app)
- Methodology not prescribed



At home | Individual work



Remote, asynchronous
communication with instructor

Design Cycle 1

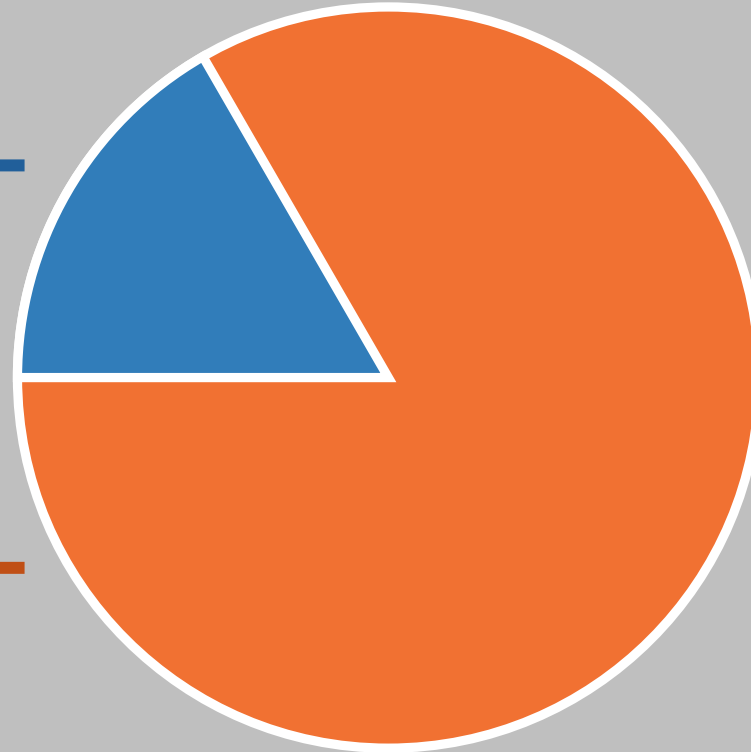
6 Honours students
(PER module)

Ap

Results

Only **1 student** found
vertical component for
magnetic field direction

Remaining **5 students**
found **horizontal**
magnetic field direction



At

Design Cycle 1

6 Honours students
(PER module)

App

Results

Only **1 student** found
vertical component
magnetic field

Remaining **5 students**
found **horizontal**
magnetic field direction

At

Technical difficulties with
smartphones and app

Conceptual difficulties with
phone and app:
3D axes

Conceptual difficulties with
magnetic field

Conclusion: Guidance too
limited



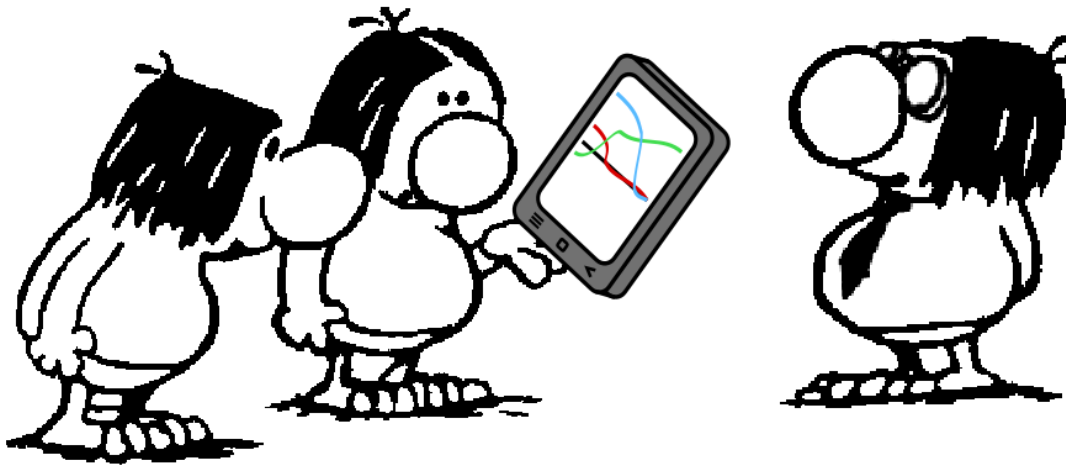
Design Cycle 2

8 Honours students
(PER module)

App (Physics Toolbox)
used out-the-box

Activity instructions slightly more
detailed

- Magnetometer sensor explained
- Methodology not prescribed



In-person | Working in groups
Instructor present

Paper axes



Design Cycle 2

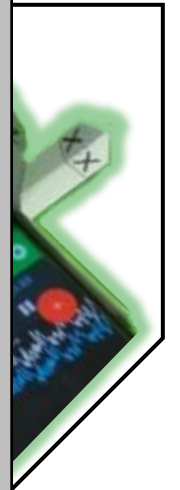
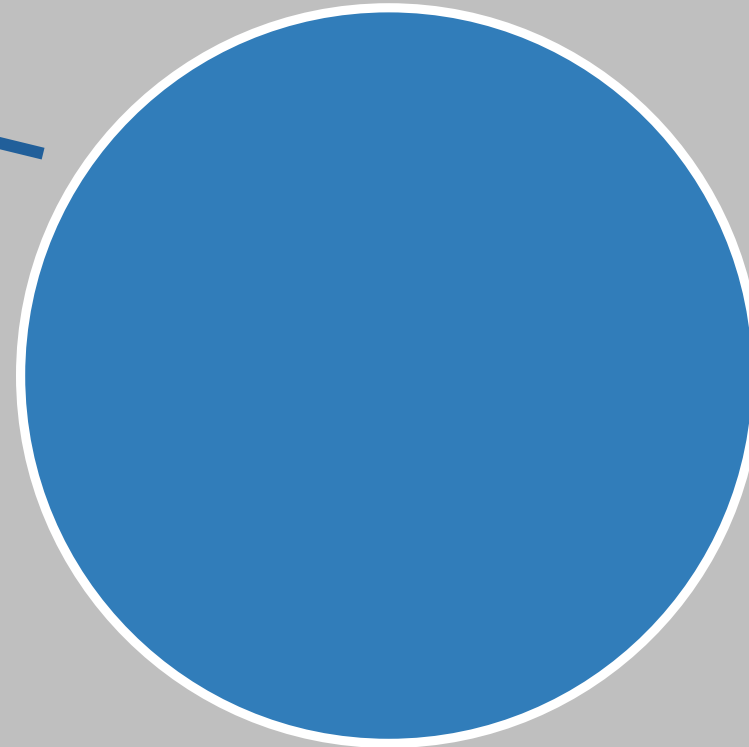
8 Honours students
(PER module)

App

Results

All 8 students found
vertical component for
magnetic field direction

(though possible
interference between
groups)



Design Cycle 2

8 Honours students
(PER module)

App

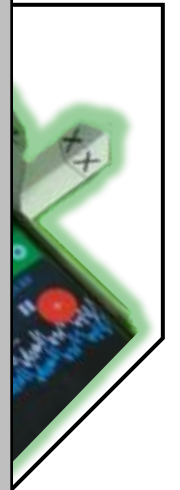
Results

All 8 students
vertical comp
magnetic field

(though possible
interference between
groups)

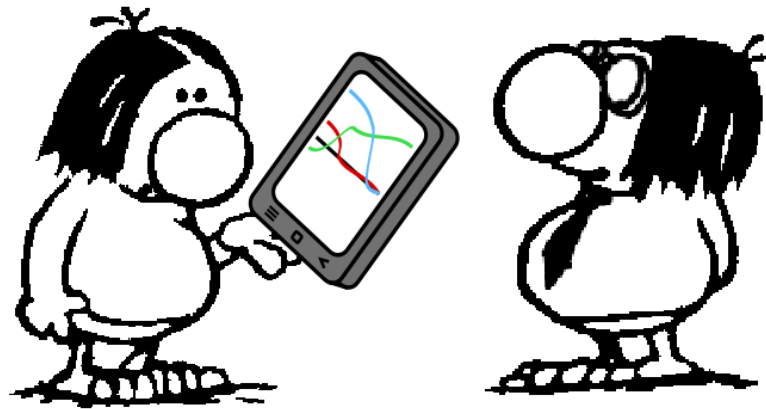
Positive response to
explanation of magnetometer
and paper axes

Insights into framing the
methodology



Design Cycle 3

App (phyphox)
customised for activity



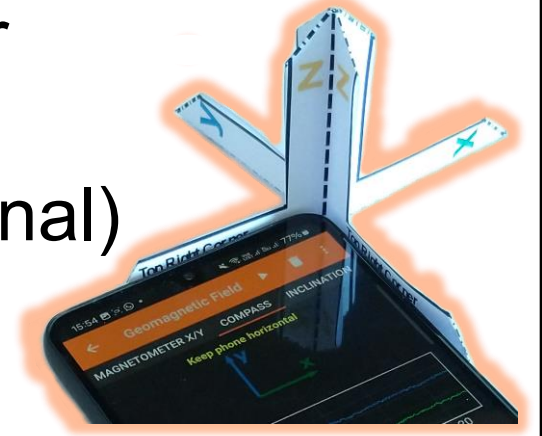
In-person | Individual work
Instructor present

14 First year students
(ECP / non-majors / majors)

Activity instructions detailed

- Magnetometer sensor explained
- Methodology framed

Paper
axes
(optional)



Design Cycle 3

14 First year students
(ECP / non-majors / majors)

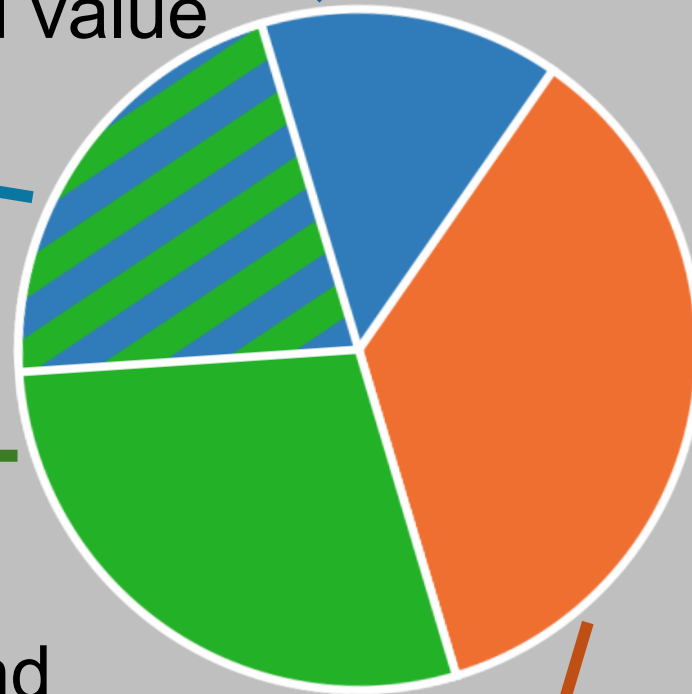
Results

5 students measured
magnetic **inclination**
near expected value

3 students did **both**

7 students described
vertical component for
magnetic field direction

Remaining 5 students found
horizontal magnetic field direction



Design Cycle 3 - Activity

Booklet »

Introduction

Smartphone Activities Research

In this booklet you are given a learning activity that requires you to use your smartphone to take physical measurements. Before the activity, you will be guided through installing the "phyphox" app to make use of your smartphone sensors.

Your feedback on these activities is needed to make improvements to them, to ensure they can be completed with minimum hassle. During the testing process, if you are having any problems, please let us know. If you are being tested, you may get stuck at some points.

Please **write your student number** at the top of each of the additional pages that you use and put them in the booklet. Please write your student number at the top of each of the additional pages that you use and put them in the booklet.

Most of the contents in these activities are contained in boxes, with different purposes. These boxes are:

Info

These boxes contain information, either on physics, smartphones or phyphox. These boxes will not contain instructions that require you to take actions or write responses.

Action

These boxes contain instructions that require you to take actions, but do not require written responses.

App»

Design Cycle 3 - Activity

Booklet »

Smart

In this booklet, you will find a physical map app to make your feedback completed. Your feedback will not get stuck at the end of the space in the app that you use. Most of the boxes are:

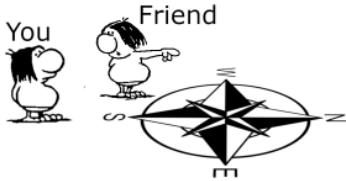
Info

These boxes will not be used.

Action

These boxes will be used to respond to your feedback.

Pre-Activity Question (Earth Magnetic Field Direction)



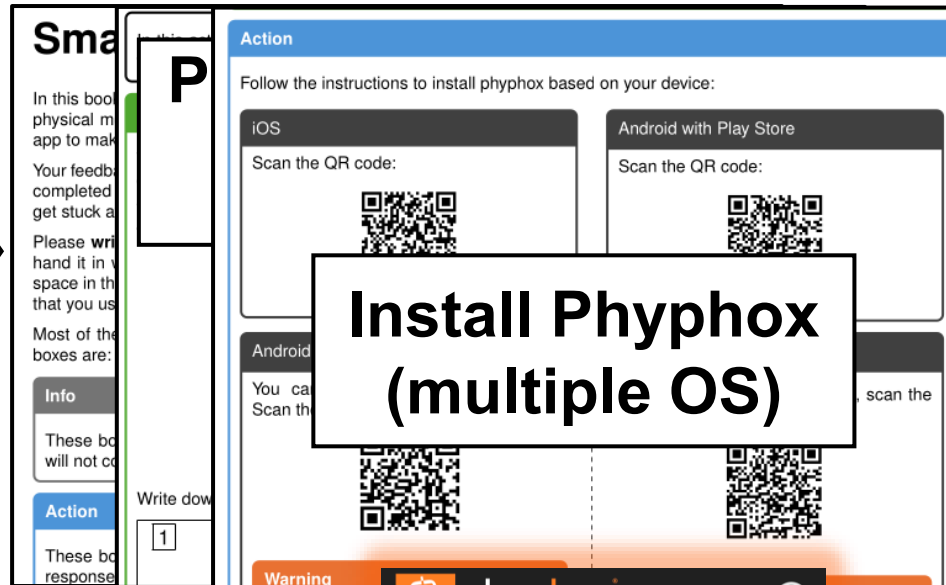
Write down what you would say to your friend (you may also include diagrams).

1

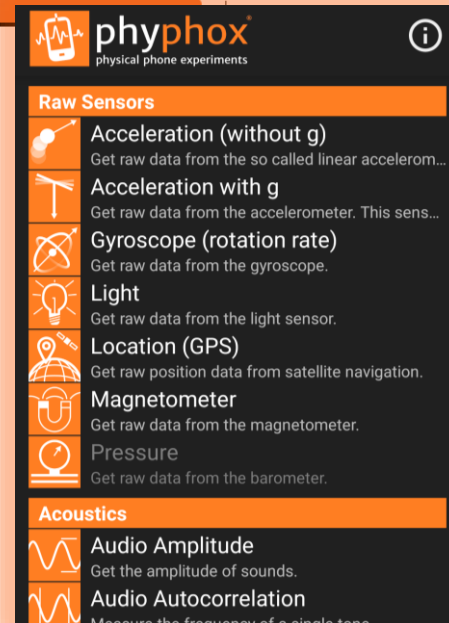
App»

Design Cycle 3 - Activity

Booklet »

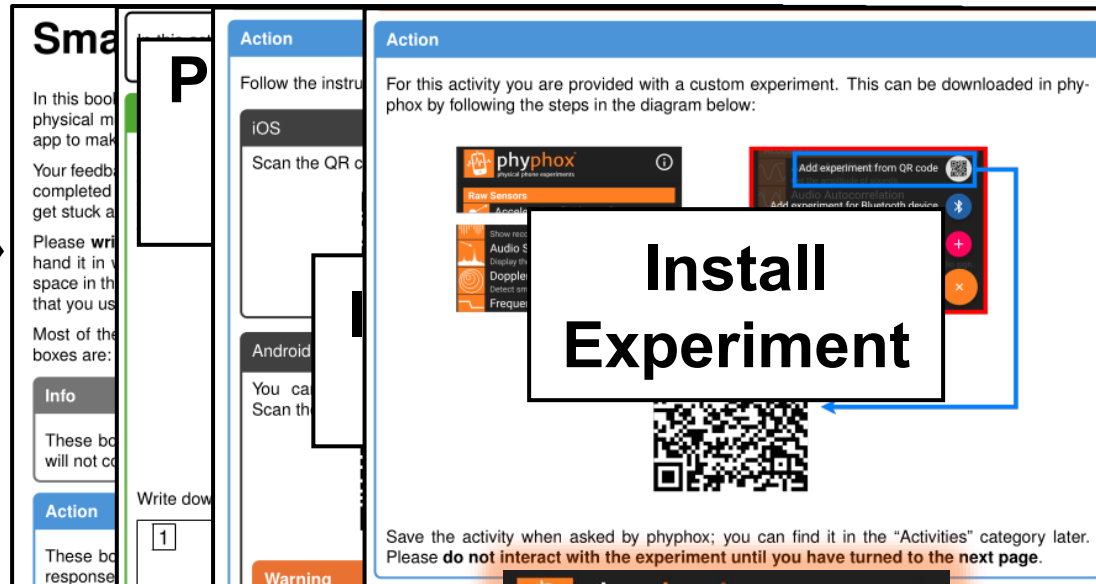


App»

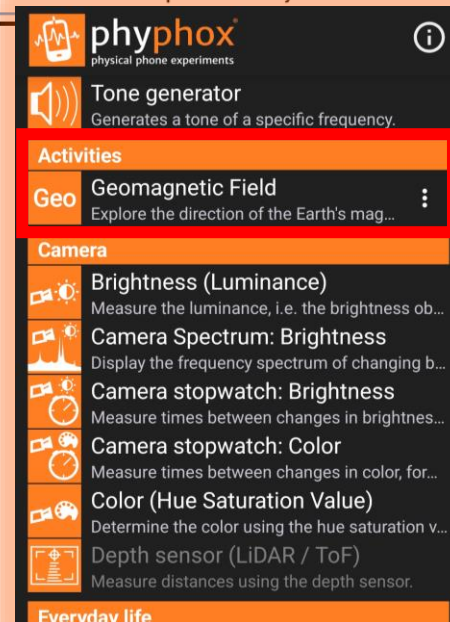


Design Cycle 3 - Activity

Booklet »

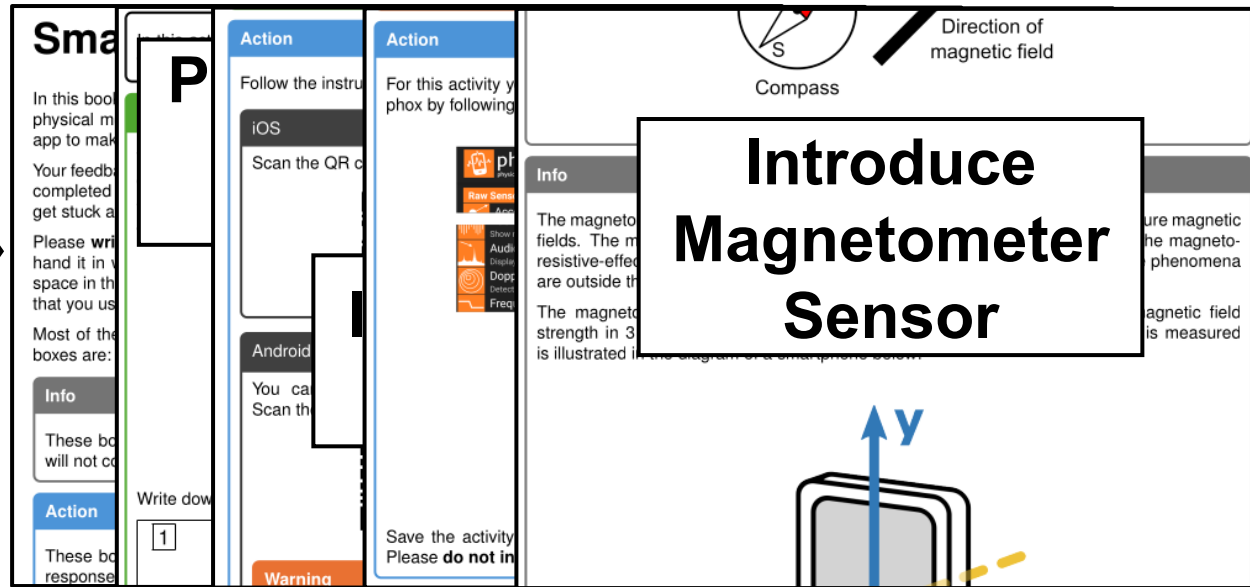


App»



Design Cycle 3 - Activity

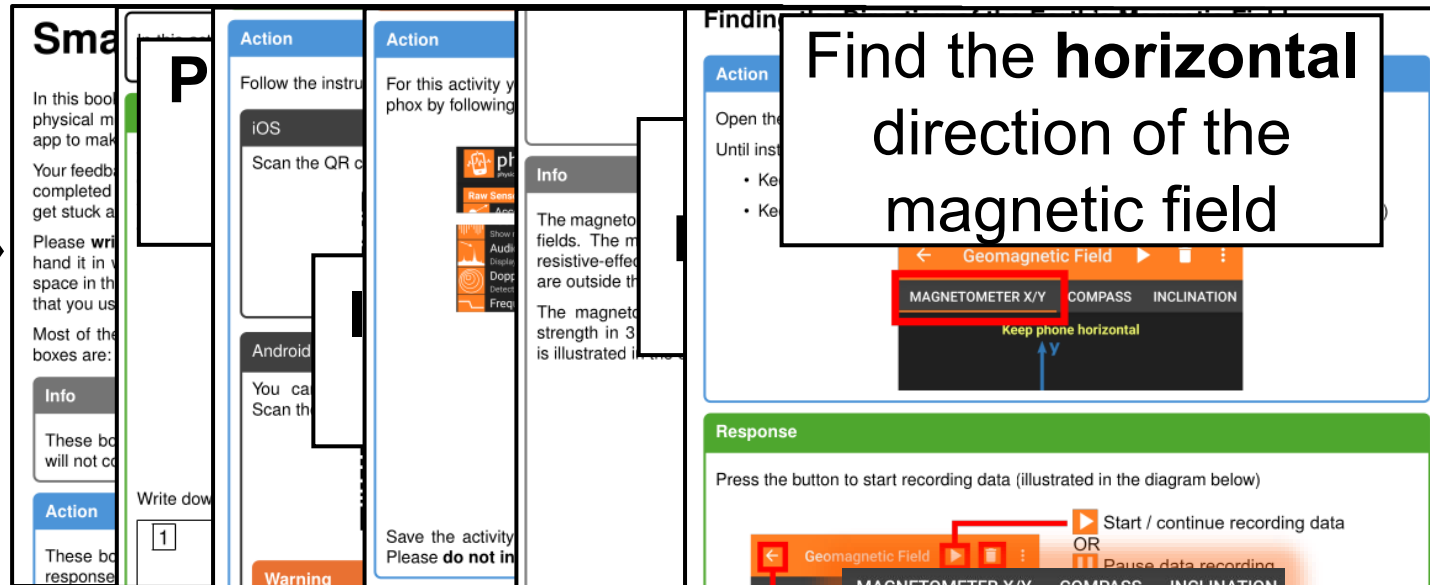
Booklet »



App»

Design Cycle 3 - Activity

Booklet »



App»



Design Cycle 3 - Activity

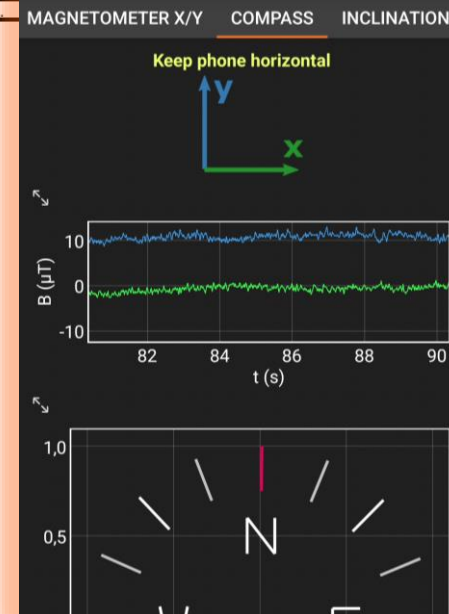
Booklet »

App»

The collage shows various stages of the design cycle:

- Booklet Page:** Contains introductory text about a physical map app, an 'Info' section, and an 'Action' section with a 'Write down' prompt.
- Wireframe:** A schematic layout of the app interface with sections for 'Action' (instructions for iOS and Android), 'Info' (magnetometer details), and 'Response' (instructions to point the y-axis).
- App Screenshot 1:** Shows the 'Geomagnetic Field' app interface with a 'COMPASS' button highlighted by a red box. Text below the button says 'Keep phone horizontal' with a blue arrow pointing up.
- App Screenshot 2:** A graph showing magnetic field strength B (μT) over time t (s). The y-axis ranges from -10 to 10, and the x-axis ranges from 82 to 90. A blue line represents the data, and a green line represents the compass direction.
- App Screenshot 3:** A compass rose showing the magnetic field direction with a red needle pointing North.

Checkpoint: Compare your result with the compass direction



Design Cycle 3 - Activity

Booklet »

App»

Find full direction of the magnetic field and inclination

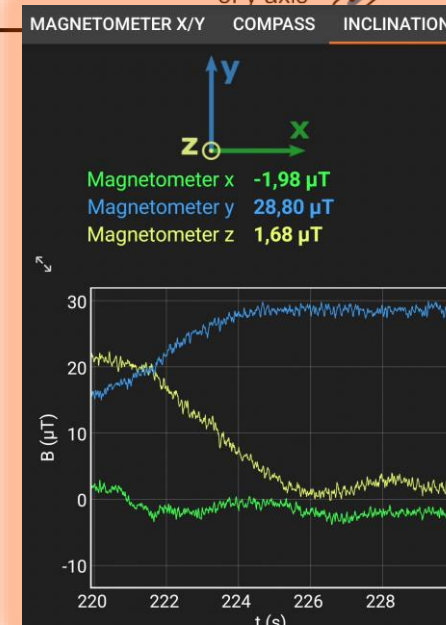
Switch to the "Inclination" view.

Use the magnetometer to find the direction of the Earth's magnetic field. Then switch to the "Inclination" view.

The angle between the y-axis and the horizontal plane:

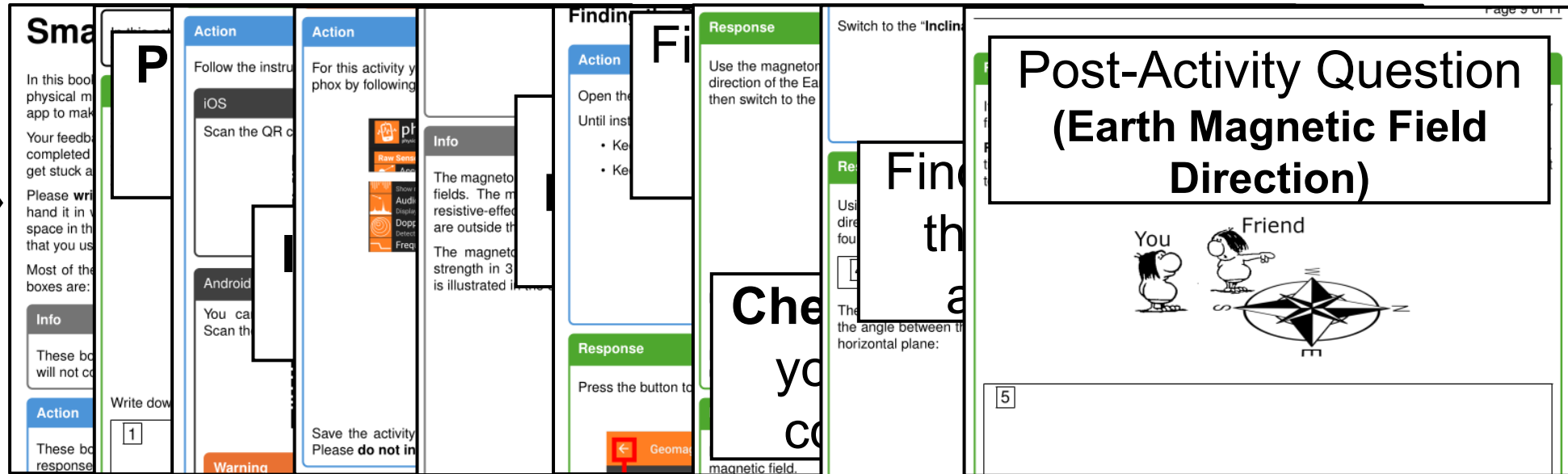
Inclination of y axis

Horizontal plane



Design Cycle 3 - Activity

Booklet »



App»

Design Cycle 3 - Activity

Booklet »

Smartphone In this booklet, you will find a physical map app to make your fieldwork easier. Your feedback is important. Please write down your feedback on the back of the booklet. Most of the boxes are: Info These boxes will not be used. Action These boxes will be used to record your response.	Post-Activity Survey If you have already covered something in a written comment earlier in the booklet, then you don't have to repeat that in the elaboration below. Consider your overall experience with the activities. With which of the statements do you agree? <table border="1"><thead><tr><th></th><th>Strongly Agree</th></tr></thead><tbody><tr><td>I enjoyed the activities</td><td>☐</td></tr><tr><td>I learnt a lot from the activities</td><td>☐</td></tr><tr><td>I encountered difficulties that were difficult / impossible to overcome</td><td>☐</td></tr><tr><td>I needed the diagrams on how to use the phyphox app</td><td>☐</td></tr><tr><td>The instructions for the activities were clear</td><td>☐</td></tr></tbody></table> If you haven't already, please elaborate on your choices: 6		Strongly Agree	I enjoyed the activities	☐	I learnt a lot from the activities	☐	I encountered difficulties that were difficult / impossible to overcome	☐	I needed the diagrams on how to use the phyphox app	☐	The instructions for the activities were clear	☐		
	Strongly Agree														
I enjoyed the activities	☐														
I learnt a lot from the activities	☐														
I encountered difficulties that were difficult / impossible to overcome	☐														
I needed the diagrams on how to use the phyphox app	☐														
The instructions for the activities were clear	☐														
Action Follow the instructions on the back of the booklet to scan the QR code and download the app. iOS Scan the QR code and download the app. Android You can scan the QR code and download the app.	Action For this activity you will use the phyphox app by following the instructions on the back of the booklet. Info The magnetic fields. The magnetic field lines are outside the Earth's surface. The magnetic strength in 3D is illustrated in the diagram below. Response Press the button to record the magnetic field.	Response Use the magnetometer to measure the direction of the Earth's magnetic field. Then switch to the 'Inclination' tab to see the angle between the horizontal plane and the magnetic field.	Post-Activity Survey If you have already covered something in a written comment earlier in the booklet, then you don't have to repeat that in the elaboration below. Consider your overall experience with the activities. With which of the statements do you agree? <table border="1"><thead><tr><th></th><th>Strongly Agree</th></tr></thead><tbody><tr><td>I enjoyed the activities</td><td>☐</td></tr><tr><td>I learnt a lot from the activities</td><td>☐</td></tr><tr><td>I encountered difficulties that were difficult / impossible to overcome</td><td>☐</td></tr><tr><td>I needed the diagrams on how to use the phyphox app</td><td>☐</td></tr><tr><td>The instructions for the activities were clear</td><td>☐</td></tr></tbody></table> If you haven't already, please elaborate on your choices: 5		Strongly Agree	I enjoyed the activities	☐	I learnt a lot from the activities	☐	I encountered difficulties that were difficult / impossible to overcome	☐	I needed the diagrams on how to use the phyphox app	☐	The instructions for the activities were clear	☐
	Strongly Agree														
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I needed the diagrams on how to use the phyphox app	☐														
The instructions for the activities were clear	☐														

App»

Design Cycle 3 - Activity

Booklet »

App»

Finding the Direction of the Earth's Magnetic Field

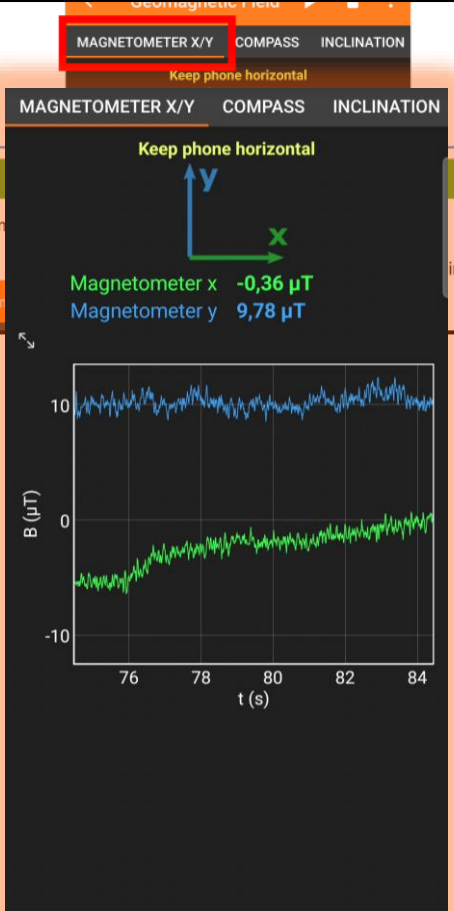
Action

Open the app until instructed to start recording data.

- Keep the phone horizontal.
- Keep the phone pointing in the direction of the Earth's magnetic field.

Response

Press the button to start recording data.



Find the **horizontal** direction of the magnetic field

Checkpoint: Compare your result with the compass direction

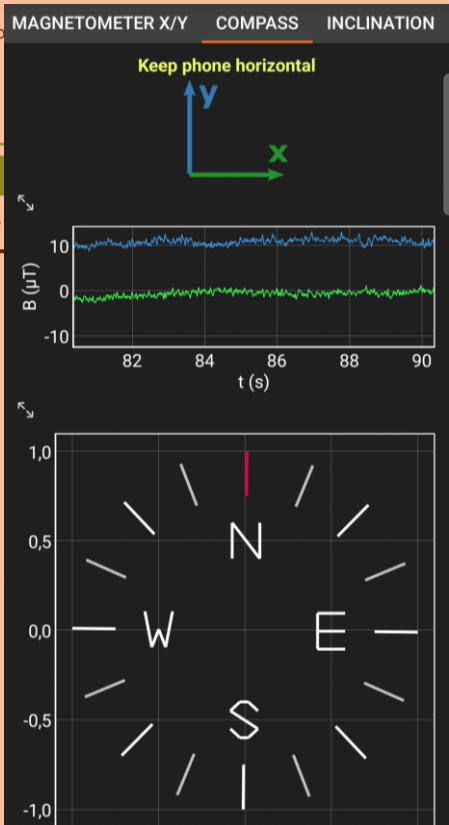
Keep phone horizontal

Does the direction of the magnetic field match the compass direction?

If you answered magnetic field.

Response

Please describe magnetic field.



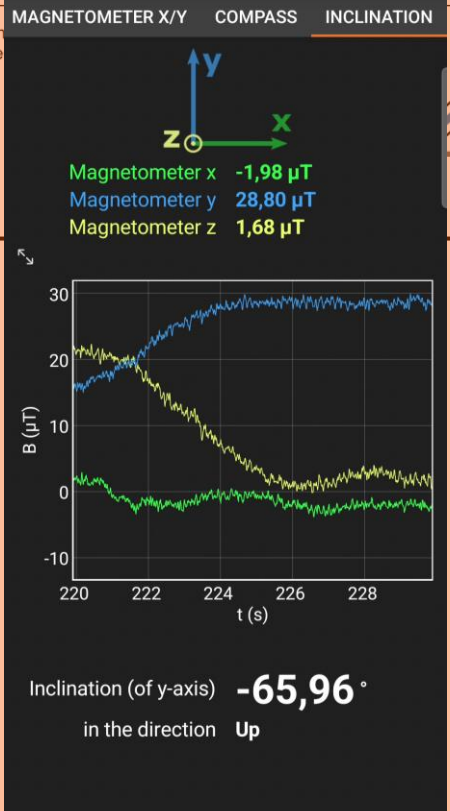
Sw

Find full direction of the magnetic field and inclination

Using the magnetometer readings to guide you, point the y-axis of your smartphone in the direction of the Earth's magnetic field, now including the vertical component. Once you have found the direction, pause data recording and quote the inclination that you read.

4

The inclination is the angle between the magnetic field and the horizontal plane:



Challenges and Interesting Results

From all design cycles

Challenges designing for the remote (at-home) environment

- Limited apparatus
 - The smartphone
 - The student (motion, voice, etc.)
 - Household items
- Physical phenomena must be accessible, e.g.
 - Earth's gravitational field
 - Earth's magnetic field

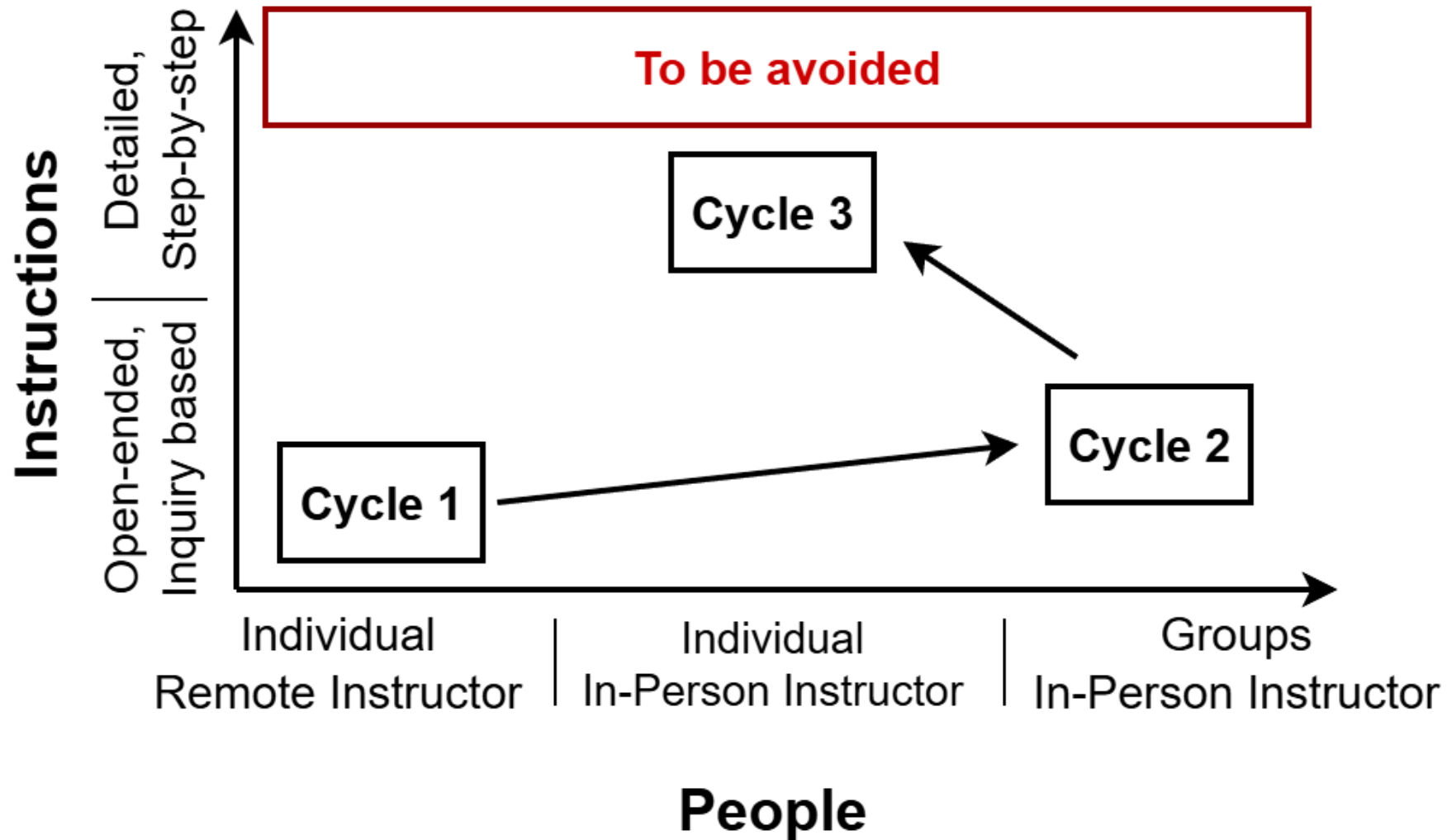
Students' Conceptual Difficulties

- Even honours students had conceptual difficulties when given **limited guidance**
- Conceptual difficulties with:
 - The apps / smartphone / sensors
(e.g. **3D axes** – not communicated well in apps)
 - The Earth's magnetic field (physics concept)

Challenges Communicating Orientation

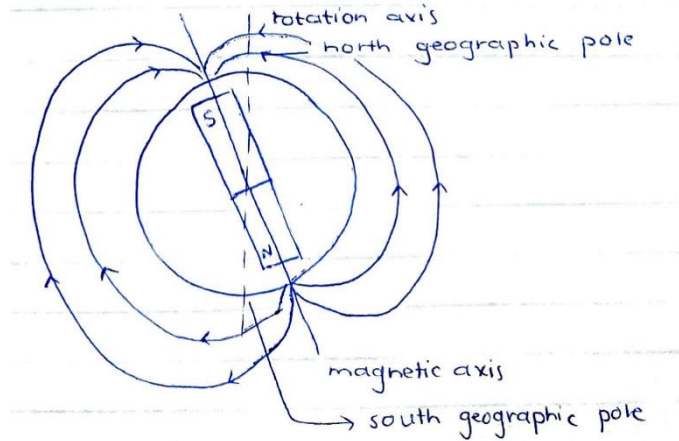
- Describing orientation of smartphone / 3D direction can be challenging
 - **Reference frame** required
 - Instructions may use videos or diagrams
 - Measure **magnetic inclination** instead of 3D direction
- Students **used wide range of terminology** to describe orientating their smartphone
 - Often used inconsistently
 - Additional context (observation, measurement data) needed to interpret

Activities and Mediation



Student Models of Geomagnetic Field

Magnetic field lines go from magnetic **pole** to magnetic **pole**



Magnetic field direction **points to** a magnetic **pole**

Both often used to justify a **horizontal** magnetic field direction (no vertical component)

Though these aren't 2D models...

References

- Bryant, A. and K. Charmaz (2007). The SAGE Handbook of Grounded Theory, SAGE Publications Ltd.
- Engestrom, Yrjo; Miettinen, Reijo and Punamaki, Raija-Leena (Ed.) (1999). Learning in doing: Social, cognitive and computational perspectives: Perspectives on activity theory. Cambridge, England, Cambridge University Press.
- Prediger, S., K. Gravemeijer and J. Confrey (2015). "Design research with a focus on learning processes: an overview on achievements and challenges." ZDM **47**(6): 877-891.
- Volkwyn, T. S., J. Airey, B. Gregorcic and F. Heijenskjöld (2019). "Transduction and Science Learning: Multimodality in the Physics Laboratory." Designs for Learning.

Special thanks to Dr. Tshiamiso Makwela, Nuraan Majiet and Chad Leukes from PhAsER

Thank You!

Any Questions / Comments?

Email me:

stymay001@myuct.ac.za

[LinkedIn](https://www.linkedin.com/in/mayhew-steyn)

<https://www.linkedin.com/in/mayhew-steyn>

↓ These slides ↓

