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

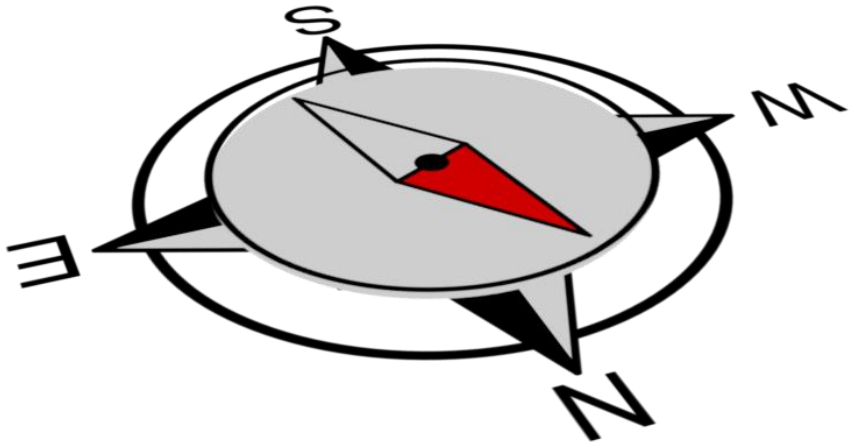
SAIP Conference 2026

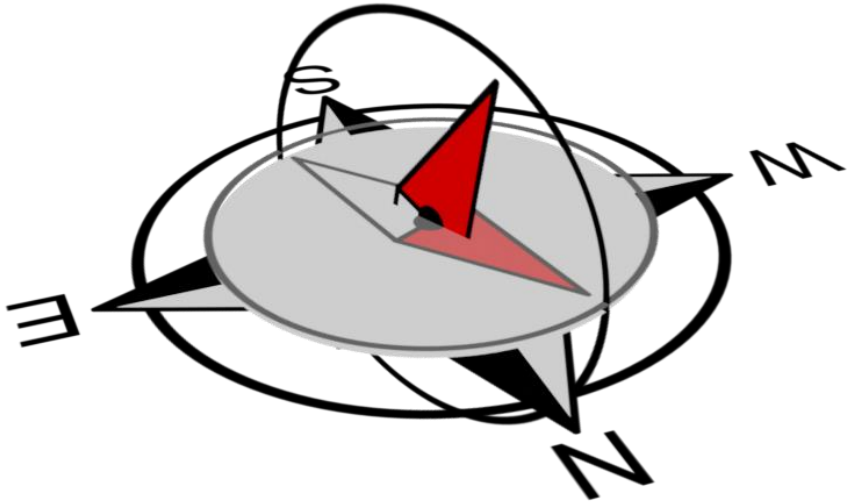
SOUTH AFRICAN INSTITUTE OF PHYSICS

What direction is the Earth's Magnetic Field?

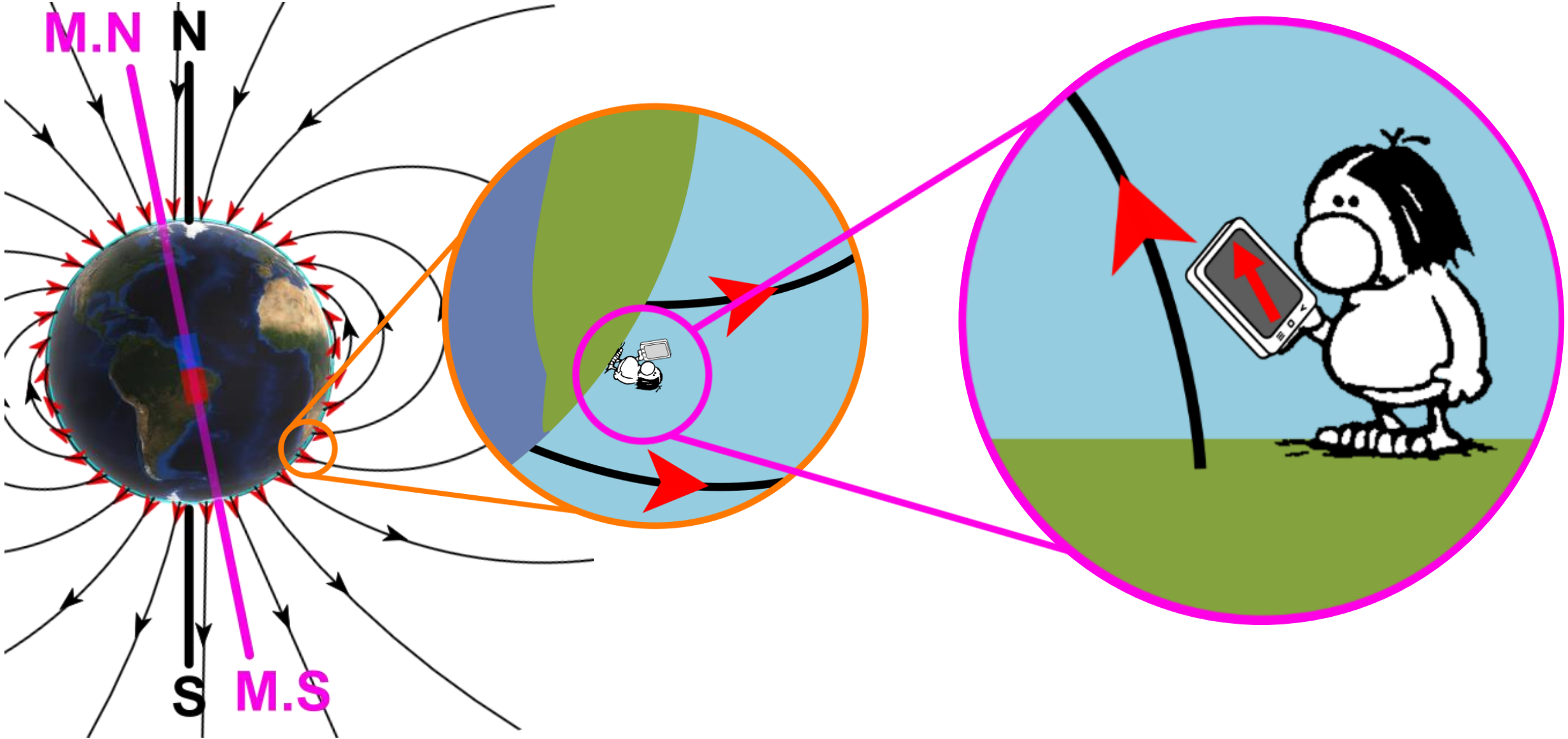
- In this room?
- How can we find it for ourselves?
- Is a compass enough?

What about the vertical component?





Earth's Magnetic Field: Global ↔ Local



Problem

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

Solution?

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

Aims

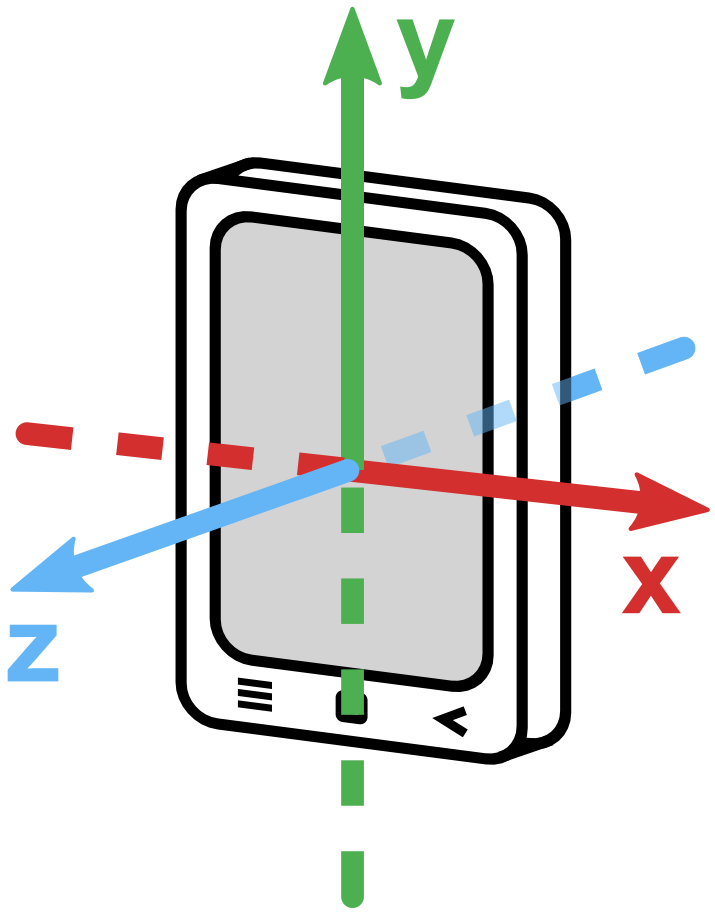
Design and test educational activities that

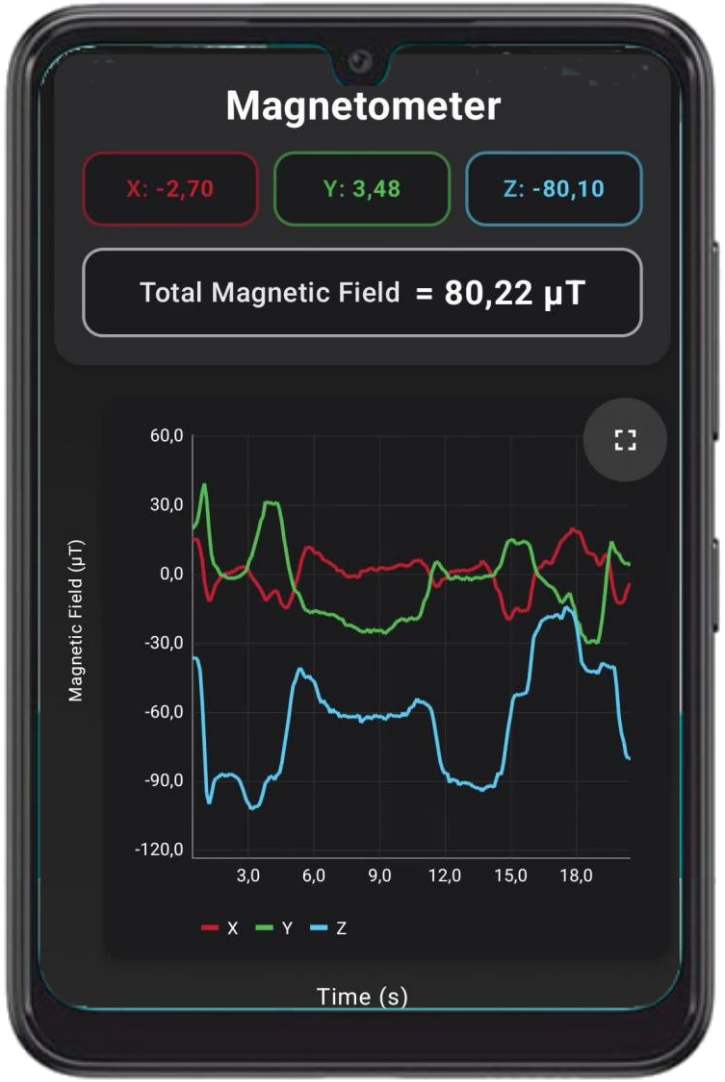
- Make use of smartphone sensors
- Use students' own smartphones
- Are suitable for self-guided learning
- Are aimed at a first-year level

Produce guides for

- Designing these activities
- Running these activities

Smartphone Sensor: Magnetometer (3D) + Application to use it





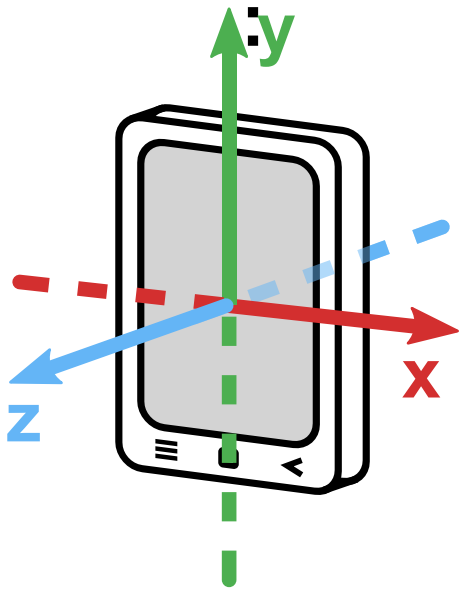
Physics Toolbox
Sensor Suite

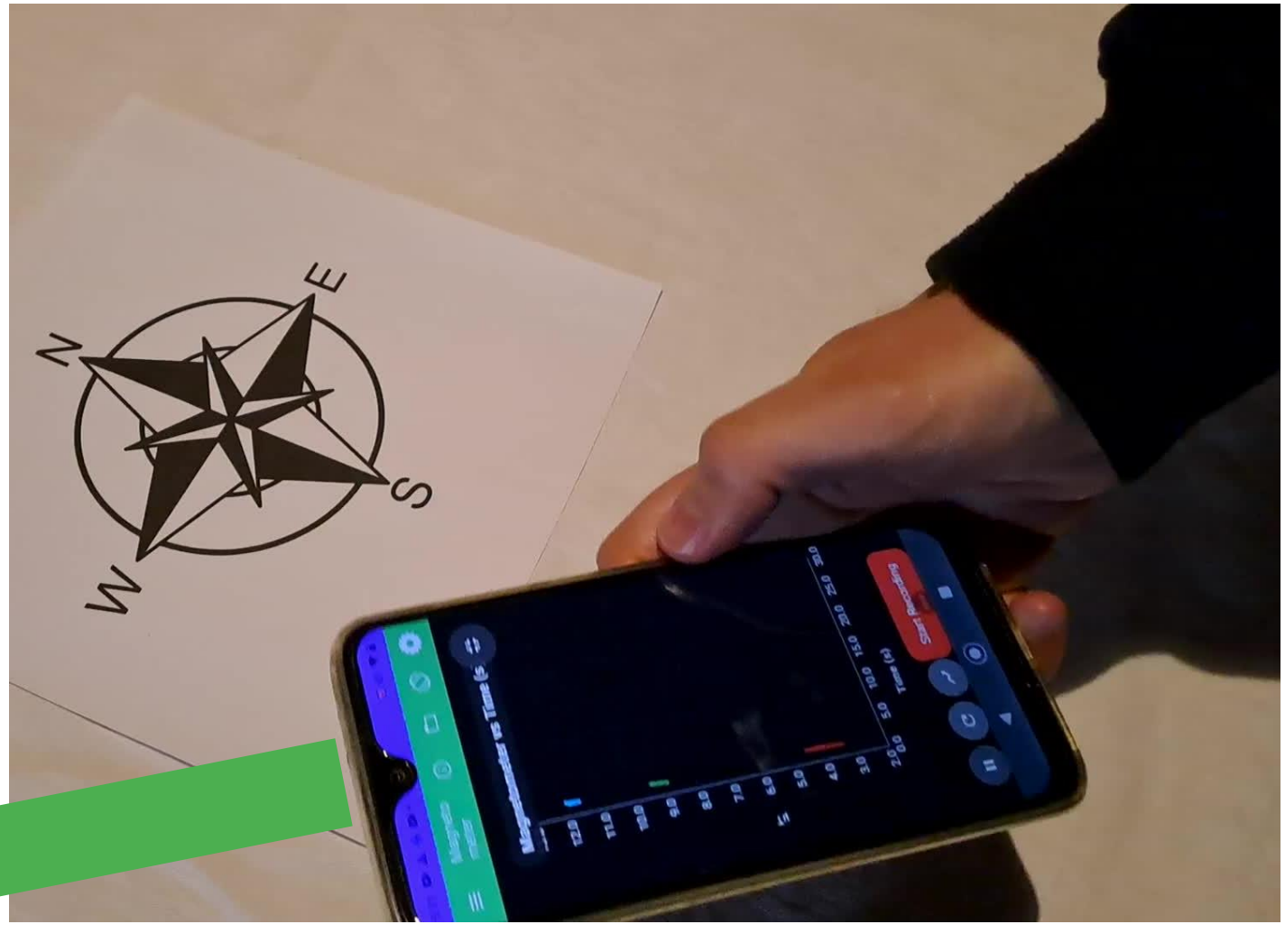
phyphox

Systematically Finding the Direction of the Earth's Magnetic Field

Goal: Point y axis in magnetic field direction

Method Zero-out **other** axes

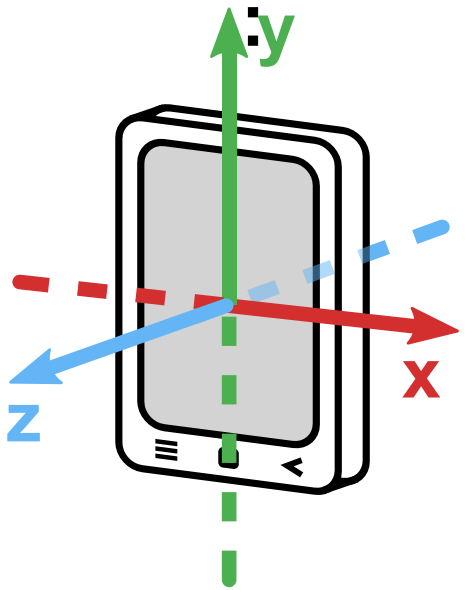


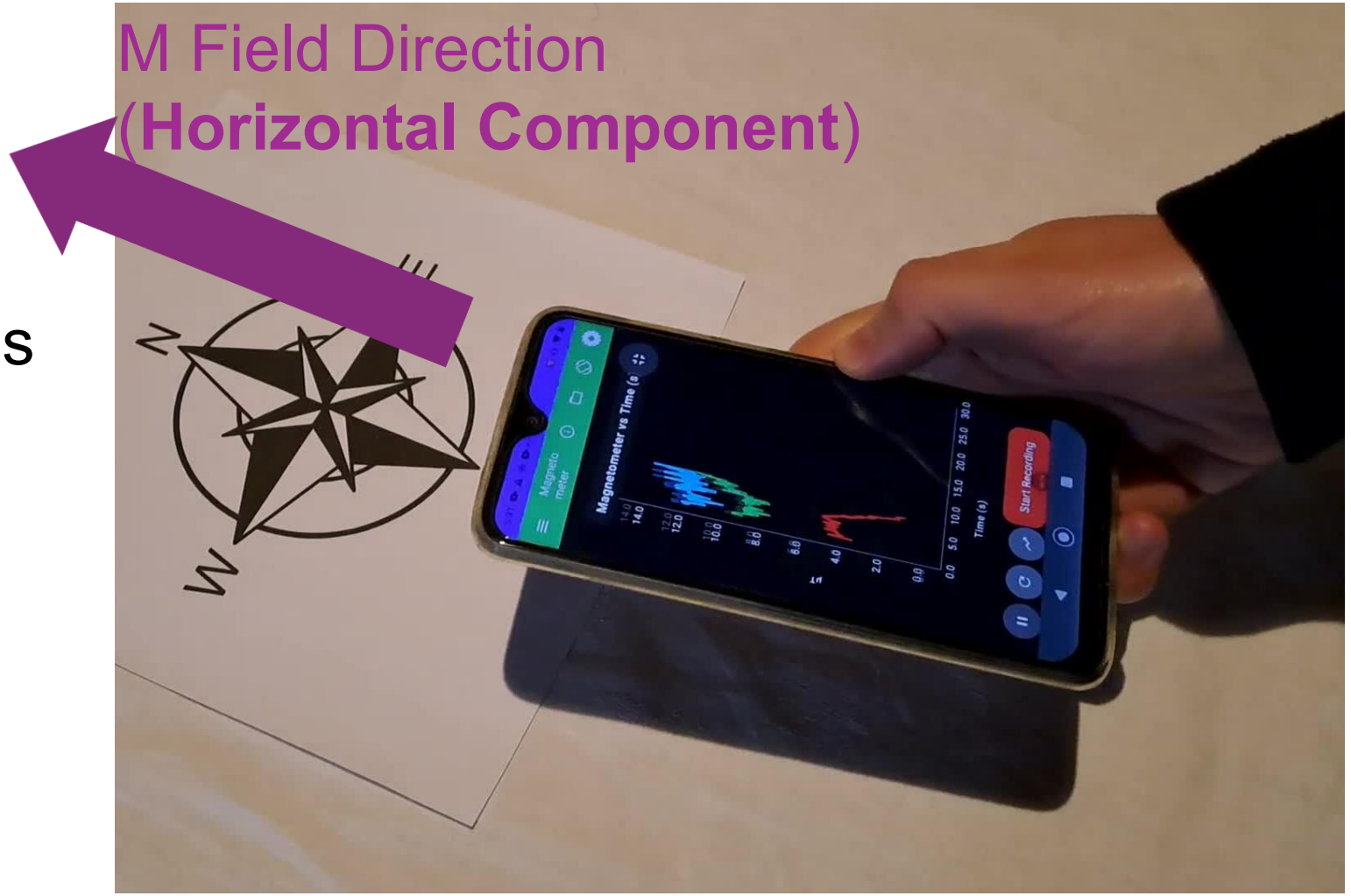


Systematically Finding the Direction of the Earth's Magnetic Field

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

Method Zero-out **other** axes

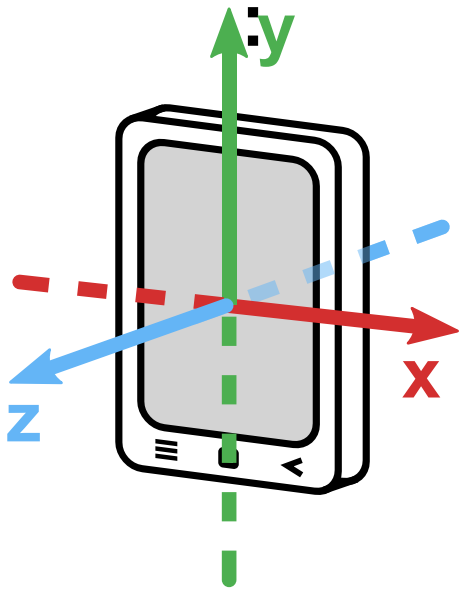


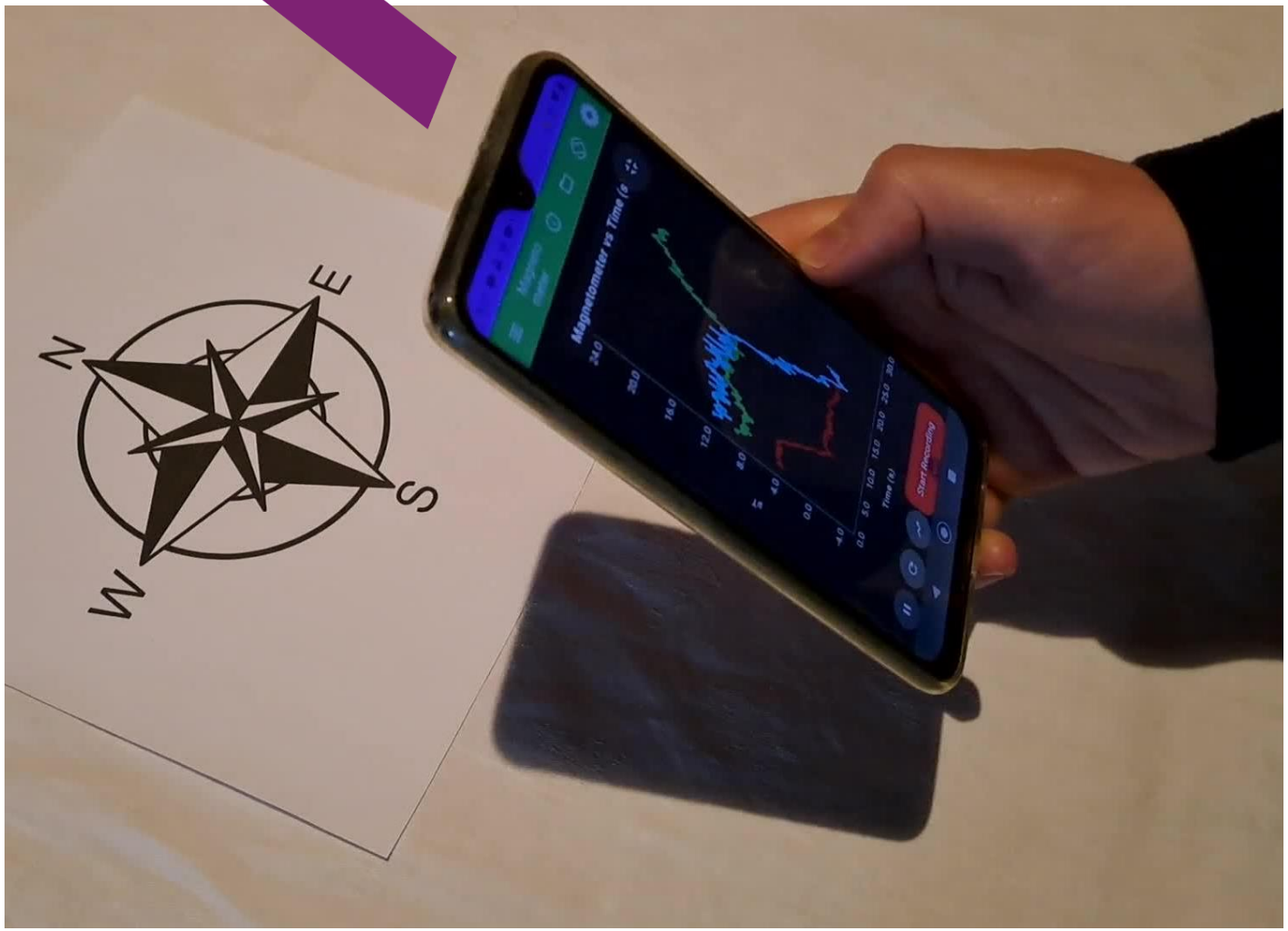


Systematically Finding the Direction of the Earth's Magnetic Field

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

Method Zero-out **other** axes



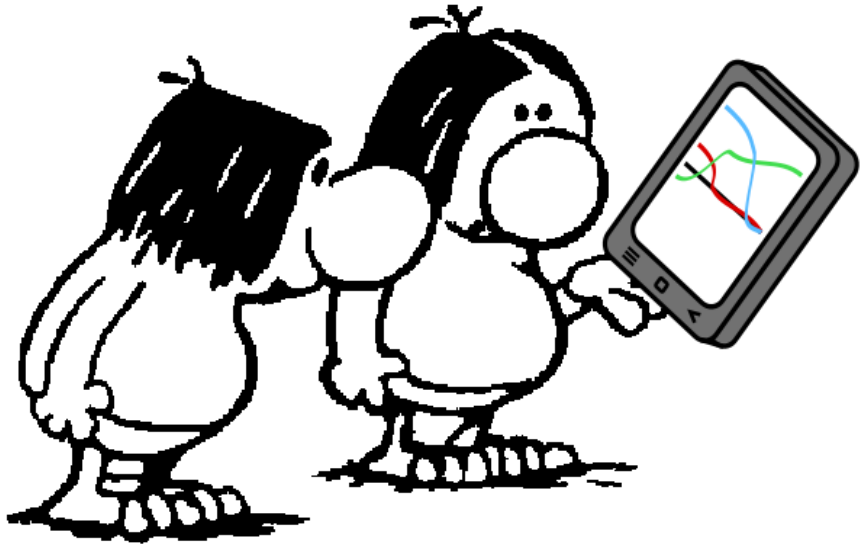


In the beginning…

Previous work:
Dedicated device
(Volkwyn, Airey et al. 2019)

VS

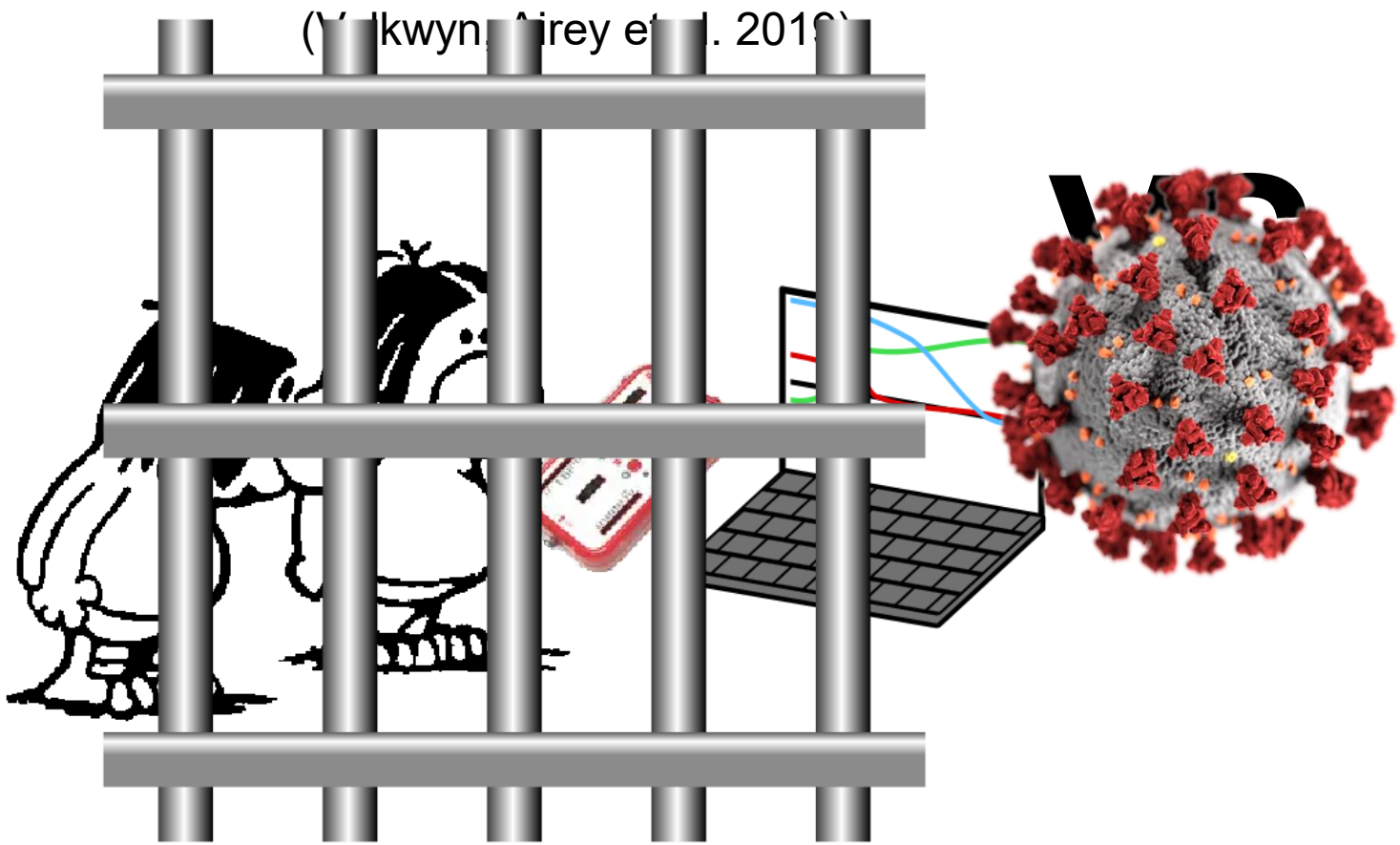
Compared to:
Students' smartphones



… but then …

Previous work: Dedicated device

(Volkwyn, Airey et al. 2019)



VS

Compared to: Students' smartphones

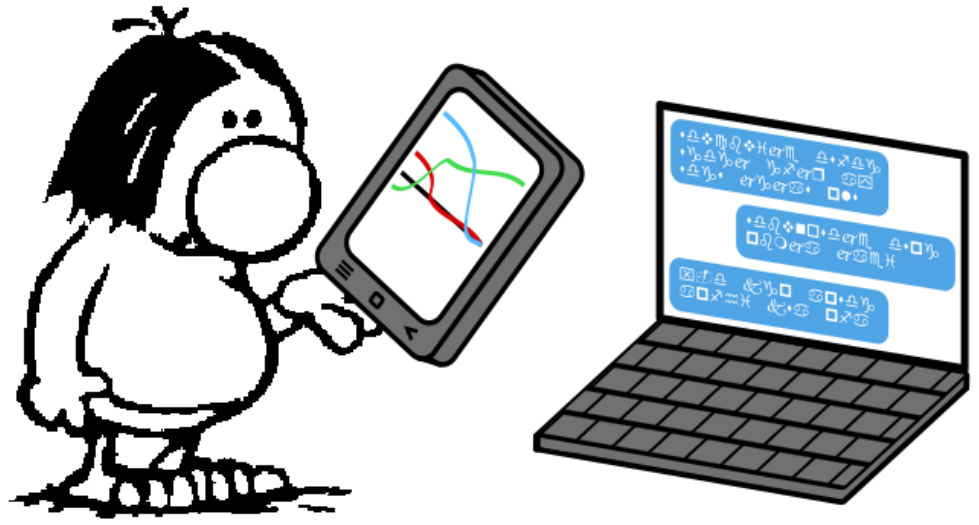
… but then …

Previous work:

Dedicated

(Volkwyn, Airey

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



Compared to:

' smartphones

It started with

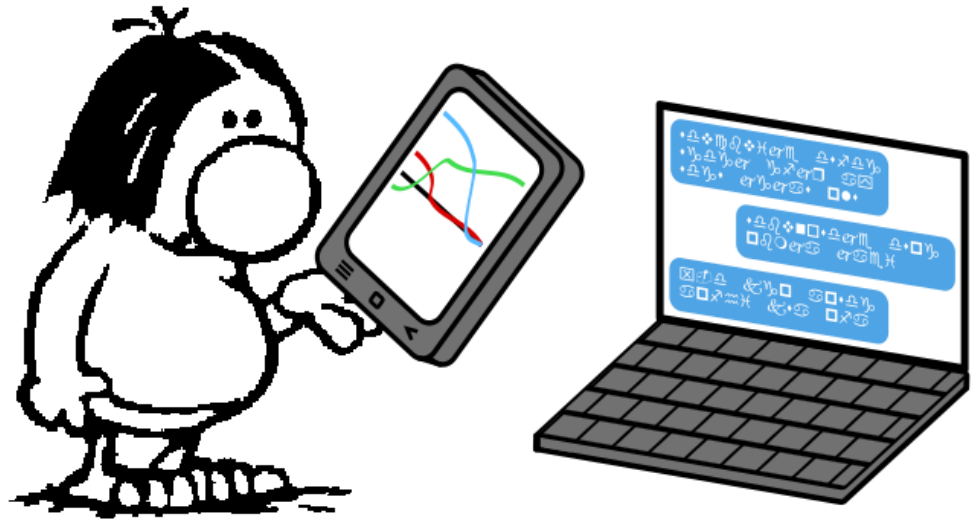
Masters

Previous work:

Dedicated

(Volkwyn, Airey

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



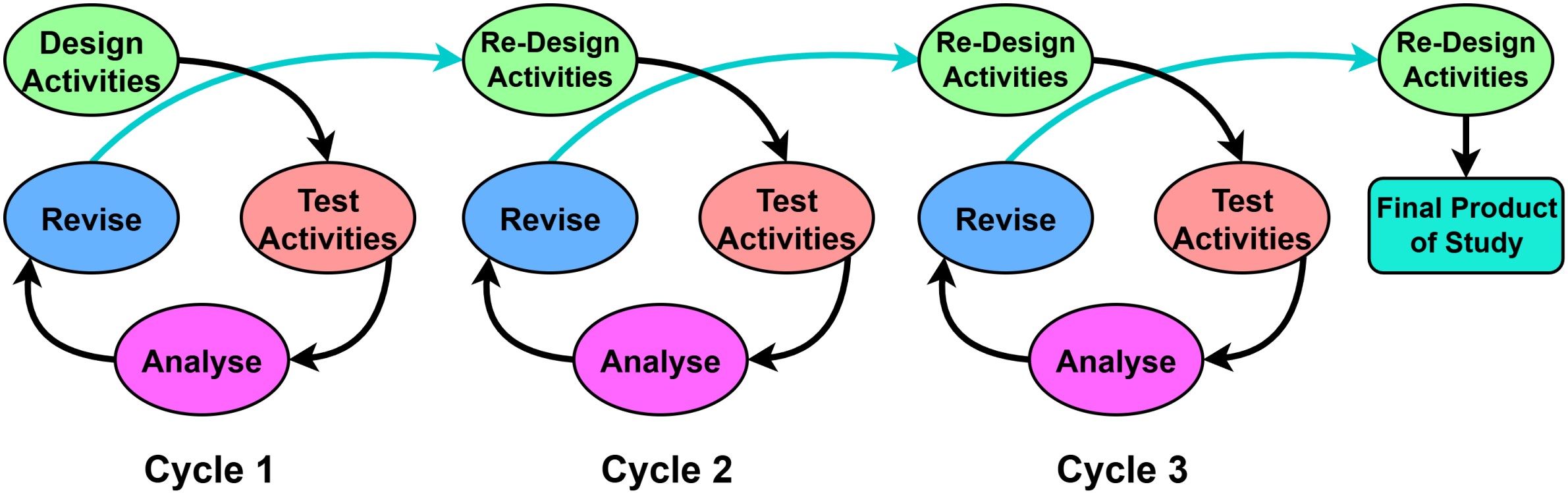
Compared to:

' smartphones

PhD

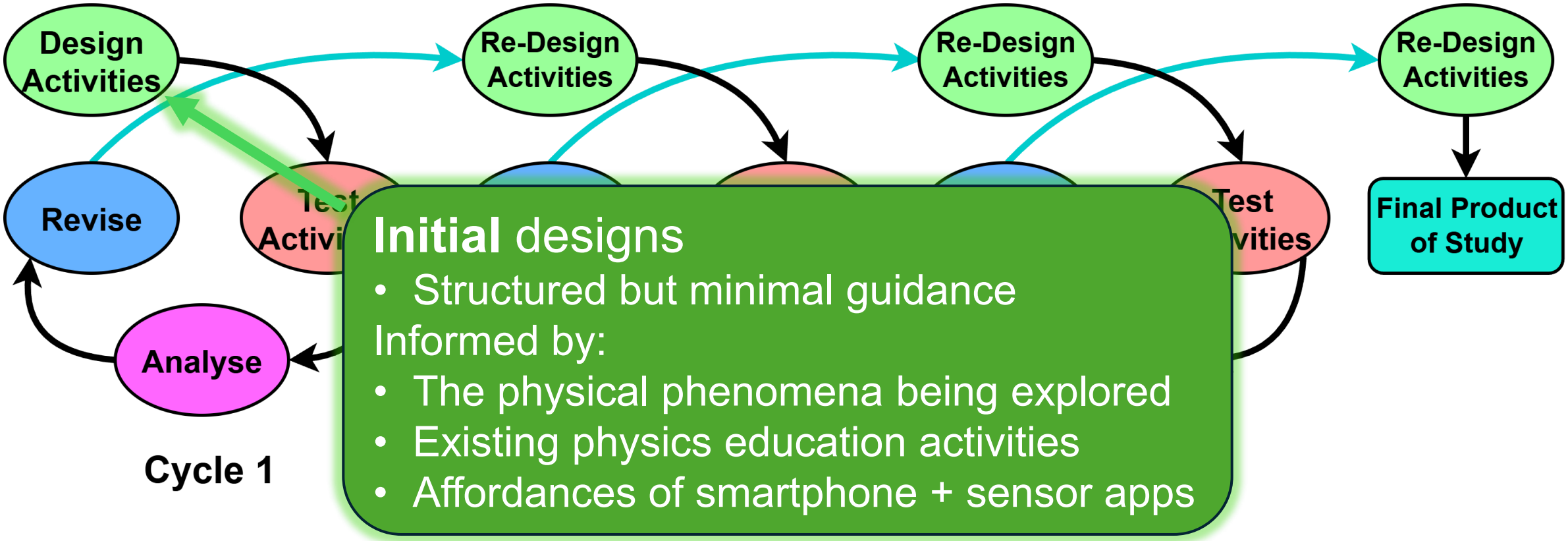
Design-Based Research Methodology

(Prediger, Gravemeijer et al. 2015)



Design-Based Research Methodology

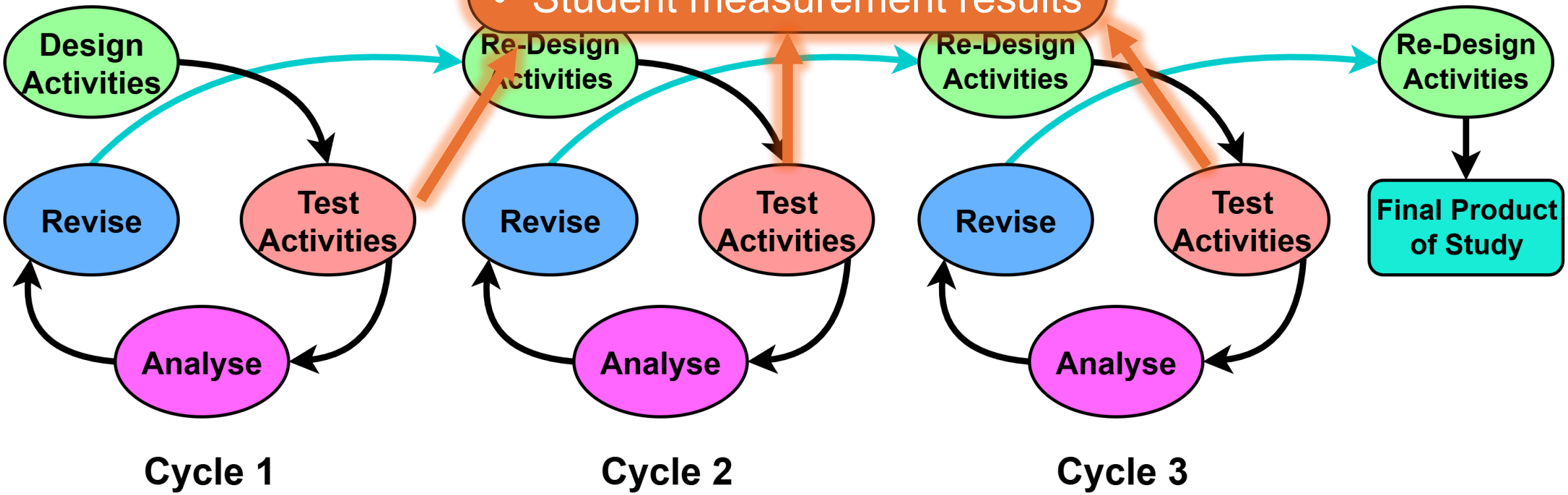
(Prediger, Gravemeijer et al. 2015)



Design-Based Research Methodology

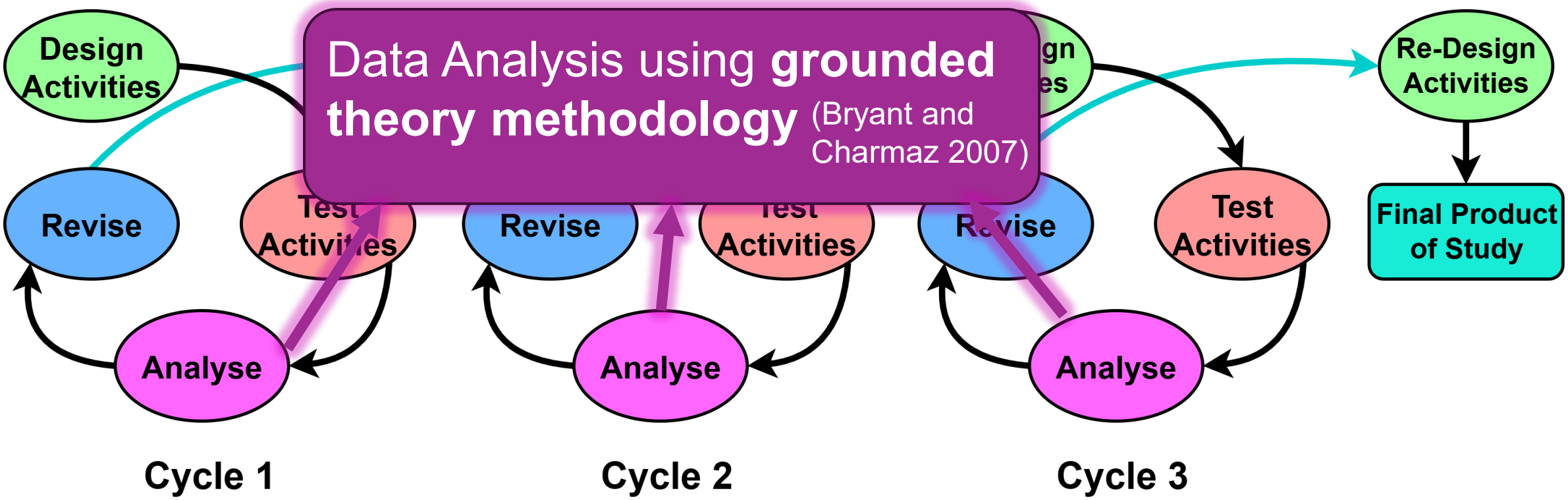
(Prediger, Gravemeijer et al. 2015)

Data
- Student written responses
- Observations of students
- Student measurement results



Design-Based Research Methodology

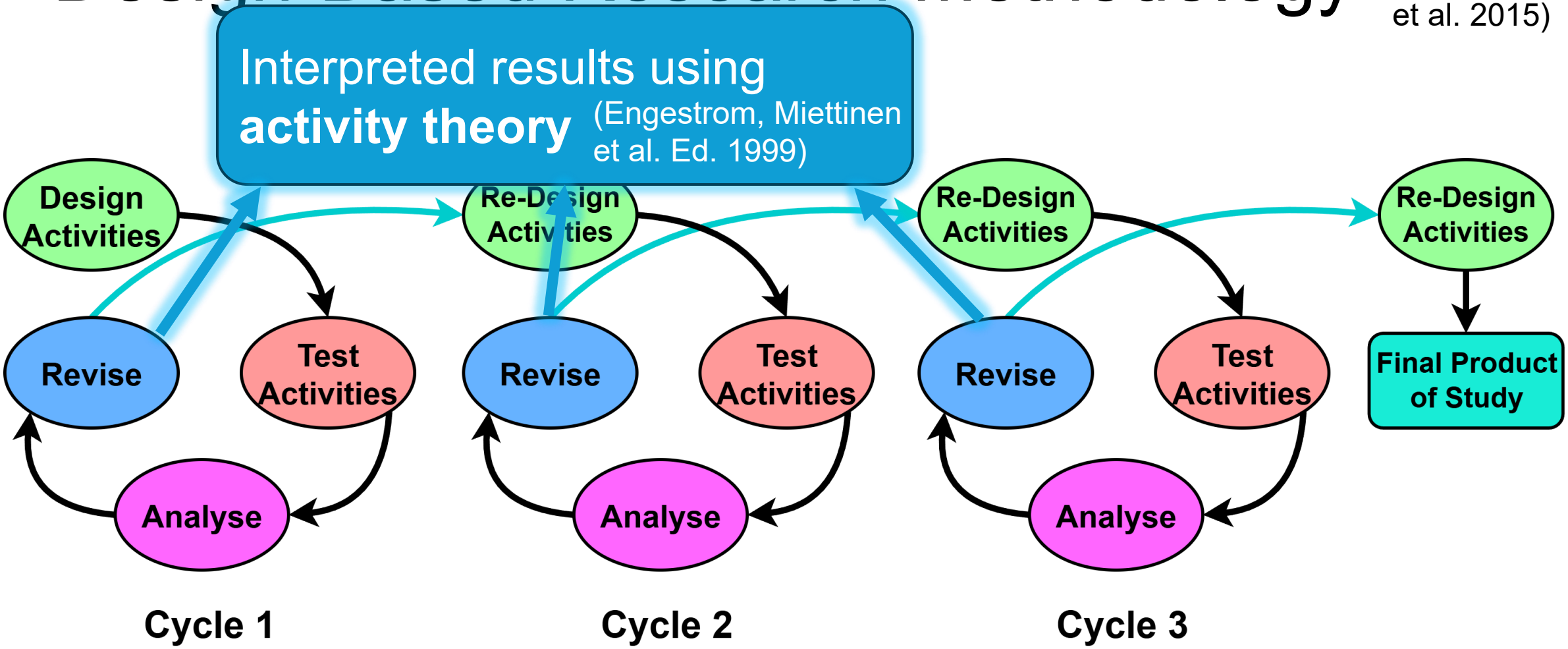
(Prediger, Gravemeijer et al. 2015)



Data Analysis using **grounded theory methodology** (Bryant and Charmaz 2007)

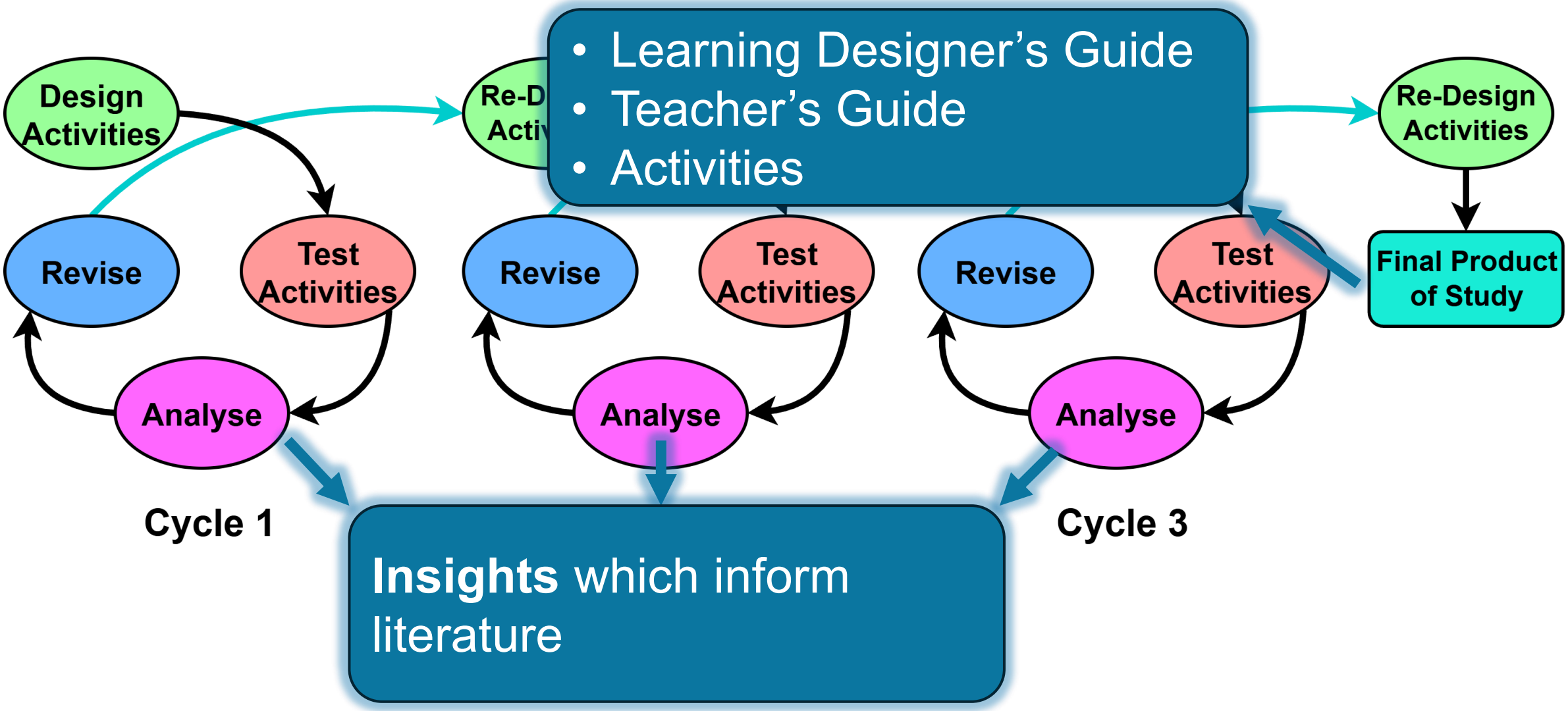
Design-Based Research Methodology

(Prediger, Gravemeijer et al. 2015)



Design-Based Research Methodology

(Prediger, Gravemeijer et al. 2015)



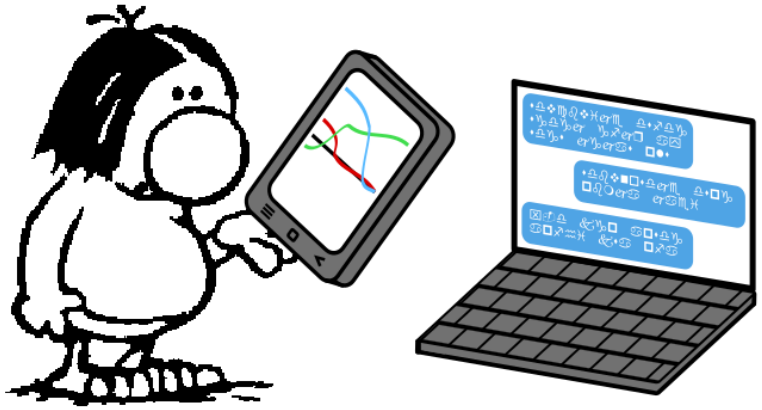
Design Cycle 1

6 Honours students
(PER module)

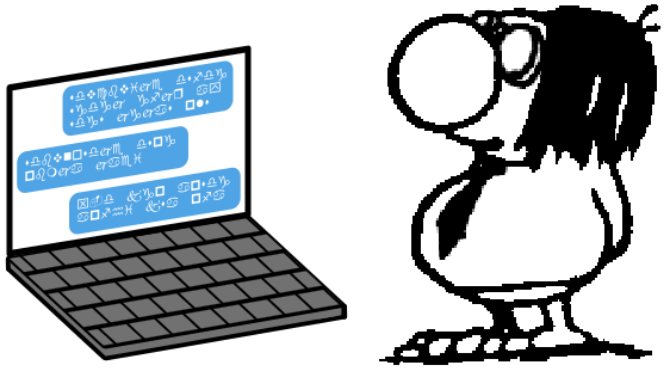
App (Physics Toolbox) used out-the-box

Activity instructions open-ended

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



At home | Individual work



Remote, asynchronous communication with instructor

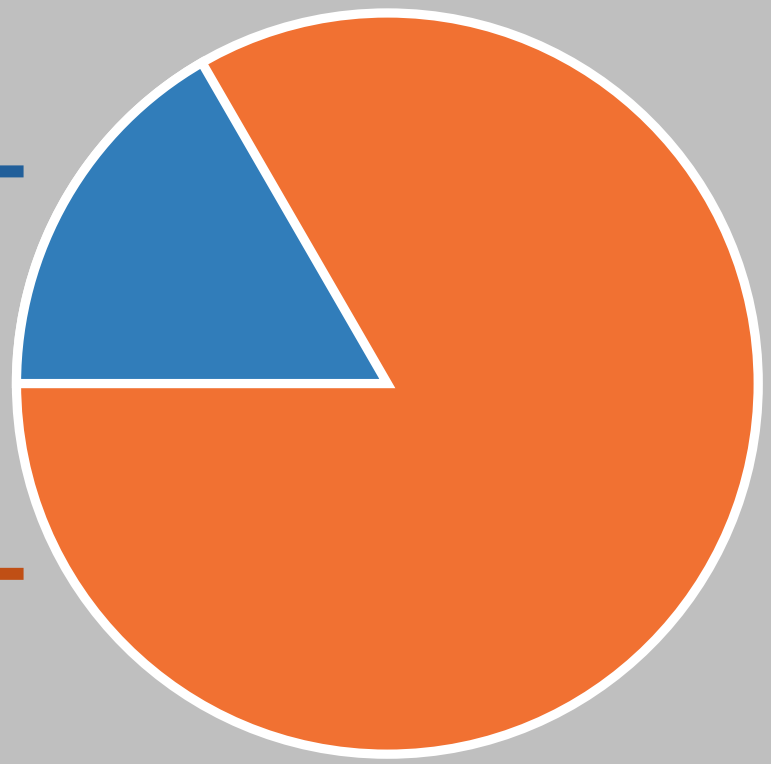
Design Cycle 1

6 Honours students
(PER module)

Results

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

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



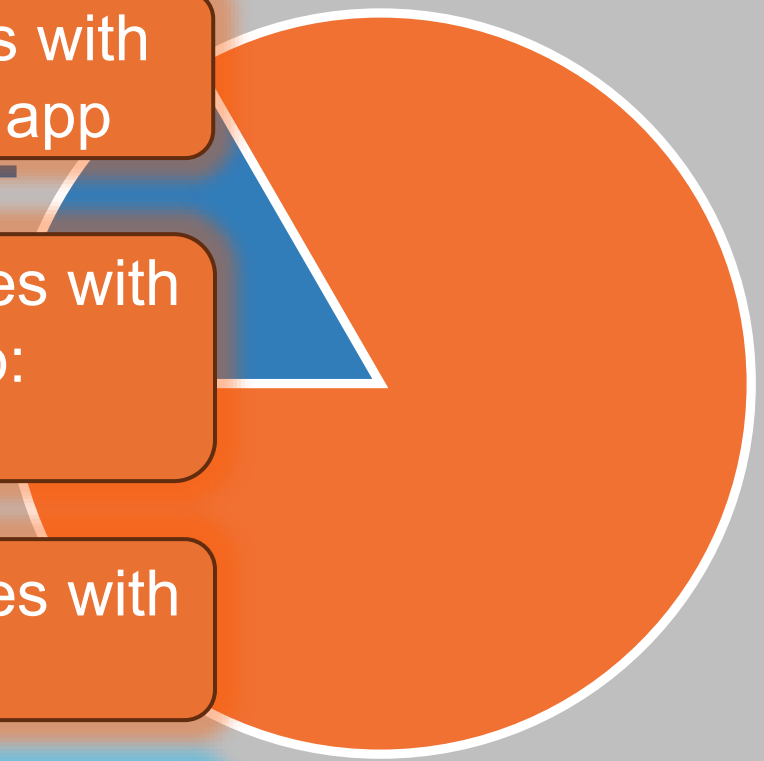
Design Cycle 1

6 Honours students
(PER module)

Results

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

Remaining **5 s**
found **horizon**
magnetic field direction



Technical difficulties with smartphones and app

Conceptual difficulties with phone and app:
3D axes

Conceptual difficulties with magnetic field

Conclusion: Guidance too limited

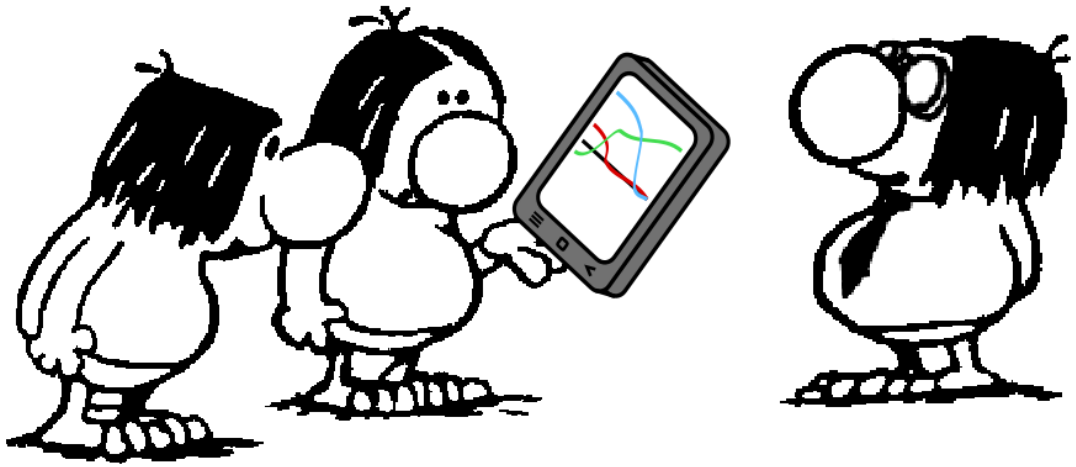
Design Cycle 2

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

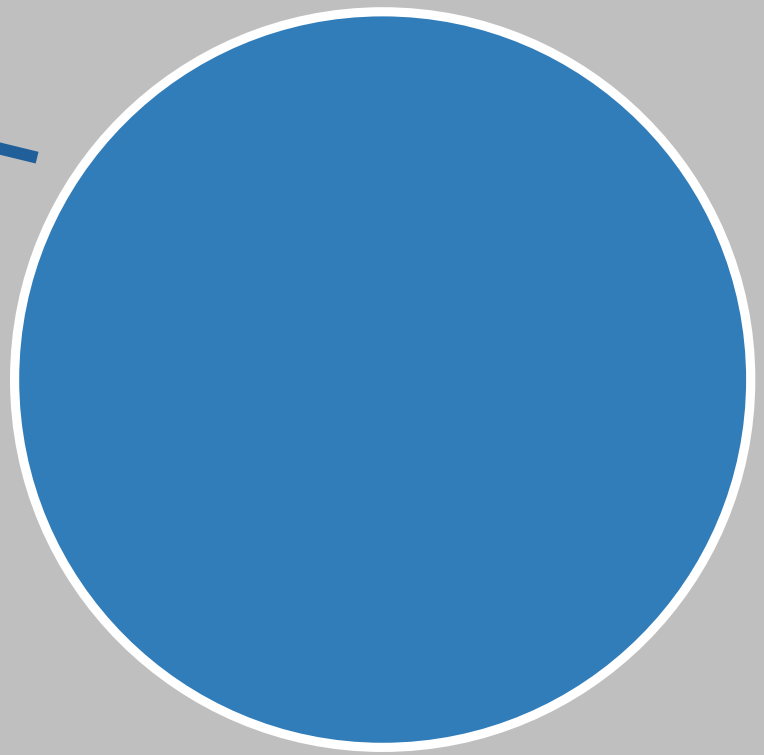
Design Cycle 2

8 Honours students
(PER module)

Results

All 8 students found **vertical** component for magnetic field direction

(though possible interference between groups)



Design Cycle 2

8 Honours students
(PER module)

Ap

Results

All 8 students
vertical comp
magnetic field

(though possible interference between groups)

Positive response to explanation of magnetometer and paper axes

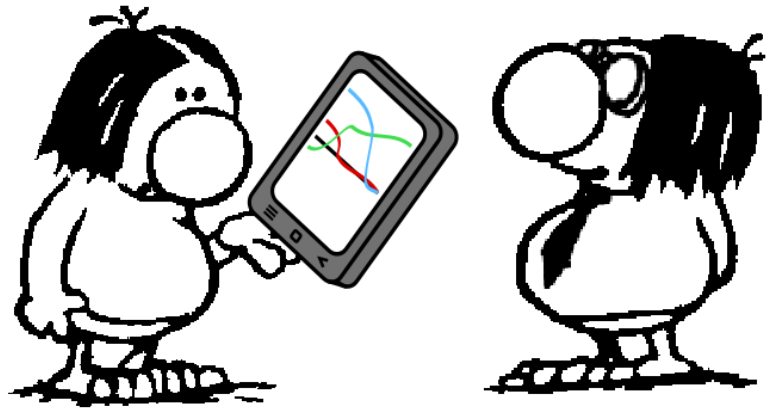
Insights into framing the methodology

Design Cycle 3

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

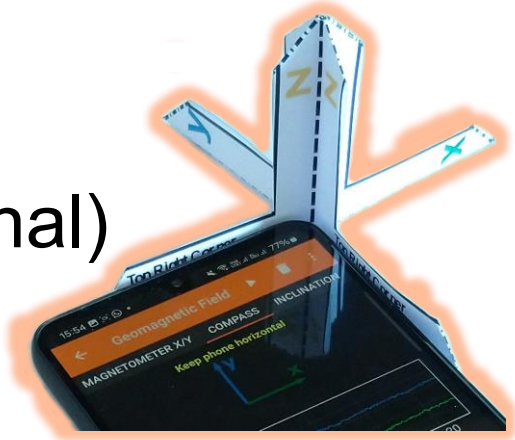
App (phyphox)
customised for activity

Activity instructions detailed
- Magnetometer sensor explained
- Methodology framed



In-person | Individual work
Instructor present

Paper
axes
(optional)



Design Cycle 3

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

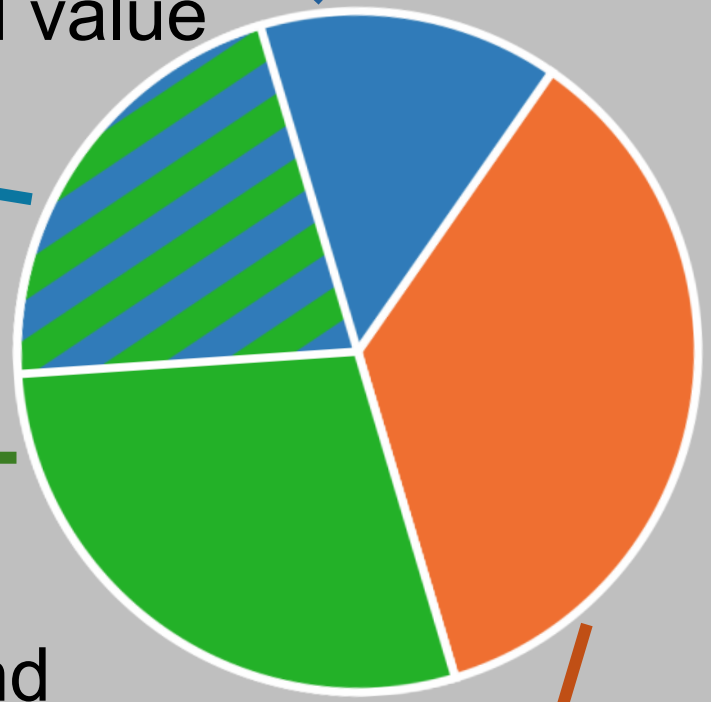
Results

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

3 students did **both**

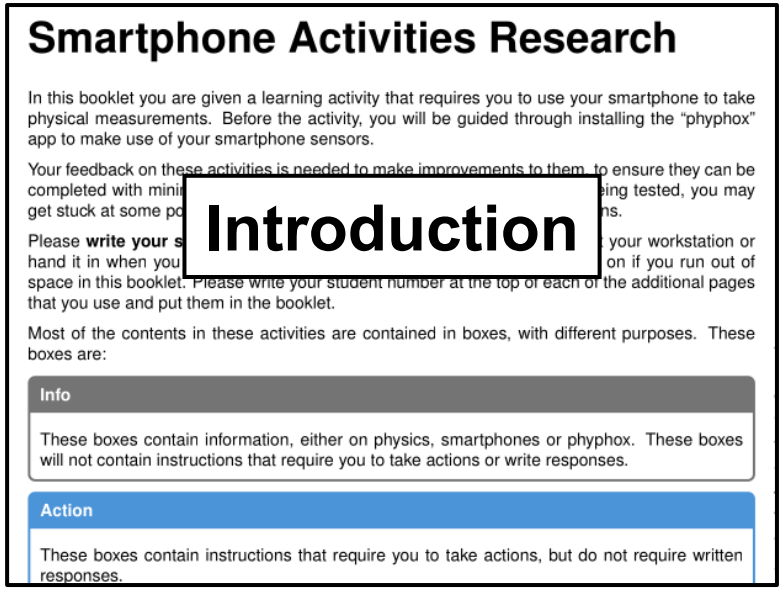
7 students described **vertical** component for magnetic field direction

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



Design Cycle 3 - Activity

Booklet »



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 mini ing tested, you may get stuck at some po ns.

Please **write your s** your workstation or hand it in when you on if you run out of space in this 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

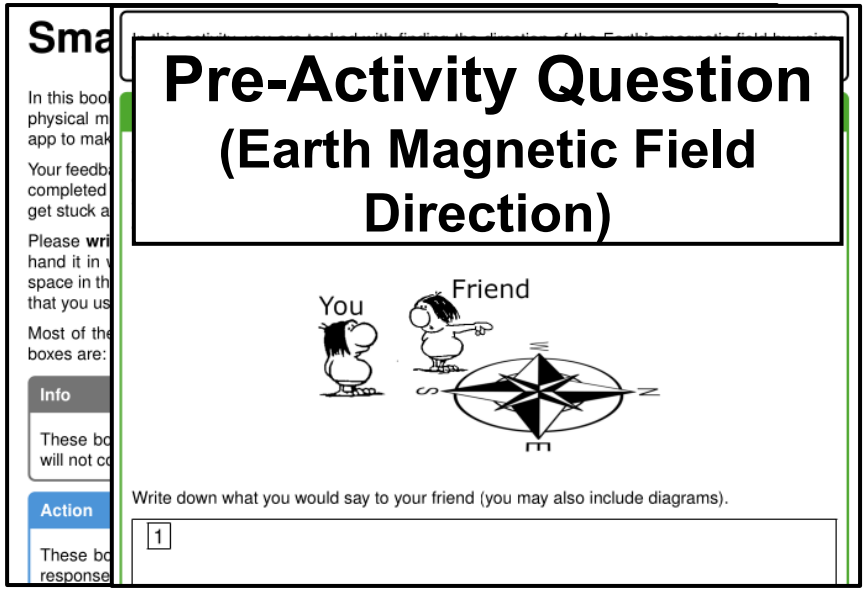
These boxes contain instructions that require you to take actions, but do not require written responses.

Introduction

App»

Design Cycle 3 - Activity

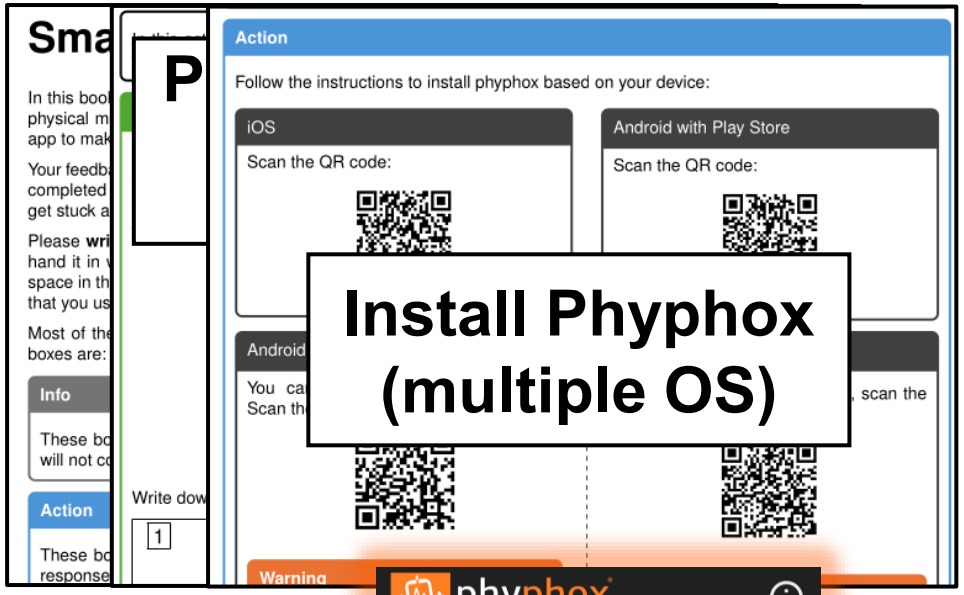
Booklet »



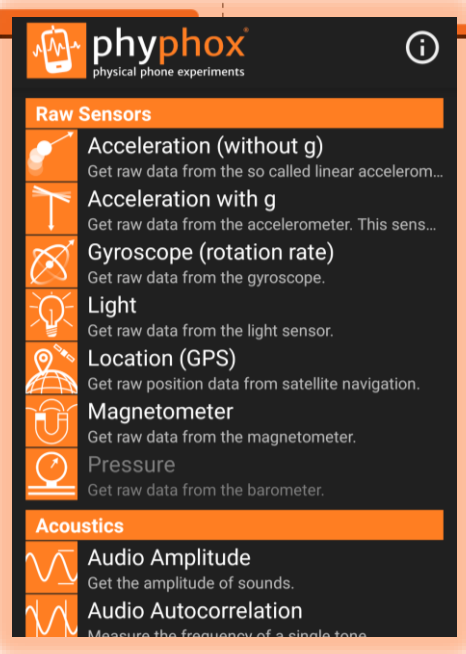
App»

Design Cycle 3 - Activity

Booklet »

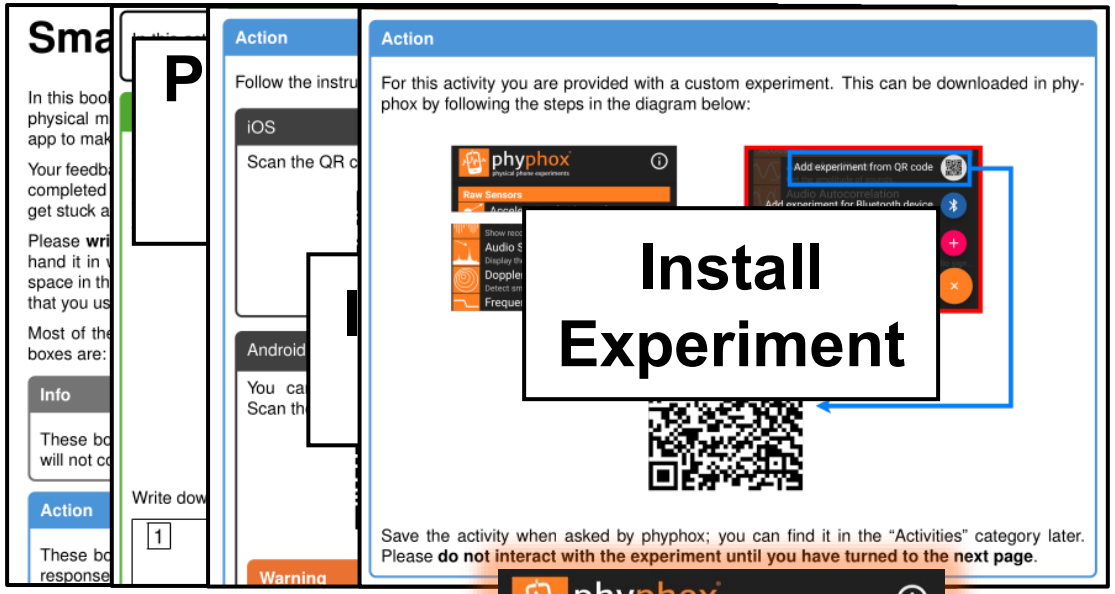


App»

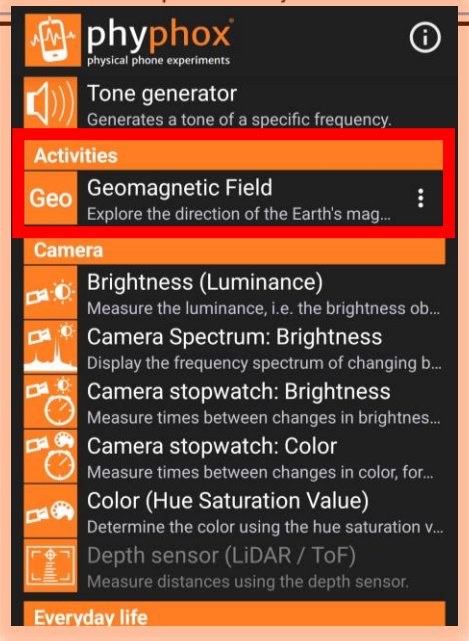


Design Cycle 3 - Activity

Booklet »

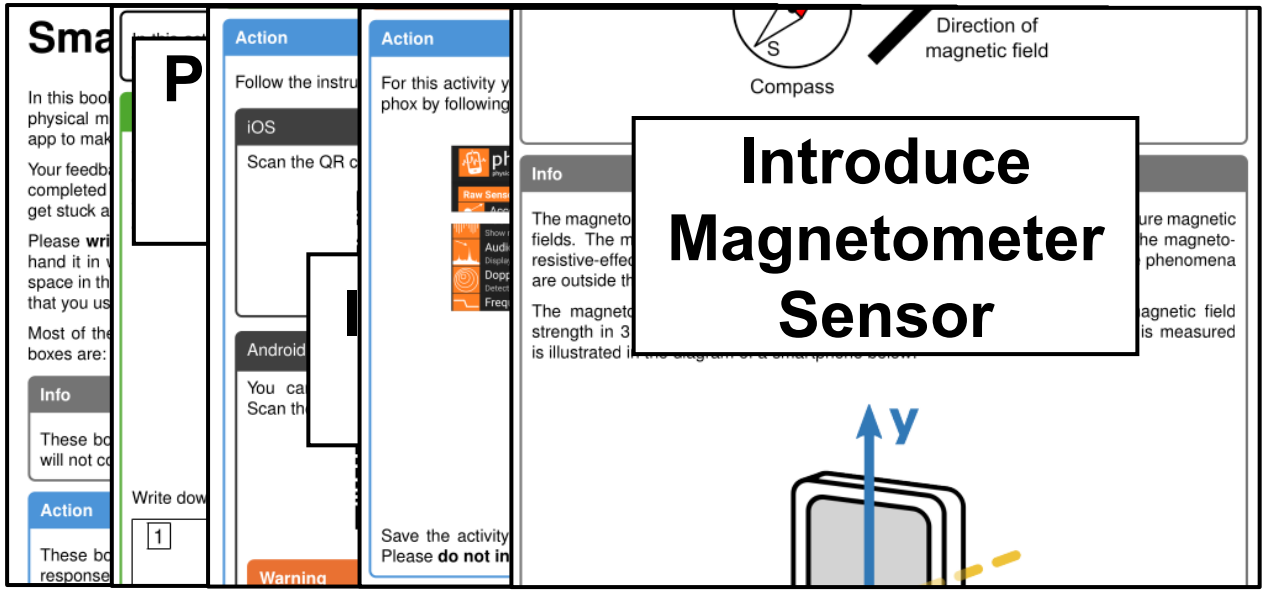


App»



Design Cycle 3 - Activity

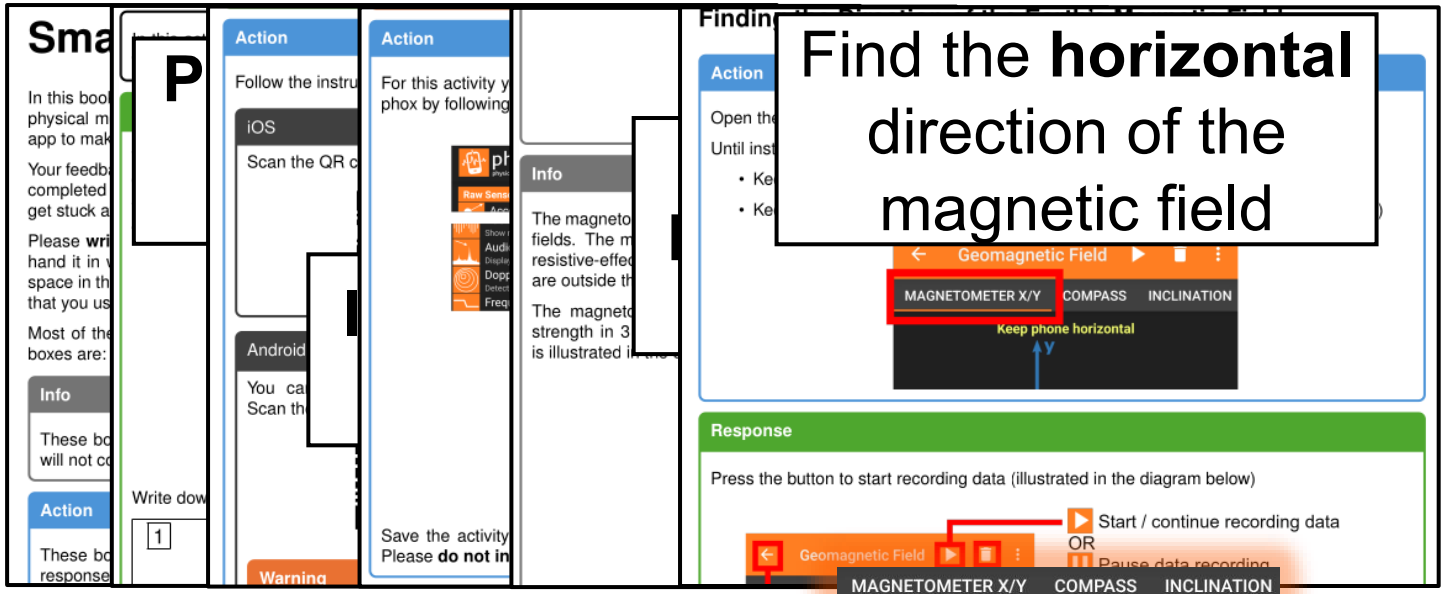
Booklet »



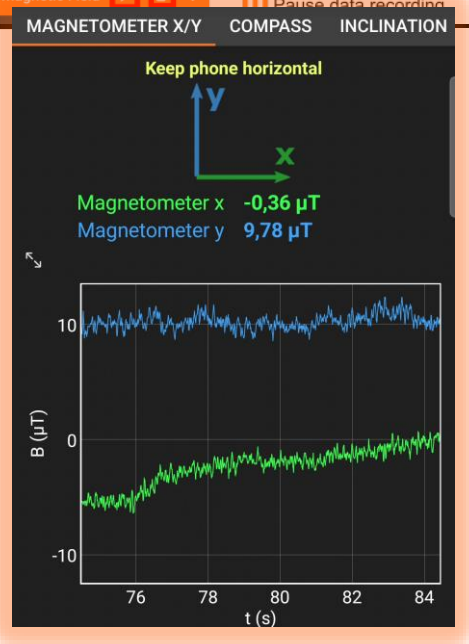
App»

Design Cycle 3 - Activity

Booklet »

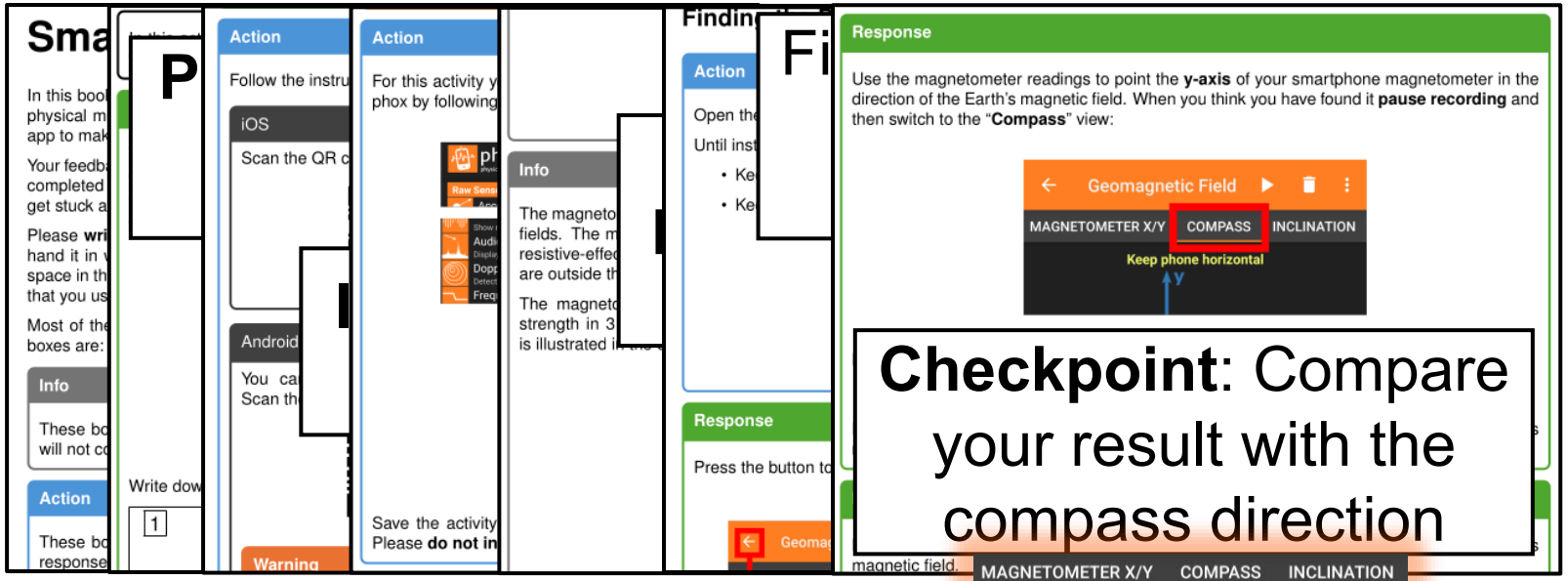


App»



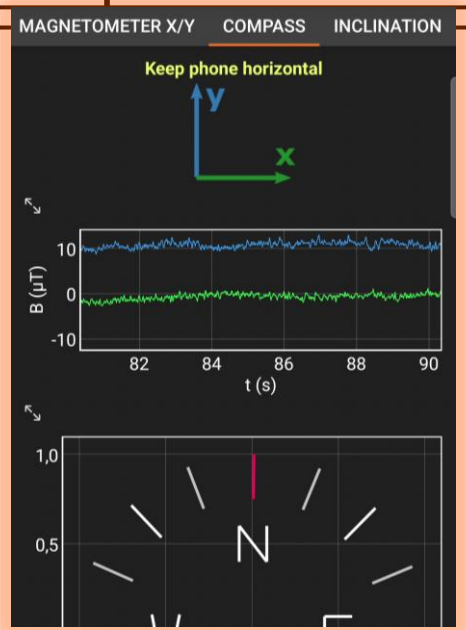
Design Cycle 3 - Activity

Booklet »



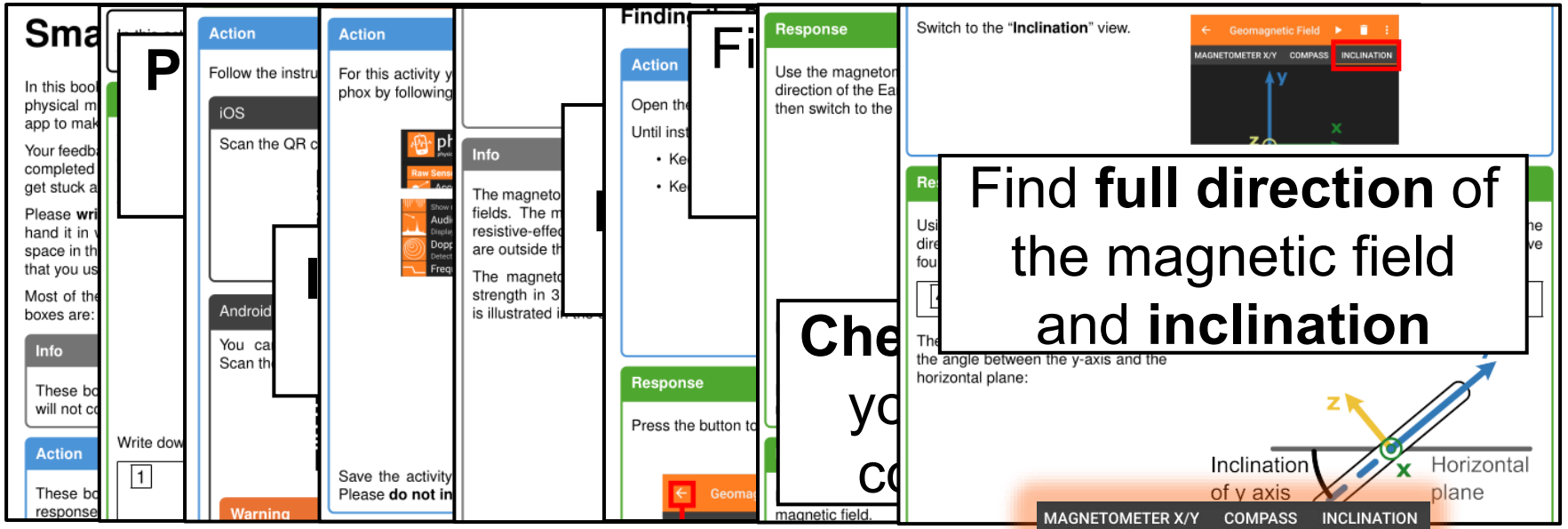
Checkpoint: Compare your result with the compass direction

App»

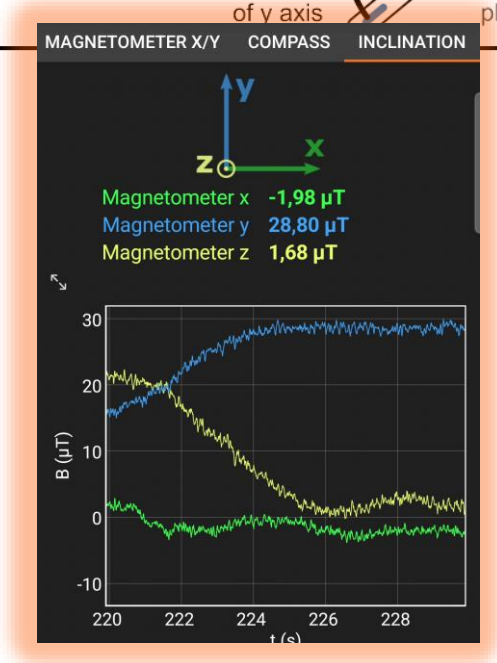


Design Cycle 3 - Activity

Booklet »

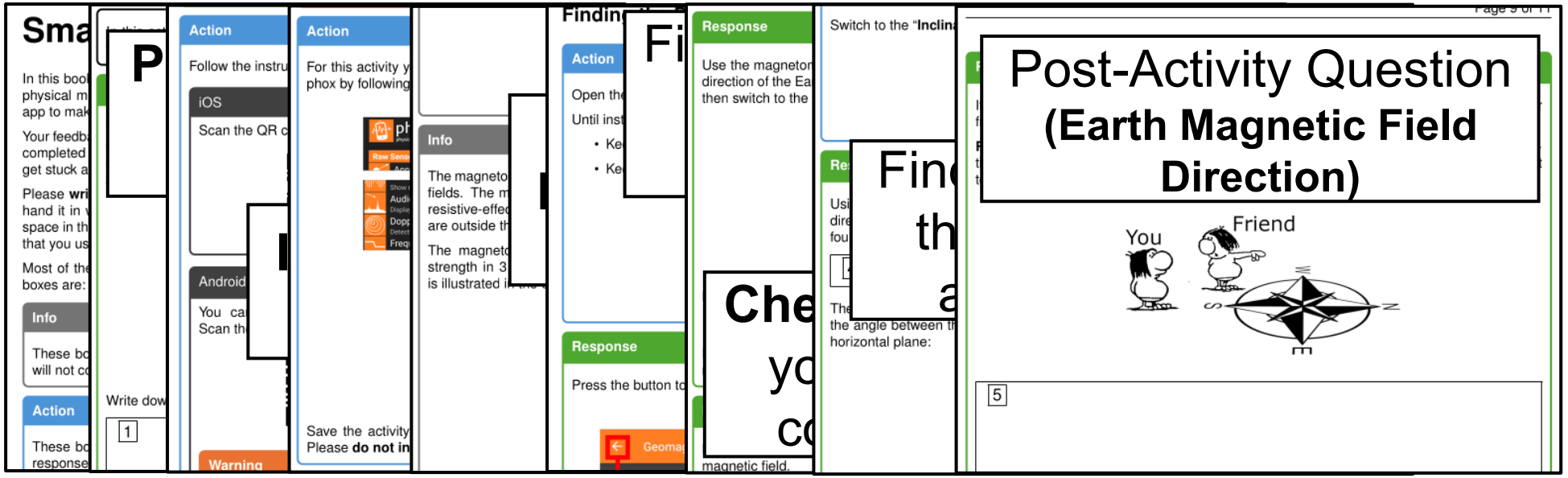


App»



Design Cycle 3 - Activity

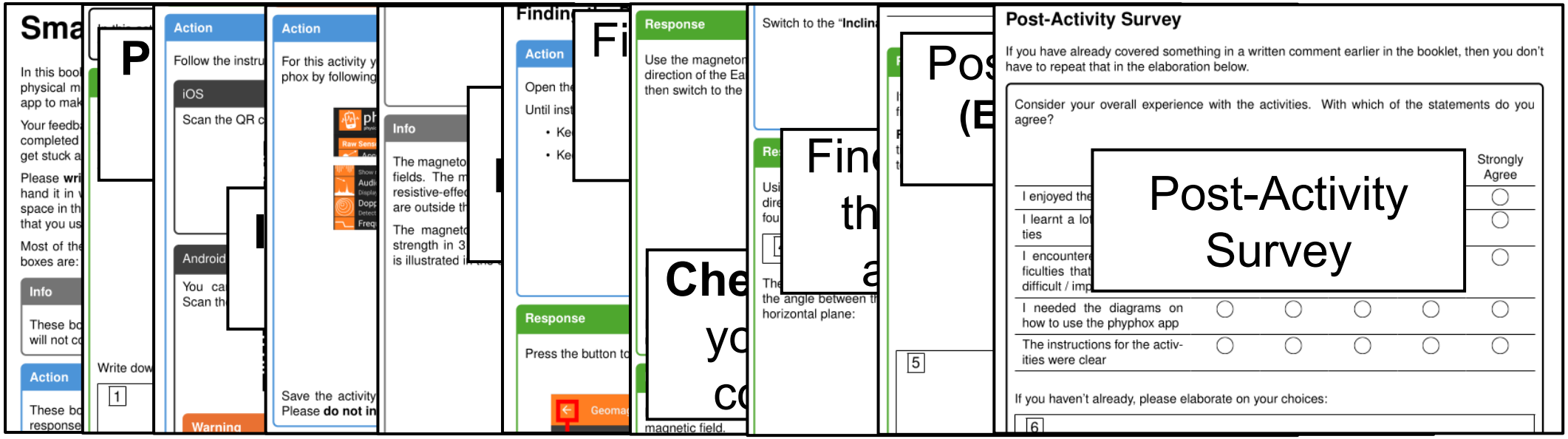
Booklet »



App»

Design Cycle 3 - Activity

Booklet »



App»

Design Cycle 3 - Activity

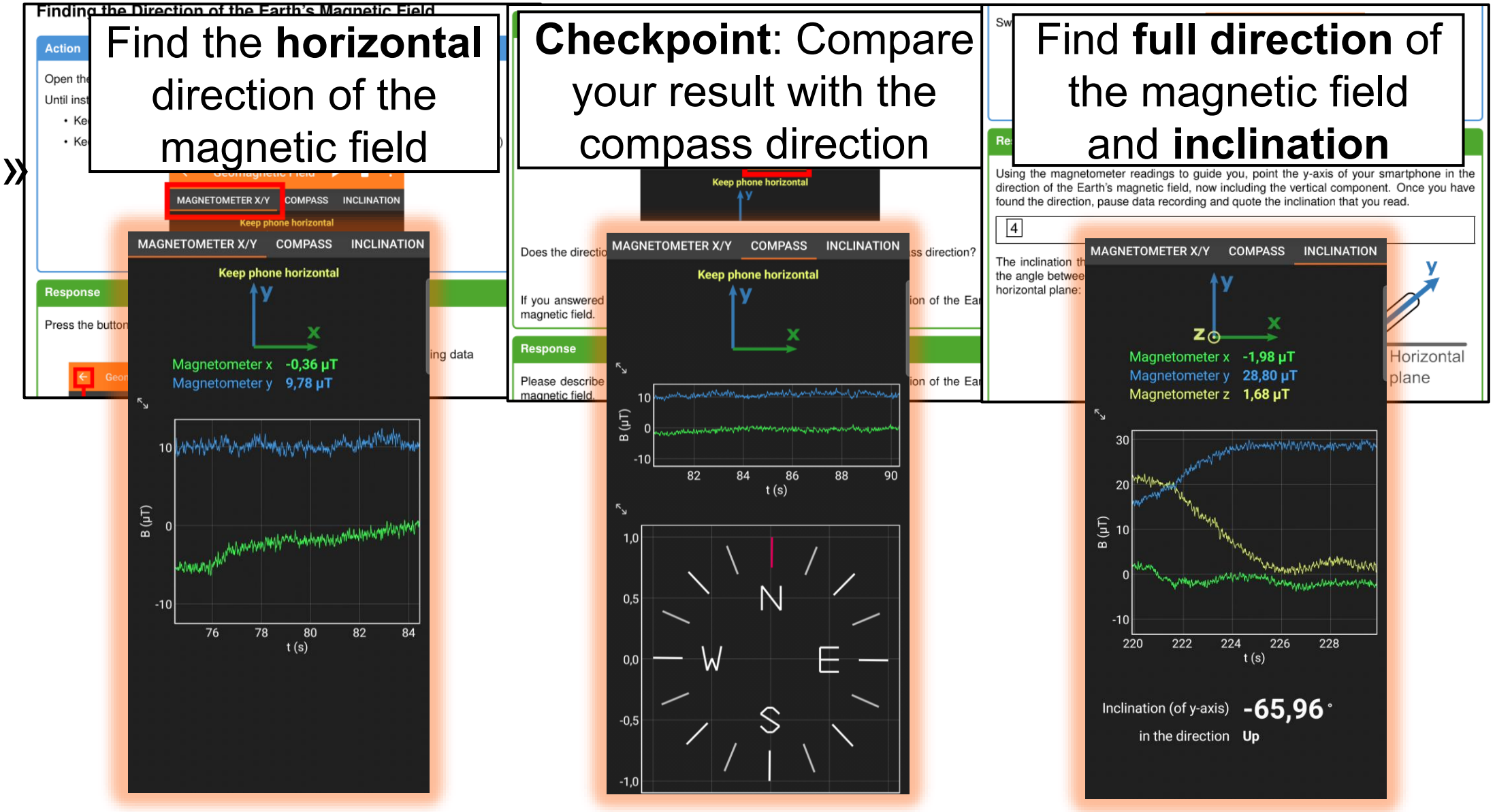
Booklet »

App»

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

Checkpoint: Compare your result with the compass direction

Find **full direction** of the magnetic field and **inclination**



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

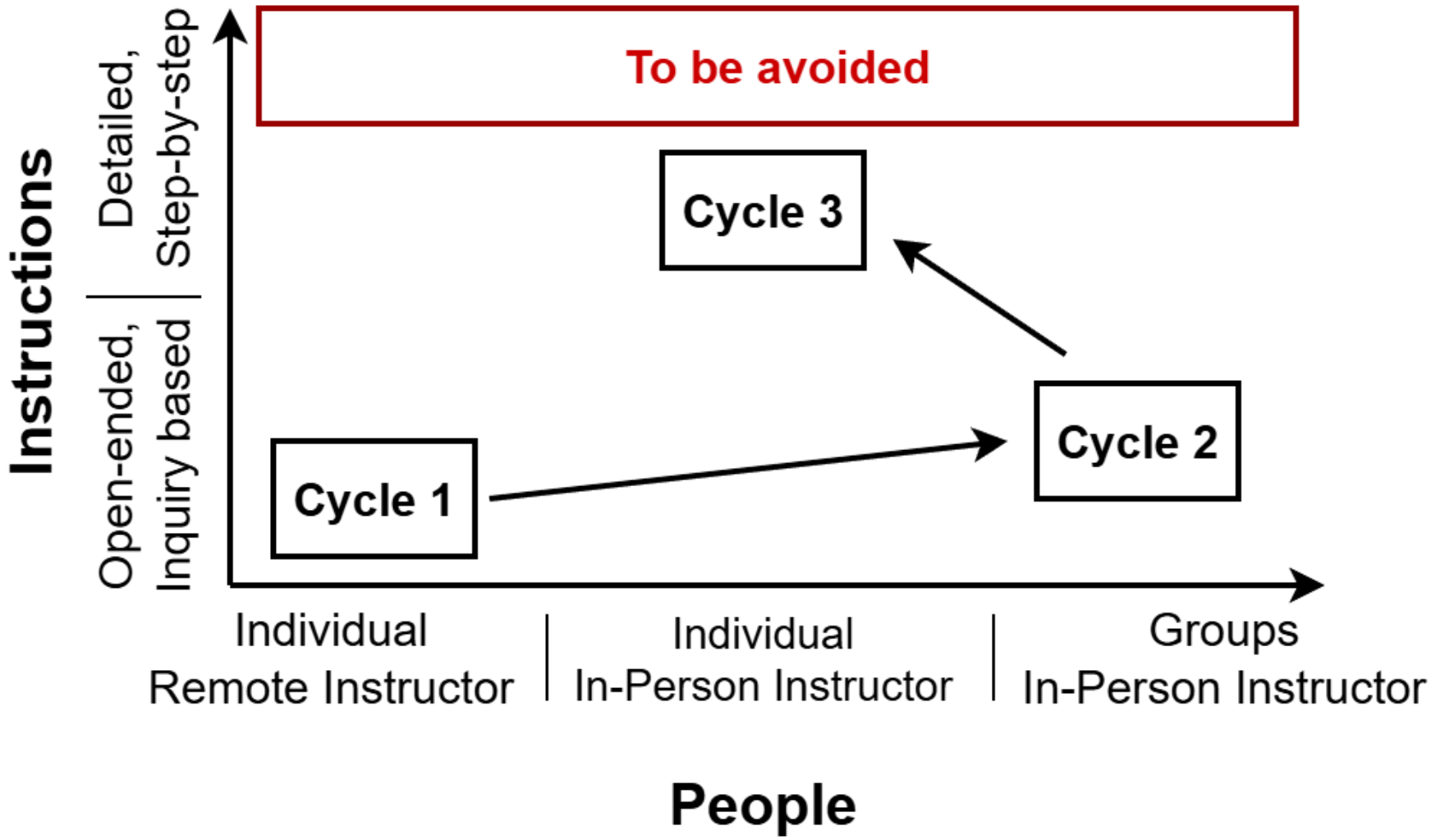
- Even honours students had conceptual difficulties when given **limited guidance**
- Conceptual difficulties with:
  - The apps / smartphone / sensors

  (e.g. **3D axes** – not communicated well in apps)
  - The Earth's magnetic field (physics concept)

Challenges Communicating Orientation

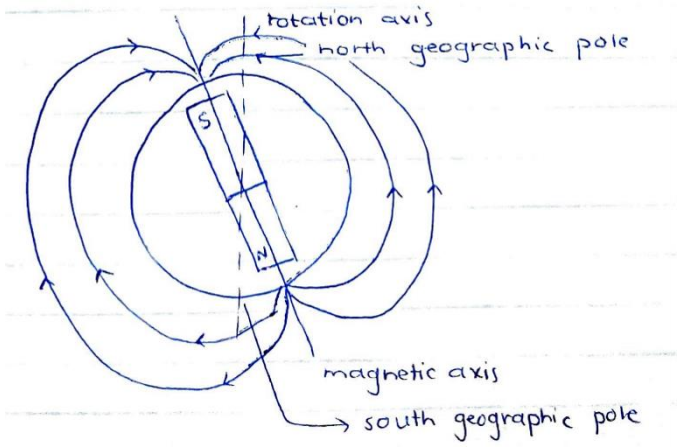
- Describing orientation of smartphone / 3D direction can be challenging
  - **Reference frame** required
  - Instructions may use videos or diagrams
  - Measure **magnetic inclination** instead of 3D direction
- Students **used wide range of terminology** to describe orientating their smartphone
  - 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. Heijkenskjöld (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?

↓ These slides ↓

Email me:
stymay001@myuct.ac.za

LinkedIn
https://www.linkedin.com/in/mayhew-steyn