



TRAINME3

TVET lecturer training in mechatronics, energy & water management, renewable energies



Überbetriebliches
Bildungszentrum
in Ostbayern



University of Stuttgart
Germany



higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

Funded by:



Federal Ministry
for Education, Family Affairs, Senior Citizens,
Women and Youth

UNIT IV

Technical Experiments

Course Presentation

TRAINME 3

MODULAR TRAINING AND FURTHER EDUCATION
OF SOUTH AFRICAN TVET LECTURERS

IN THE FIELDS OF MECHATRONICS, ENERGY AND WATER
MANAGEMENT AND RENEWABLE ENERGIES



EDITING

Academic Guidance: Prof. Dr. Bernd Zinn,
University of Stuttgart (Dept. BPT)

Author & Layout: Simon Kammeyer M.Sc.
University of Stuttgart (Dept. BPT)

Research Assistants: Emilia Espinosa Niemann B.Sc.
University of Stuttgart (Dept. BPT)
Lennart Brinkmann B.Eng.
University of Stuttgart (Dept. BPT)

Edition: 2nd

This presentation has been developed within the bilateral program TRAINME 3 - Modular training and further education of South African TVET lecturers in the fields of mechatronics (MT), energy and water management (EWM), and renewable energies (RE). The program was designed by the University of Stuttgart, Department of Vocational Education focused on Teaching Technology (BPT) and the Inter-Company Training Center in Easter Bavaria (ÜBZO) on behalf of the German Federal Ministry for Education, Family Affairs, Senior Citizens, Women and Youth (BMFSFJ), in cooperation with the South African Department of Higher Education (DHET).



© 2026. This work is openly licensed via [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/).

Cite as: Kammeyer, S. H. (2026). *TRAINME 3 Unit IV: Technical Experiments: Course Presentation*. Department of Vocational Education Focused on Teaching Technology, Institute of Educational Science, University of Stuttgart.



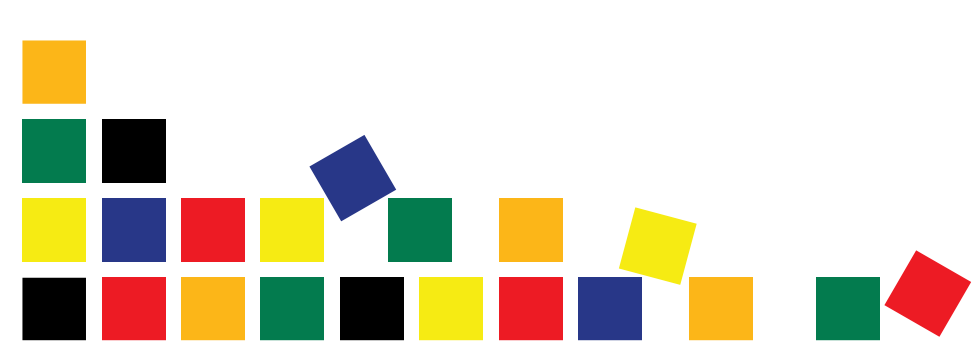
Funded by:



Version: 10 June 2026

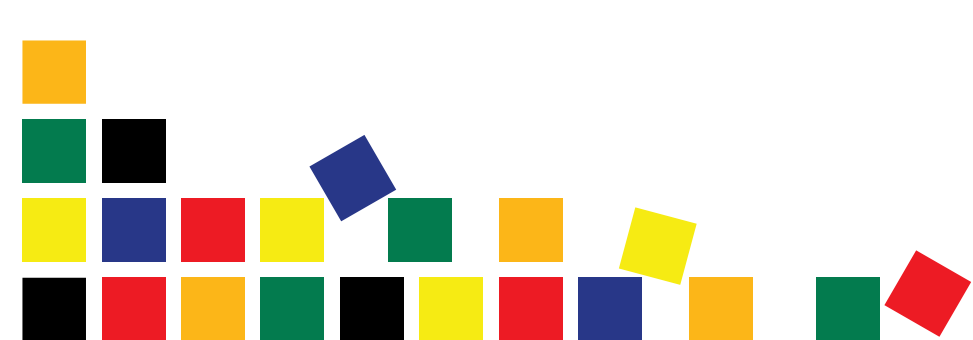
CONTENT (MT)

- Introduction
- Theory: *Definitions, Technical vs. Scientific Experiments*
- Study: *Evaluation Procedure*
- 1. Activity: *Network Typologies (MT)*
- Theory: *Phases of Experimentation*
- 2. Activity: *Cantilever Beam (MT)*
- Theory: *Types of Experiments*
- 3. Activity: *Line-Following Robot (MT)*
- Theory: *State of Research, Effects, Competency Dimensions*
- Summary and Conclusion



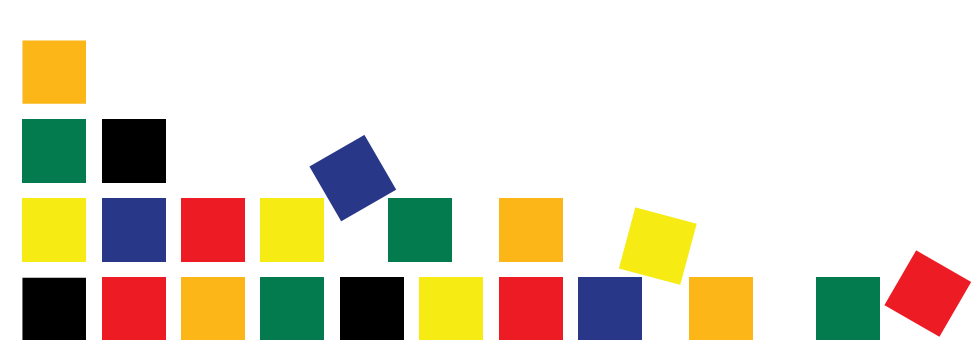
CONTENT (EWM)

- Introduction
- Theory: *Definitions, Technical vs. Scientific Experiments*
- Study: *Evaluation Procedure*
- 1. Activity: *Level Control (EWM)*
- Theory: *Phases of Experimentation*
- 2. Activity: *Insulation Materials (EWM)*
- Theory: *Types of Experiments*
- 3. Activity: *Maximum Power Point (EWM)*
- Theory: *State of Research, Effects, Competency Dimensions*
- Summary and Conclusion

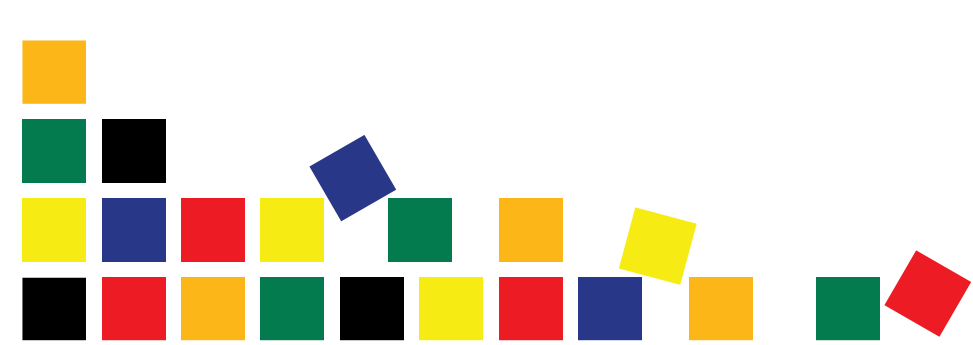


CONTENT (RE)

- Introduction
- Theory: *Definitions, Technical vs. Scientific Experiments*
- Study: *Evaluation Procedure*
- 1. Activity: *PV Battery Ratio (RE)*
- Theory: *Phases of Experimentation*
- 2. Activity: *PV Panel Alignment (RE)*
- Theory: *Types of Experiments*
- 3. Activity: *Wind Turbine Geometry (RE)*
- Theory: *State of Research, Effects, Competency Dimensions*
- Summary and Conclusion

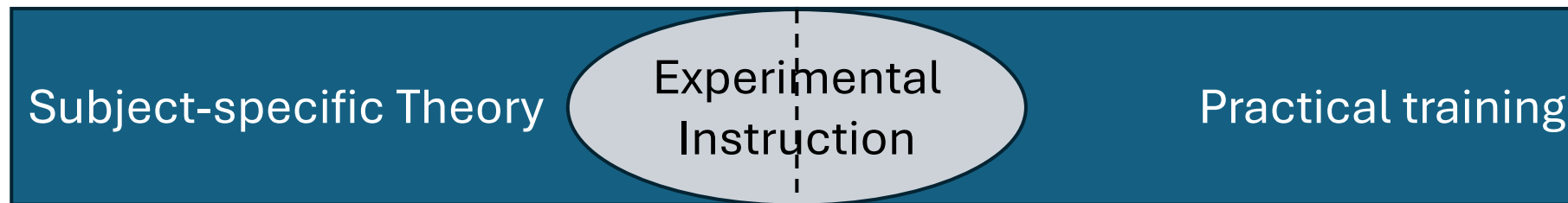


- Are you currently using experiments in your lessons?
 - Which ones?
 - How often?
- What would you need to implement experiments more often?

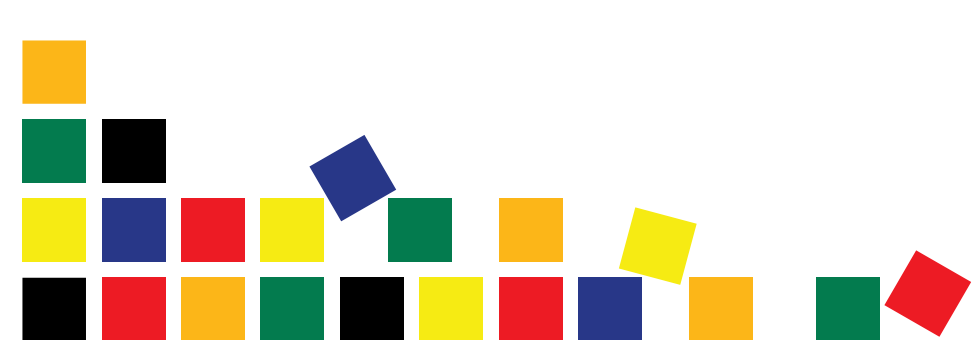


Theory: Definitions

- The Experiment (noun)
 - “an operation or procedure carried out under controlled conditions in order to discover an unknown effect or law, to test or establish a hypothesis, or to illustrate a known law” (<https://www.merriam-webster.com/dictionary/experiment>)
- Experimental instruction:

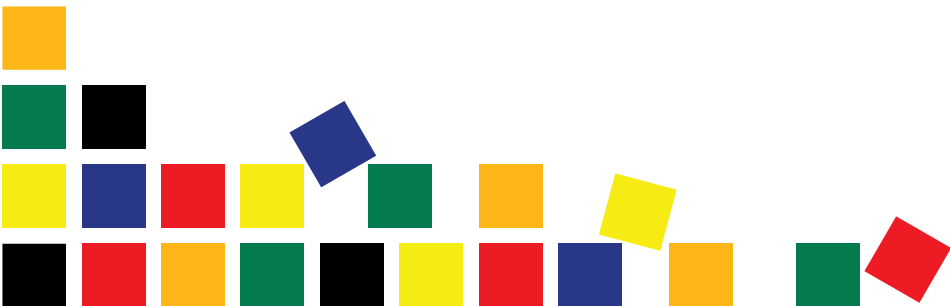


Reference: Own Translation based on Pahl (2013), S. 195.



Theory: *Technical vs. Scientific Experiments*

Scientific Experiments	Technical Experiments
Science experiments focus on the cause-and-effect relationship to confirm the theory, such as <i>ohm's law</i> or the <i>law of leverage</i>.	Technical experiments focus on the means-end relationship to find an applicable solution or design, for example: "<i>At what angle does a photovoltaic cell deliver the most energy?</i>"

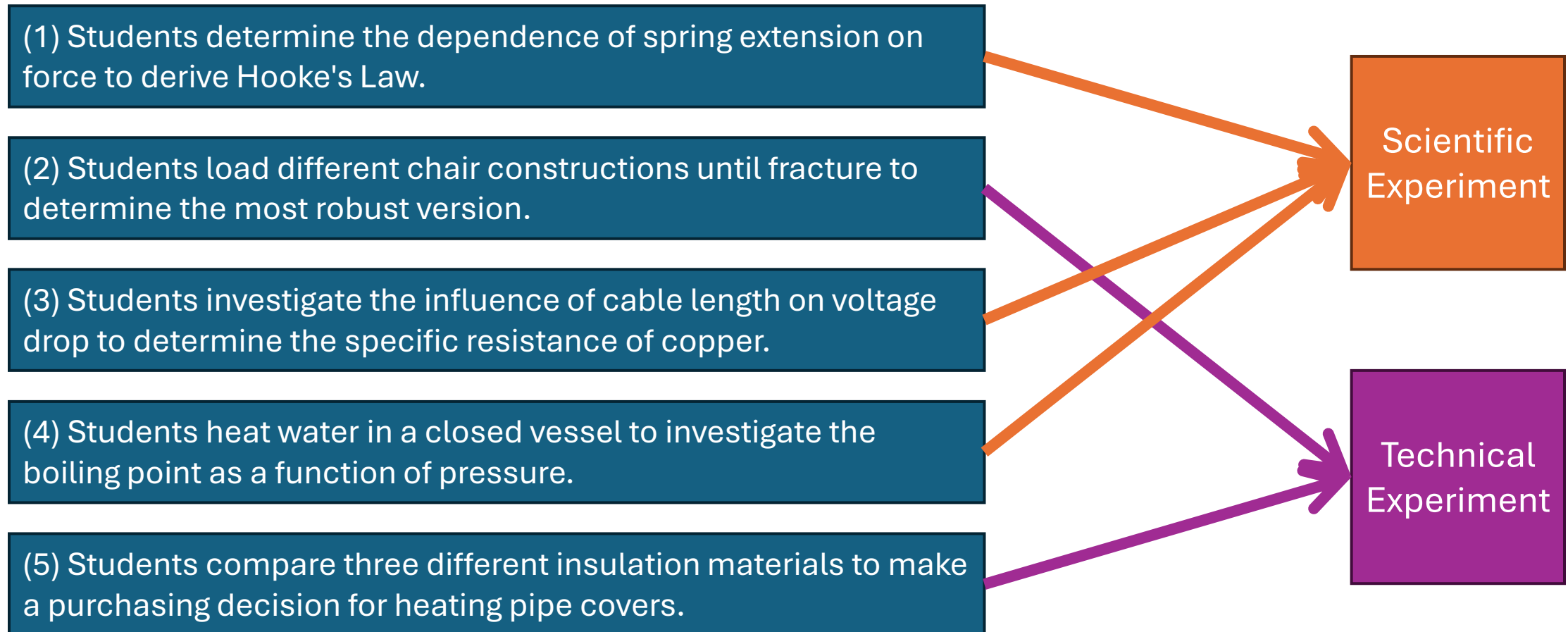


Theory: *Technical vs. Scientific Experiments*

	Scientific Experiments	Technical Experiments
Main objective	Epistemological goal (including consideration of contexts, causalities, drawing generalizable conclusions)	Final goal (including practice-, solution- and problem-orientation, functionality, efficiency, user-friendliness)
Variables	Manipulate independent variables and observe their effects on dependent variables (measurable results)	Focus is on optimizing parameters and functions to achieve the desired result or performance
Generalizability	Designed to be repeatable and deliver generalizable results	Not always generalizable, often specific to the developed technology or the problem
Validation and Testing	Are subject to review by the scientific community to ensure their validity and credibility	May follow standards and guidelines
Timeline and Application	Often long-term, contribute to the accumulation of new knowledge over time, which can lead to new applications and innovations	Usually focused on the immediate solution of practical problems and can lead to direct applications and commercial products in the short term

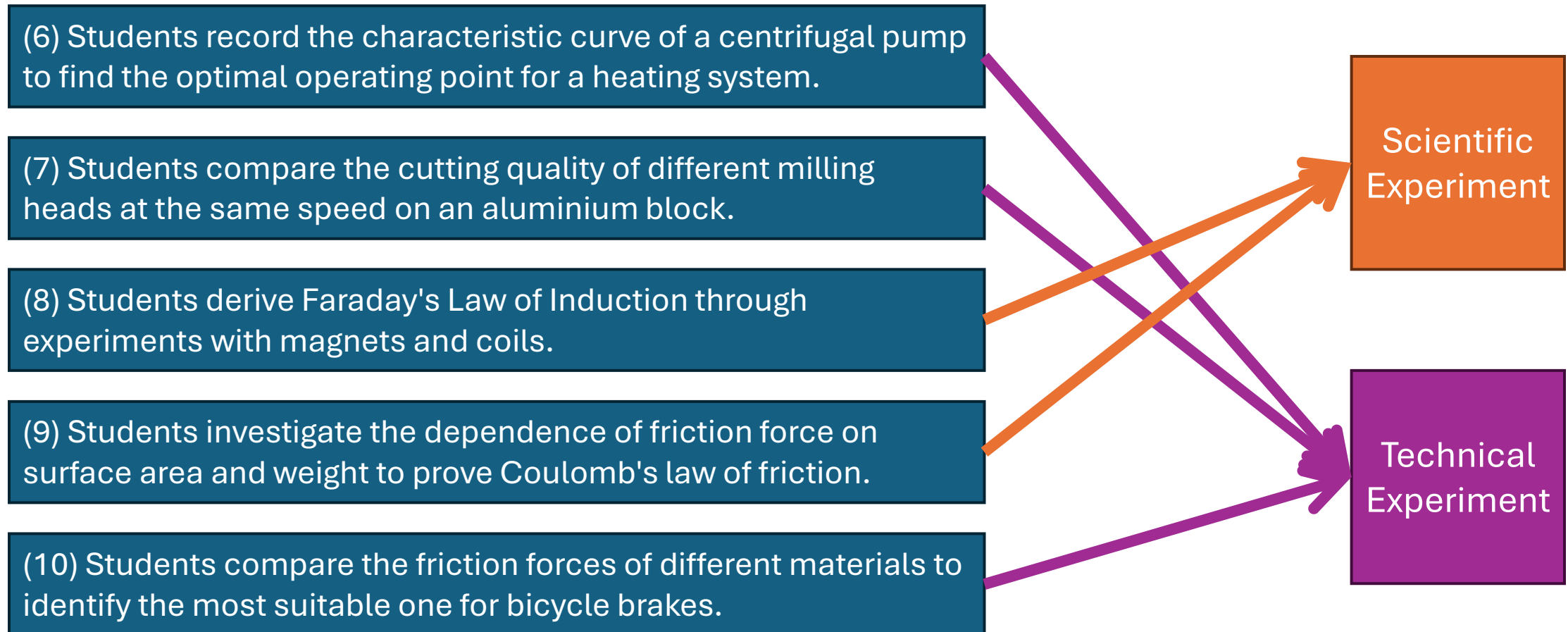
Theory: *Technical vs. Scientific Experiments*

- Assign the following examples to the correct type of experiment



Theory: *Technical vs. Scientific Experiments*

- Assign the following examples to the correct type of experiment

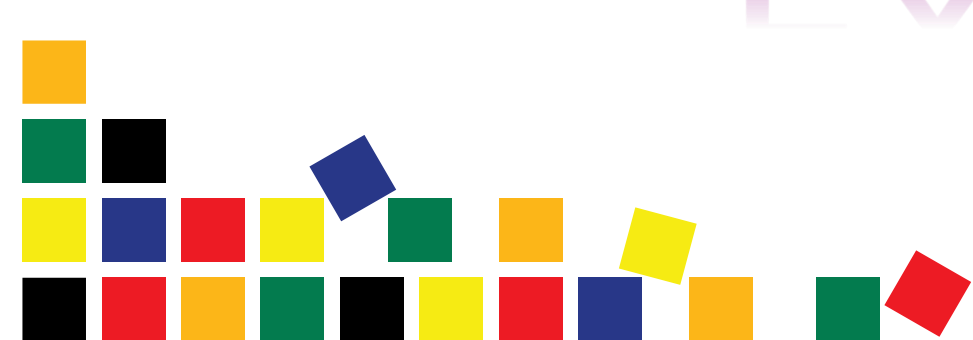


Study: *Evaluation Procedure*

- Research Objective: Initial empirical test of the normative KomTEx-L model.
- Method: Triangulation with videography, think-aloud protocols, and stimulated recall interviews.



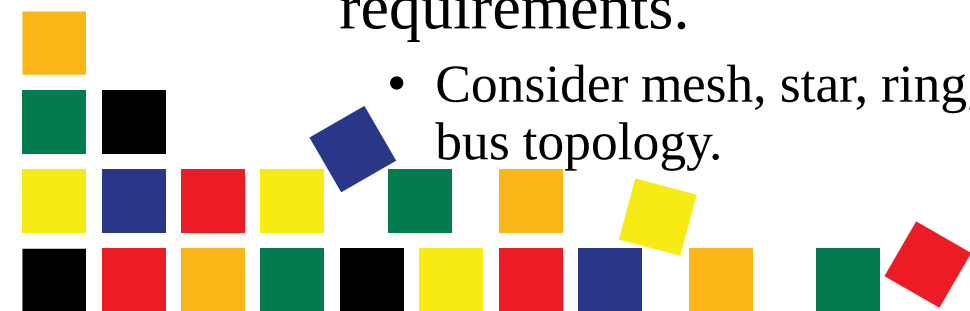
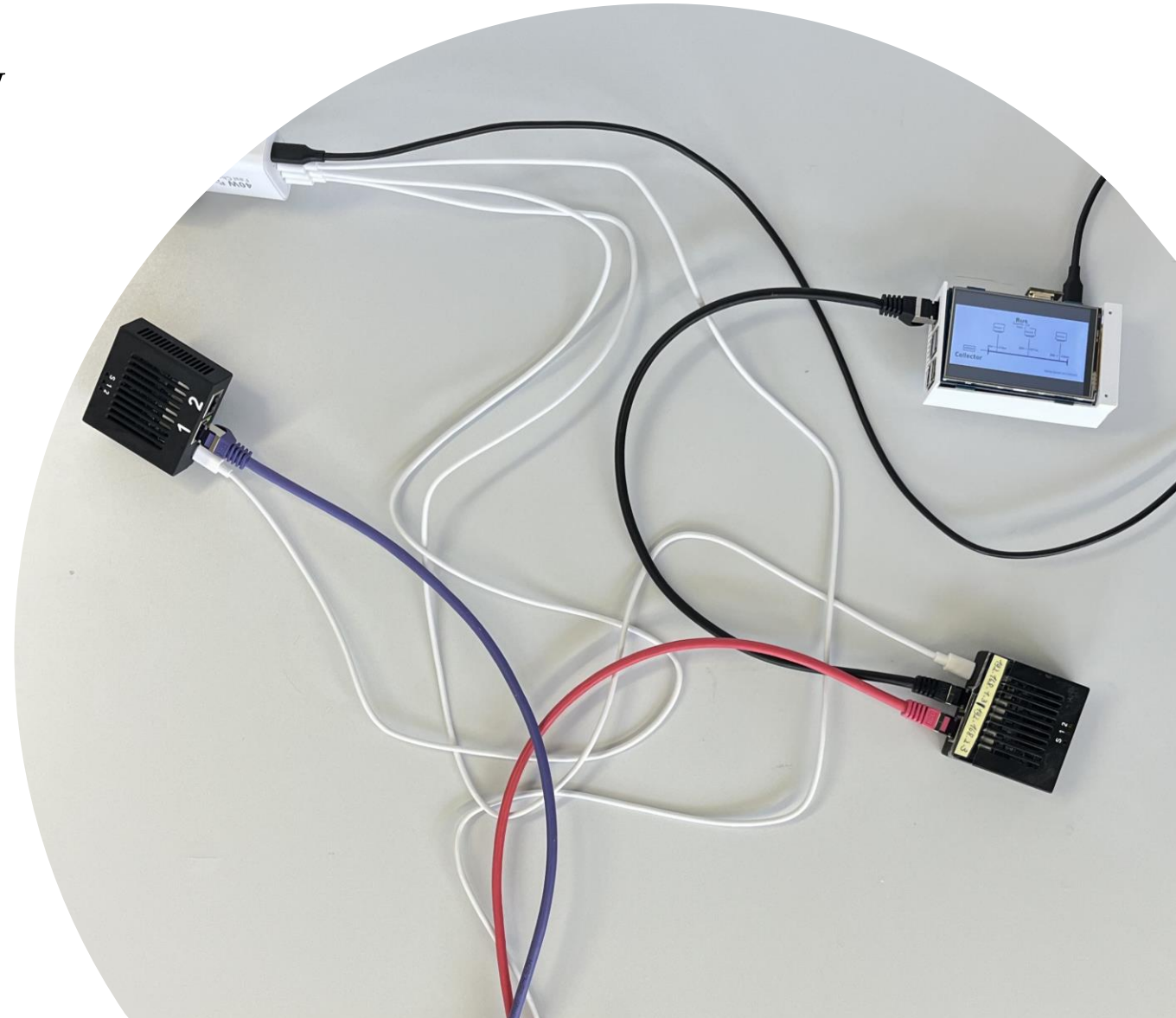
EXERCISE



1. Activity: *Network Typologies (MT)*

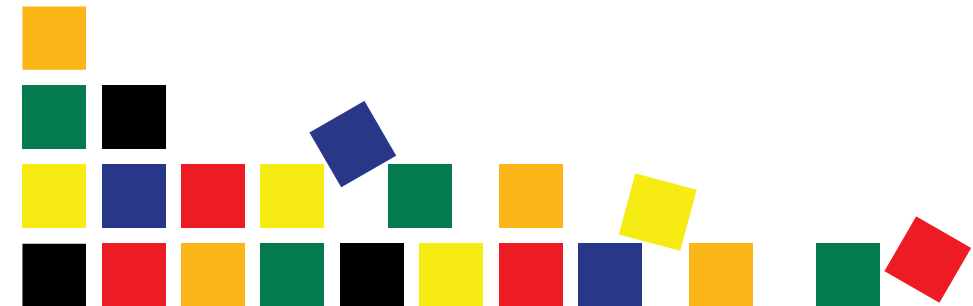
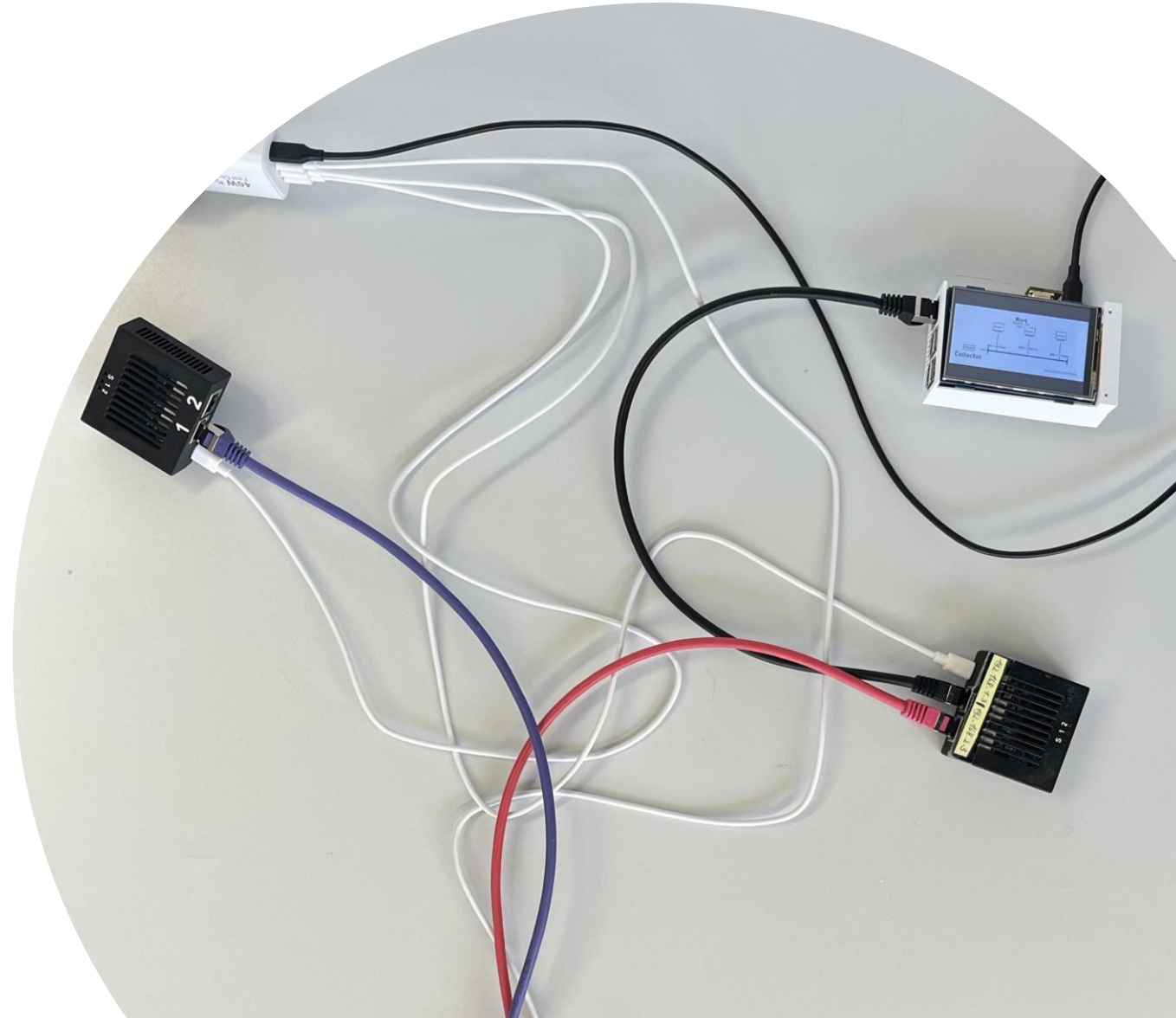
• Experimental Question:

- Your TVET wants to set up a new network infrastructure and has asked for your advice on which network topology to use. They want to install as few cables as possible. However, if a cable or connection fails, the network should still remain operational. Since no time-sensitive infrastructure runs over the network, there are no latency requirements.
- Consider mesh, star, ring, tree and bus topology.



1. Activity: *Network Typologies (MT)*

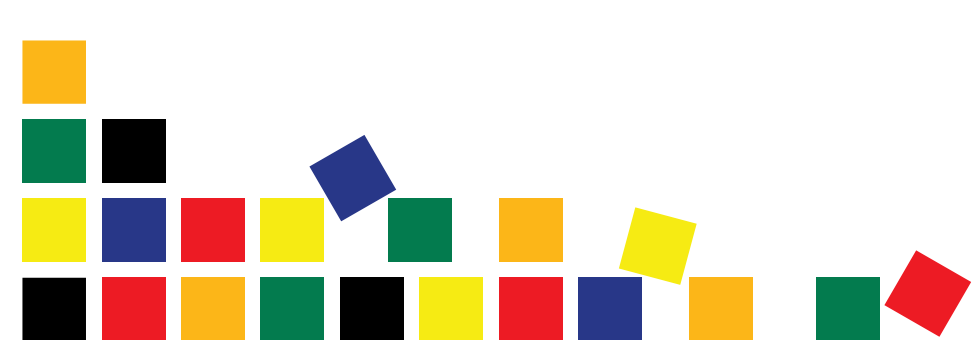
- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



1. Activity: *Level Control (EWM)*

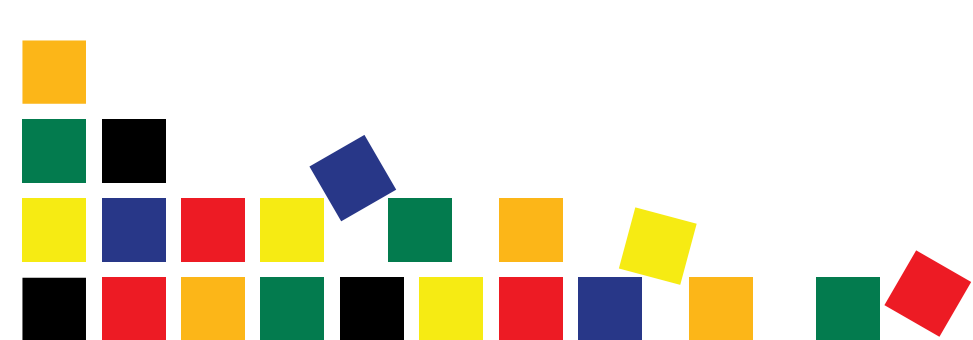
- Experimental Question:

- What is the optimal setting for the level control system to keep the water level as constant as possible?
 - Manual control, two-point control, PID controller
 - Labor costs, energy costs



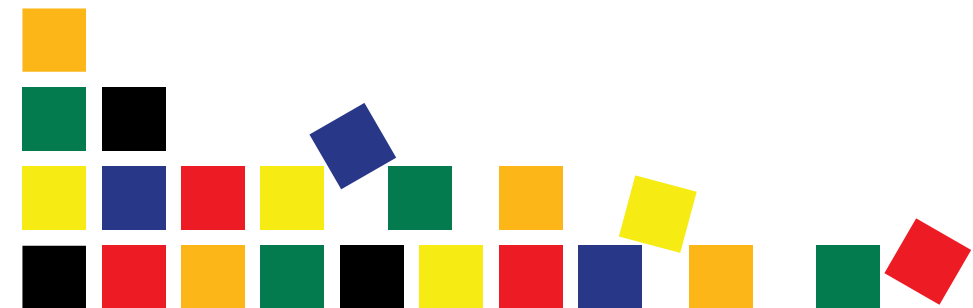
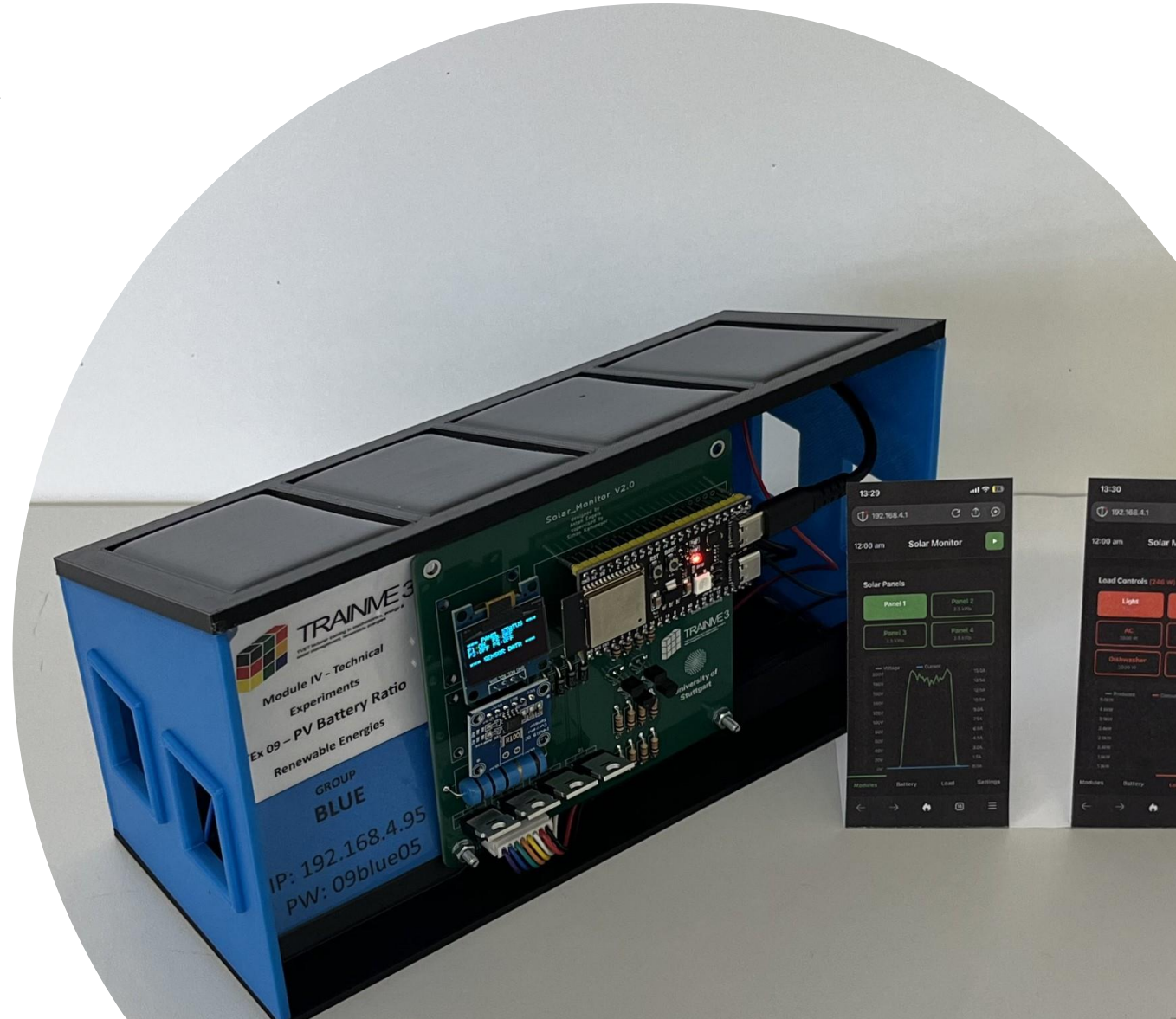
1. Activity: *Level Control (EWM)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



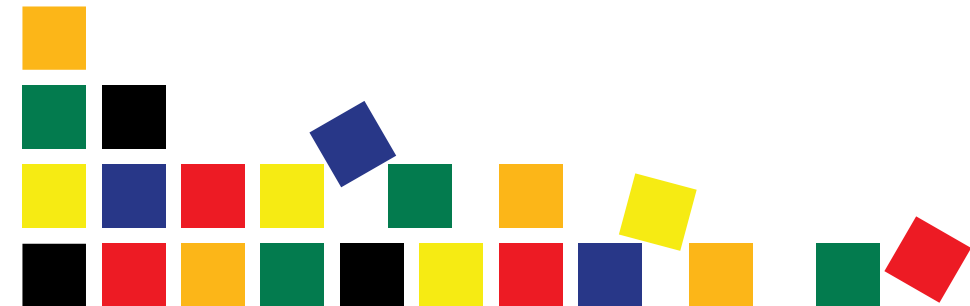
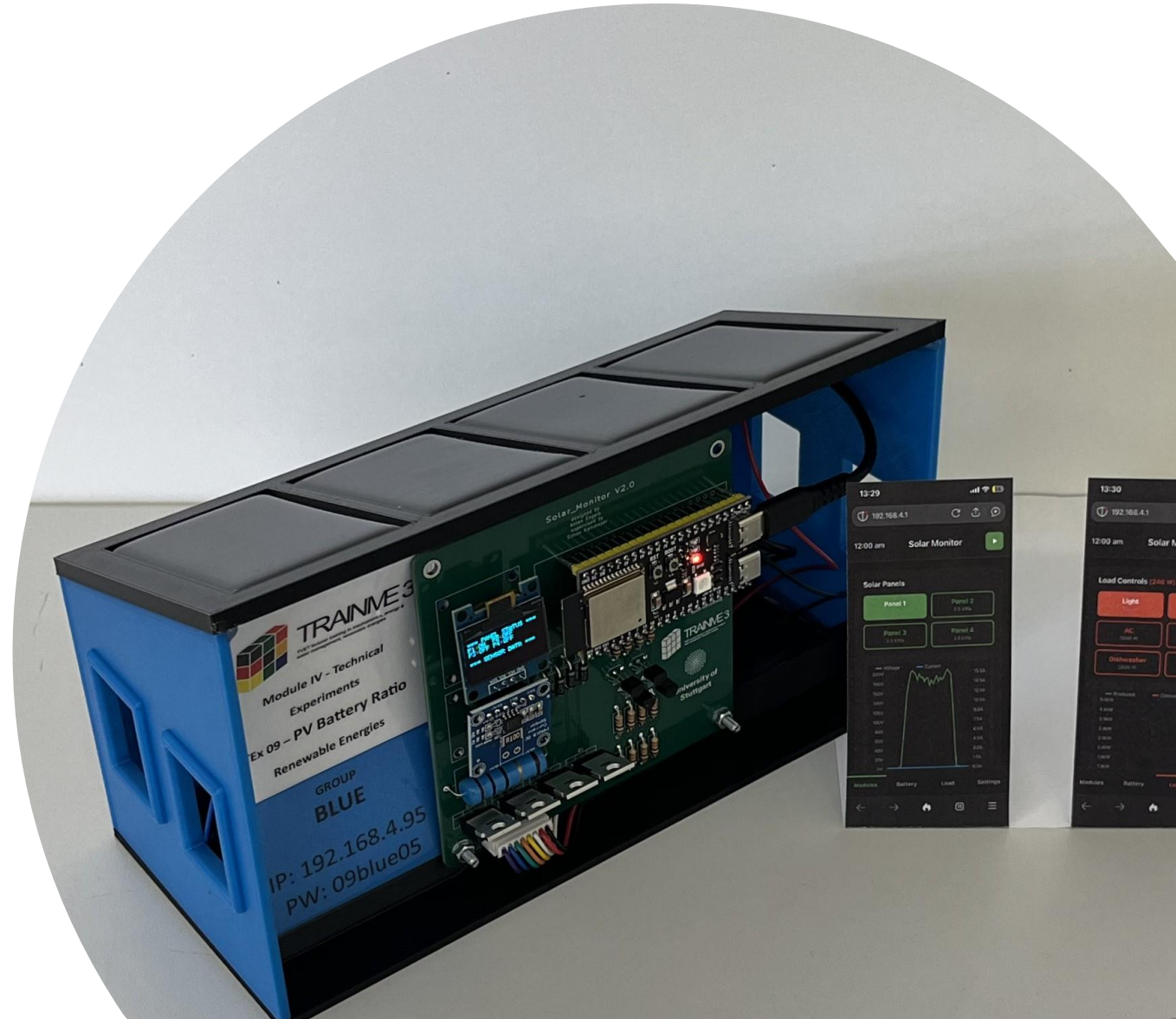
1. Activity: *PV Battery Ratio (RE)*

- Experimental Question:
 - What is the optimal ratio between PV installation area on the roof and battery capacity in the basement to have energy throughout the whole night?
 - Consider that one PV panel costs ZAR 5000 and one battery costs ZAR 15000.

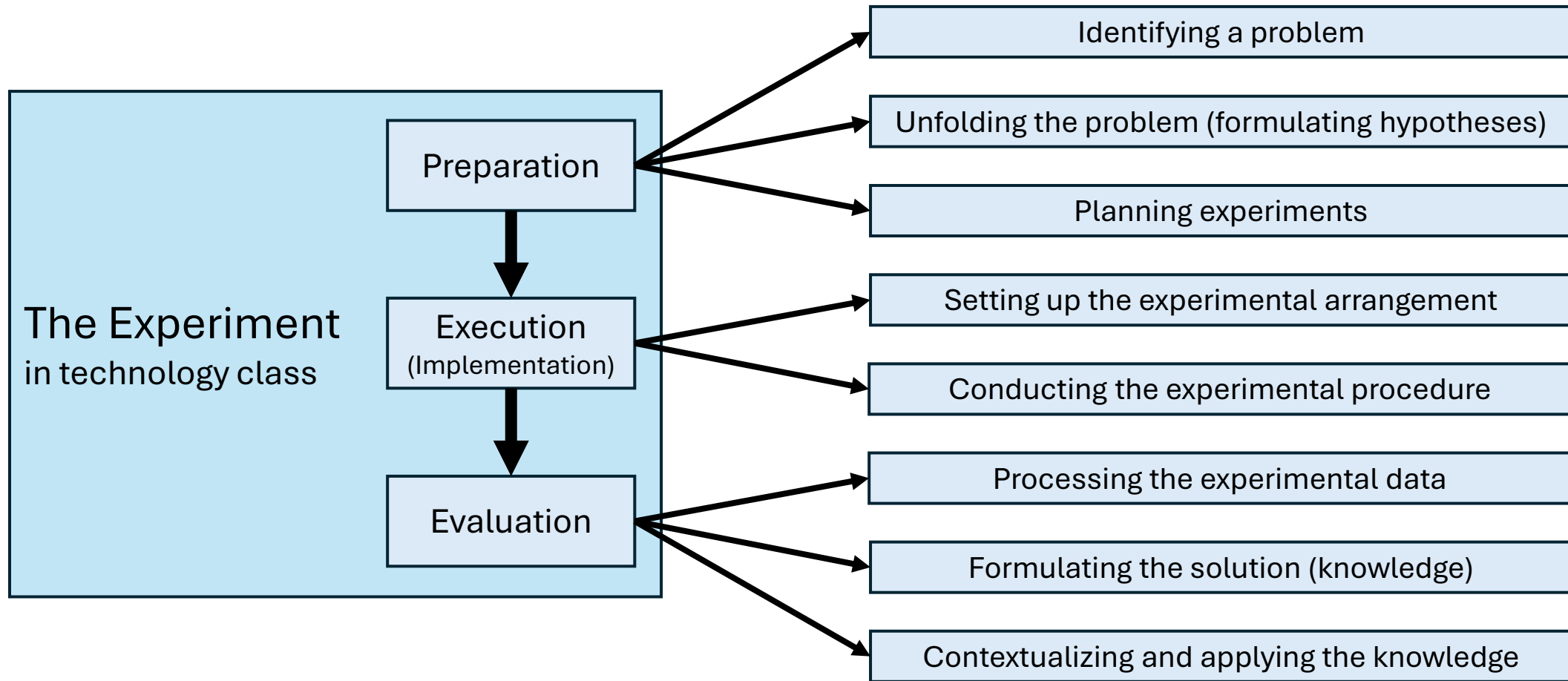


1. Activity: *PV Battery Ratio (RE)*

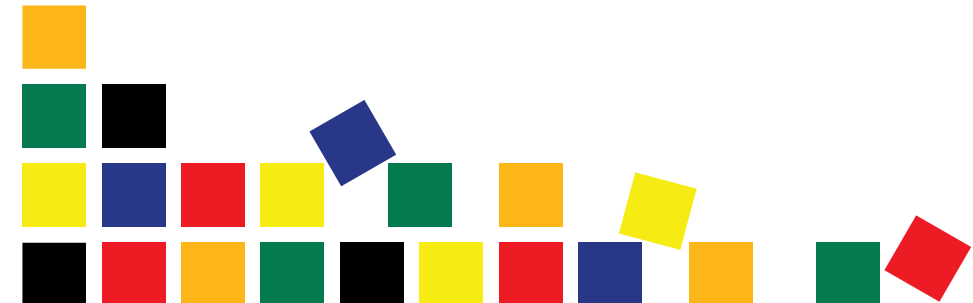
- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



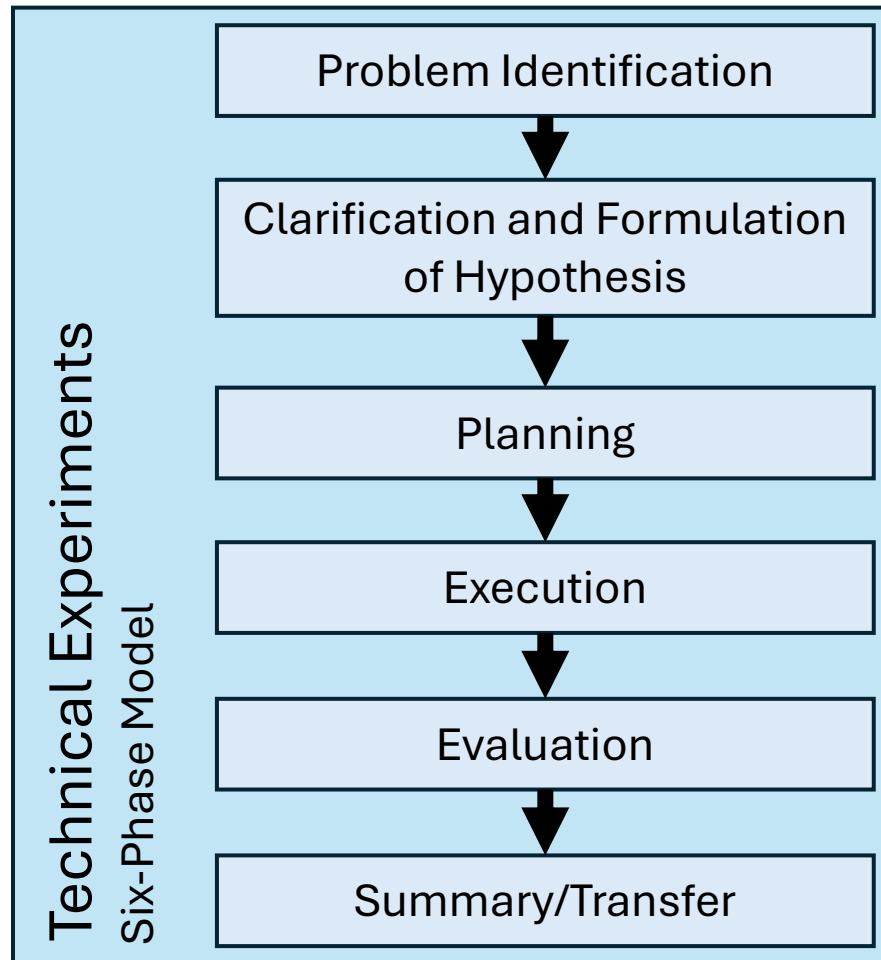
Theory: *Phases of Experimentation*



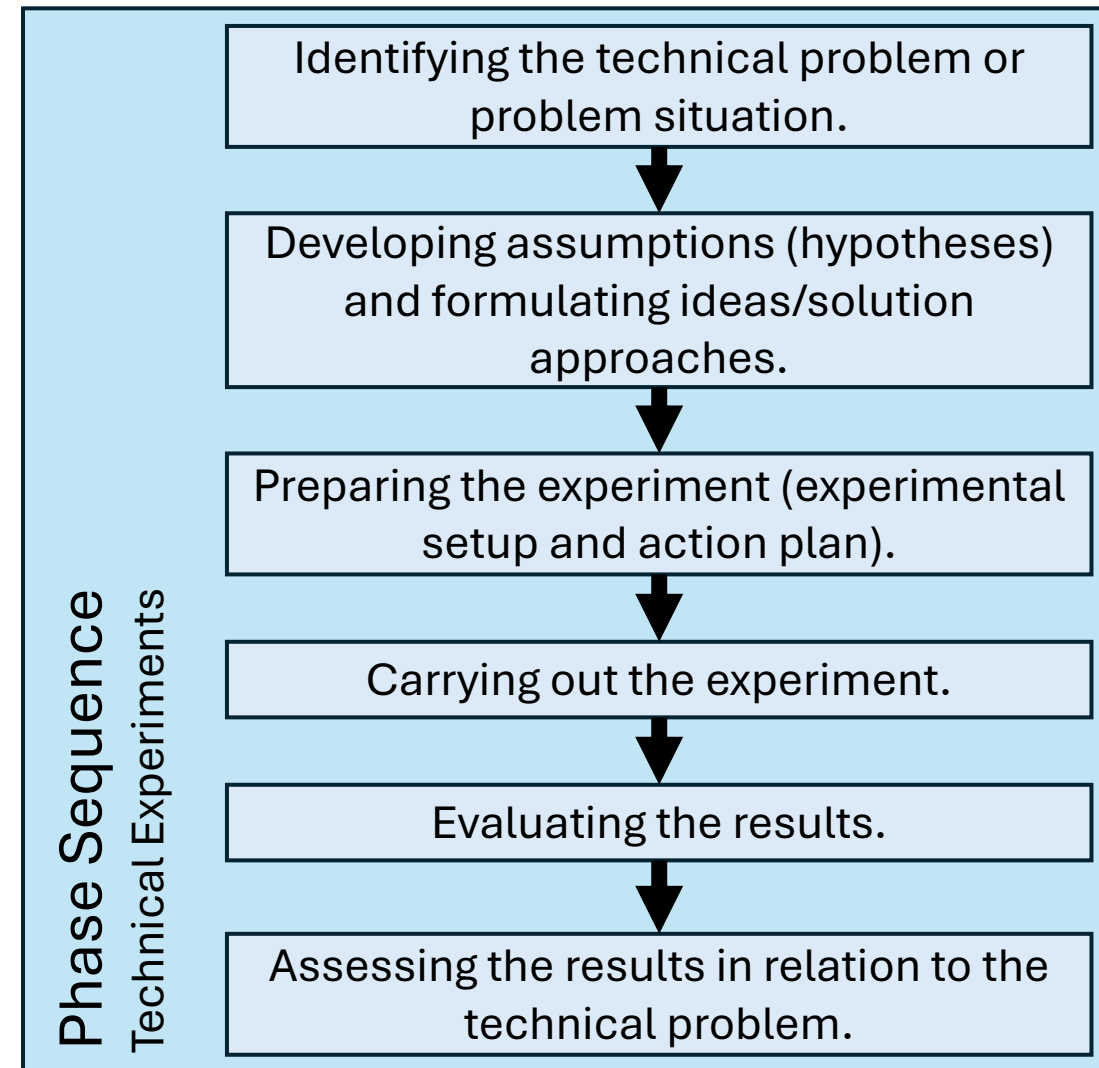
Reference: Own Translation based on Schmayl (1982).



Theory: *Phases of Experimentation*

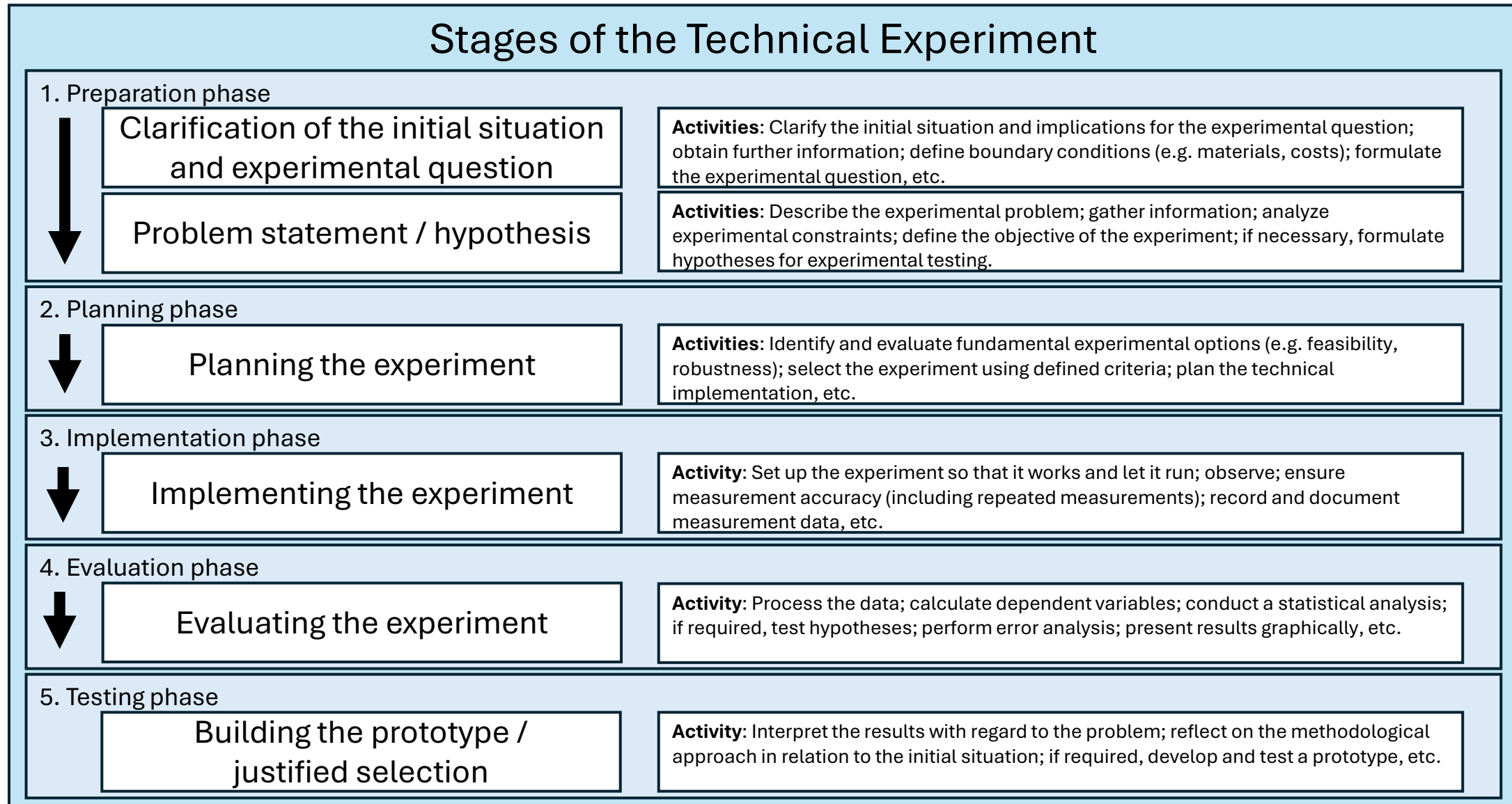


Reference: Own Translation based on Pahl (2013).



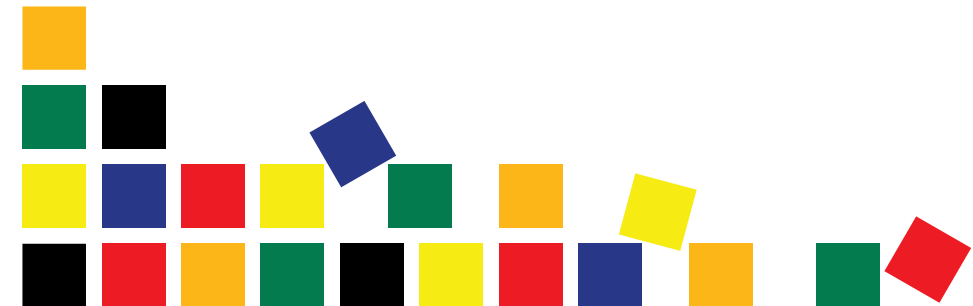
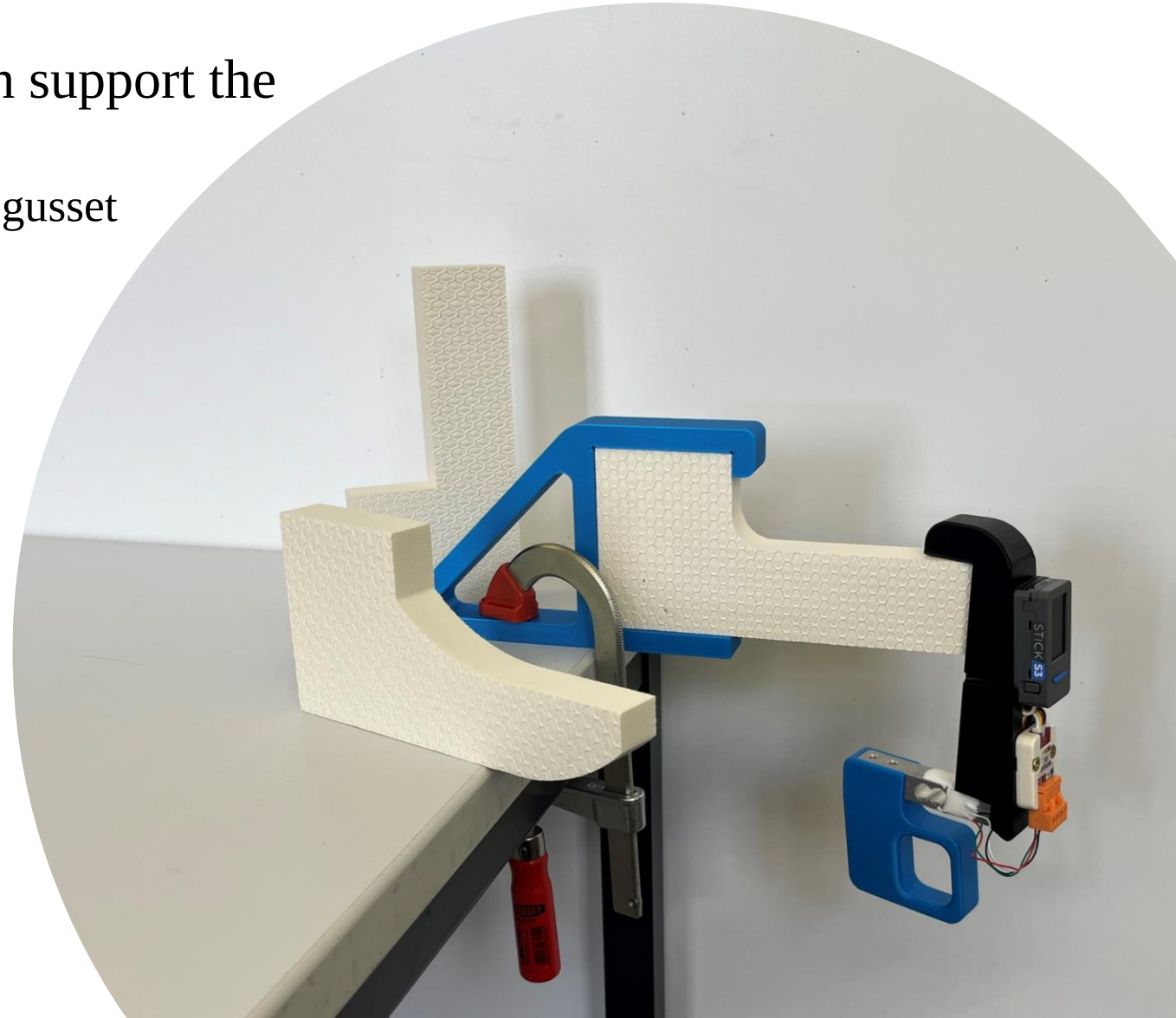
Reference: Own Translation based on Walker (2013).

Theory: *Phases of Experimentation*



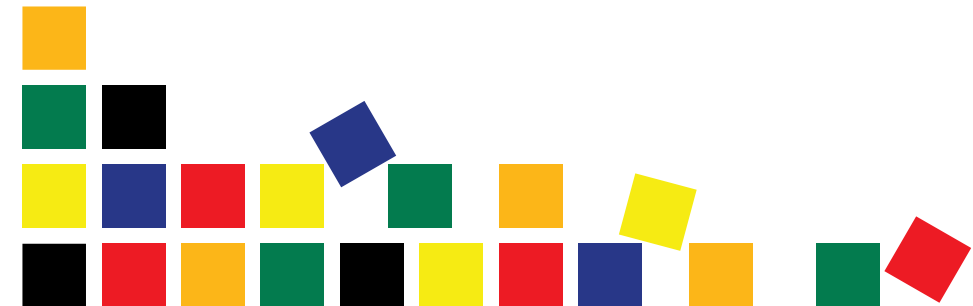
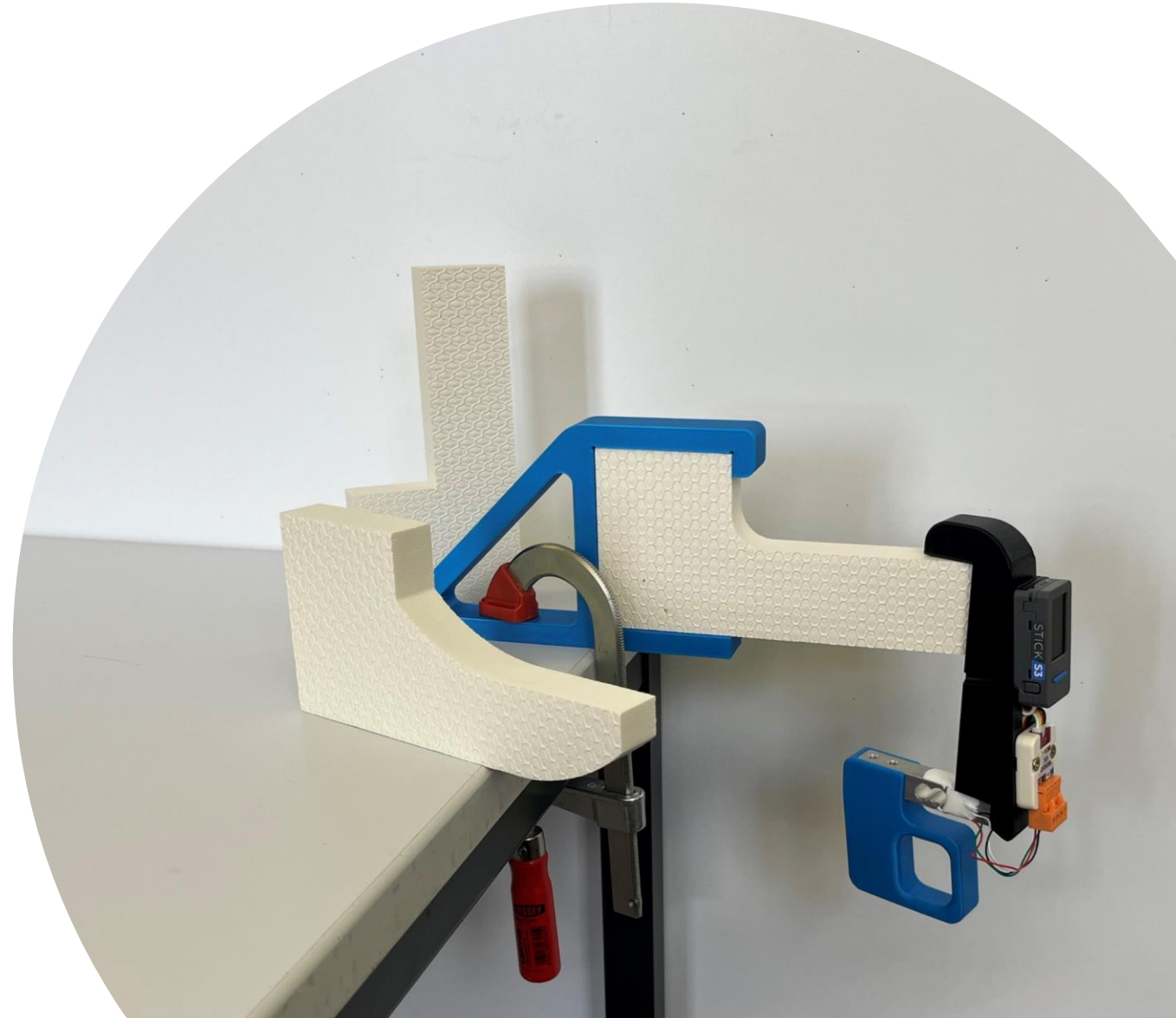
2. Activity: *Cantilever Beam (MT)*

- Experimental Question:
 - Which cantilever beam design can support the greatest weight?
 - Consider sharp corner, fillet corner, gusset (triangular reinforcement)



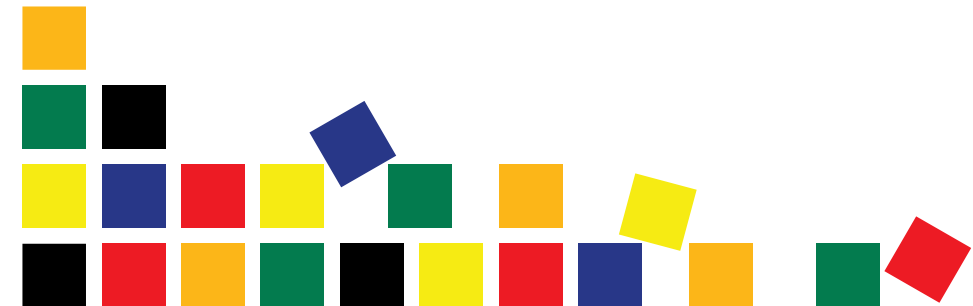
2. Activity: *Cantilever Beam (MT)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



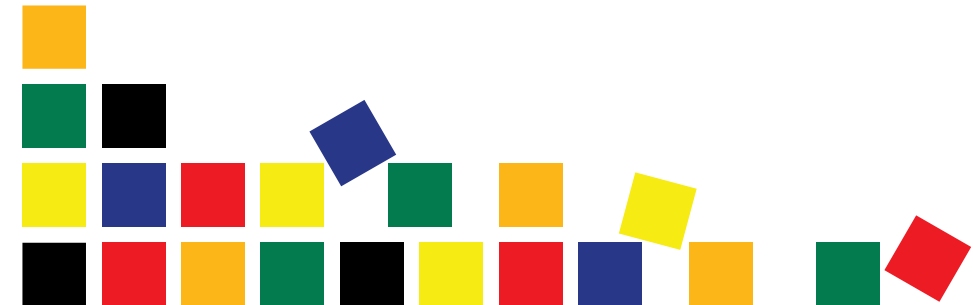
2. Activity: *Insulation Materials (EWM)*

- Experimental Question:
 - Which type of insulation is best for insulating a house?
 - Styrofoam, hard foam, cork



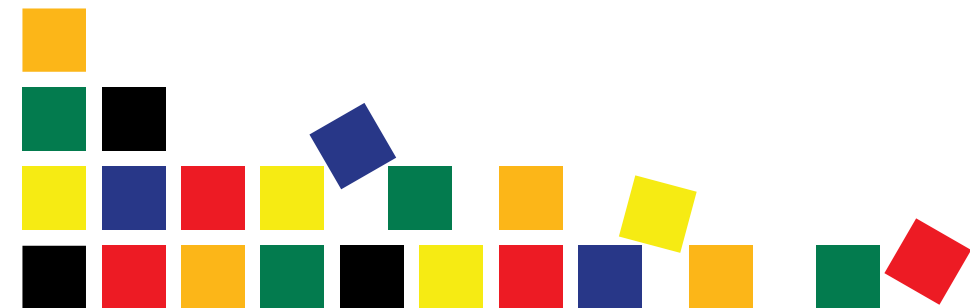
2. Activity: *Insulation Materials (EWM)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



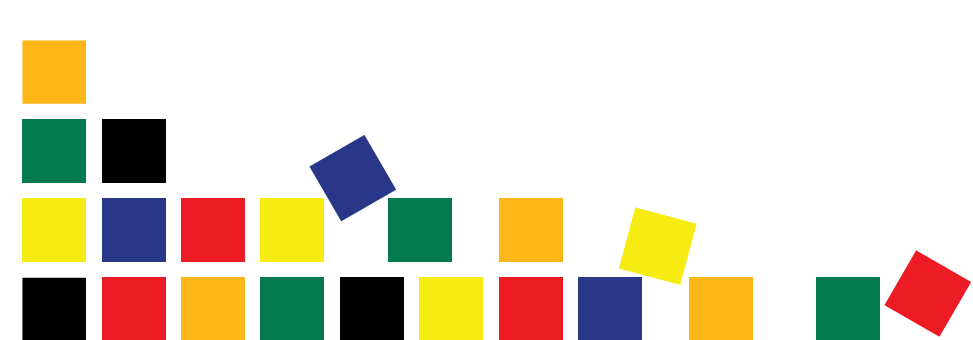
2. Activity: *PV Panel Alignment (RE)*

- Experimental Question:
 - What is the optimal installation angle for a PV panel to generate the most energy?
 - Consider tilt (altitude) and azimuth



2. Activity: *PV Panel Alignment (RE)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



2. Activity: *PV Panel Alignment (RE)*

- Step 1.: Download the phyphox app



2. Activity: *PV Panel Alignment (RE)*

- **Step 2.: Connect to the test setup**



- **Activate Bluetooth on your smartphone**

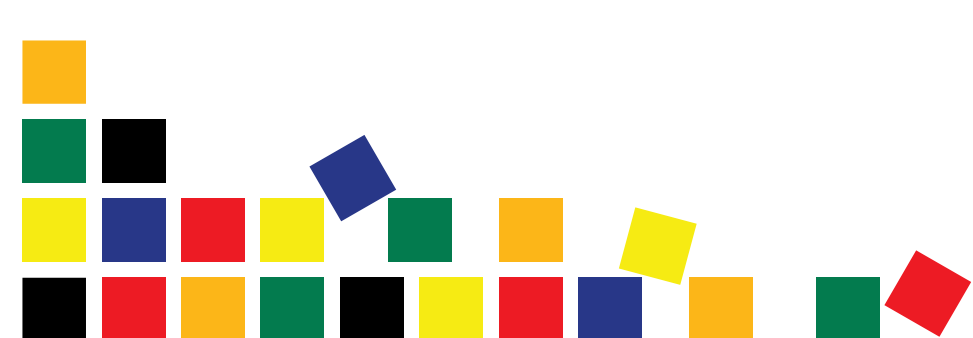


- **Open the phyphox app**



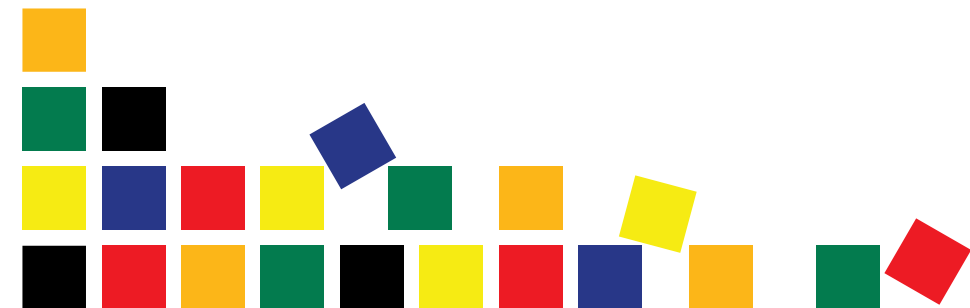
- **Add experiment for Bluetooth device**

!!! Chose the right group color !!!



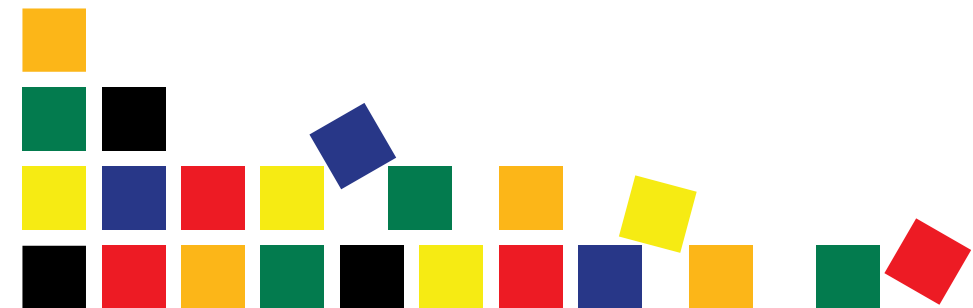
2. Activity: *PV Panel Alignment (RE)*

- Experimental Question:
 - What is the optimal installation angle for a PV panel to generate the most energy?
 - Consider tilt (altitude) and azimuth



2. Activity: *PV Panel Alignment (RE)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation

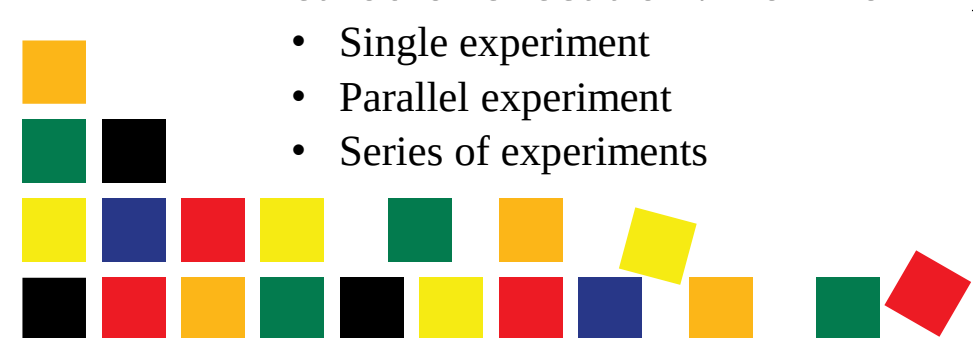


Theory: *Types of Experiments*

Classification of physics experiments in schools

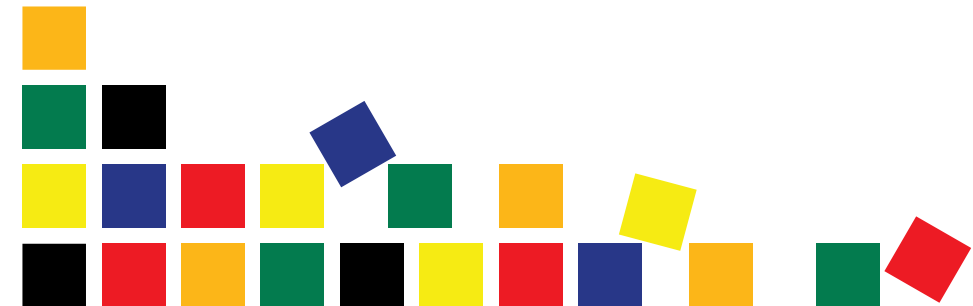
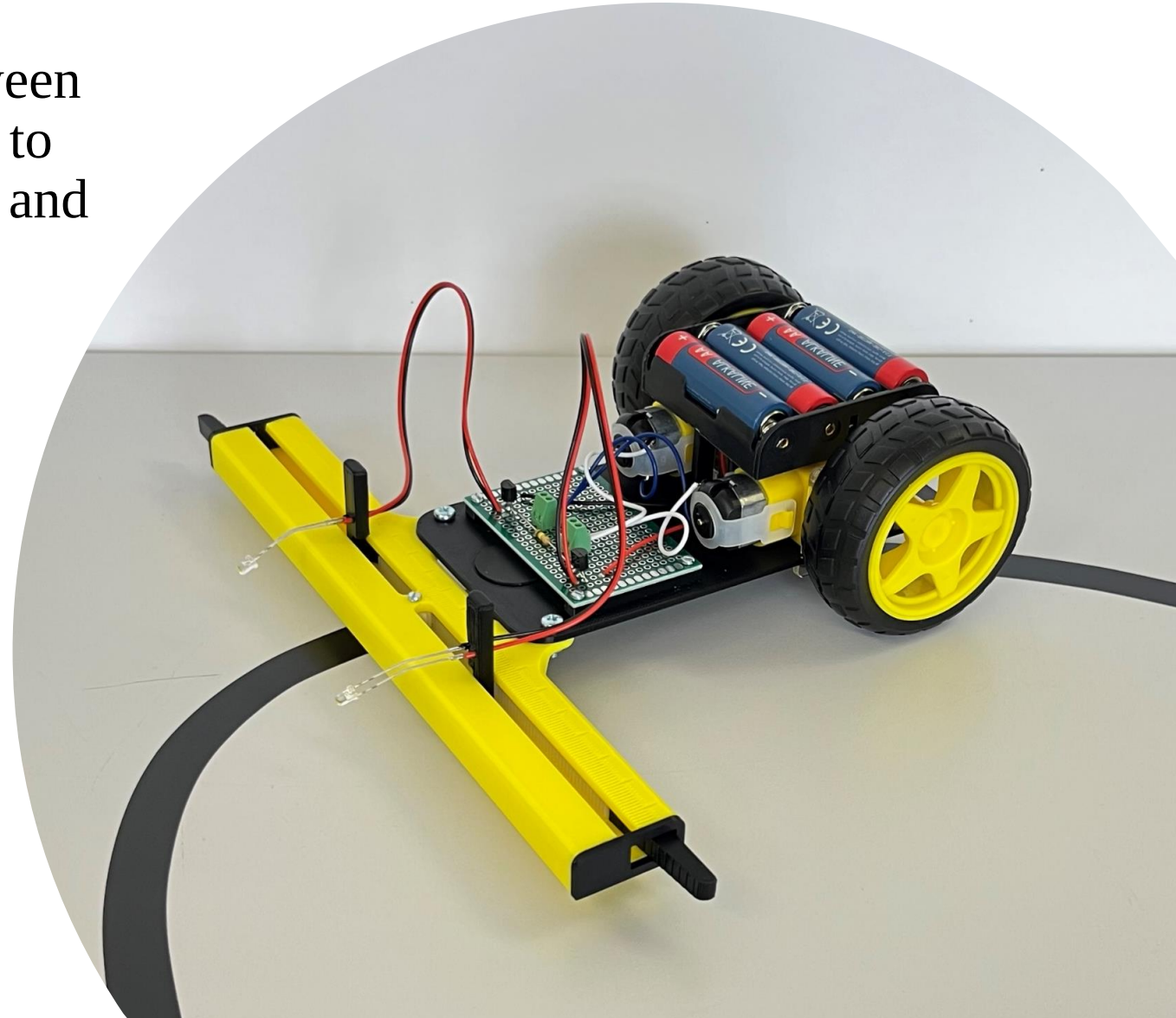
- Qualitative – Quantitative
- Demonstration experiment or student experiment (teacher-led vs. hands-on)
- Integration into lesson phases (instructional phases)
 - Introductory experiments
 - Interactive / Execution experiments
 - Deepening experiments
 - Comprehension check / Consolidation experiments
- Equipment / Instrumentation
 - Low-cost / Hands-on experiments
 - Experiments using specialized apparatus and measuring instruments
 - Simulation experiments
 - Thought experiments
- Method of execution / Form of implementation
 - Single experiment
 - Parallel experiment
 - Series of experiments

Reference: Own Translation based on Girwidz (2020).



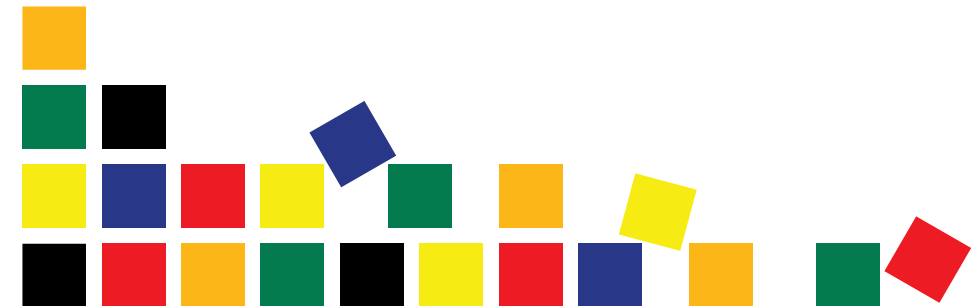
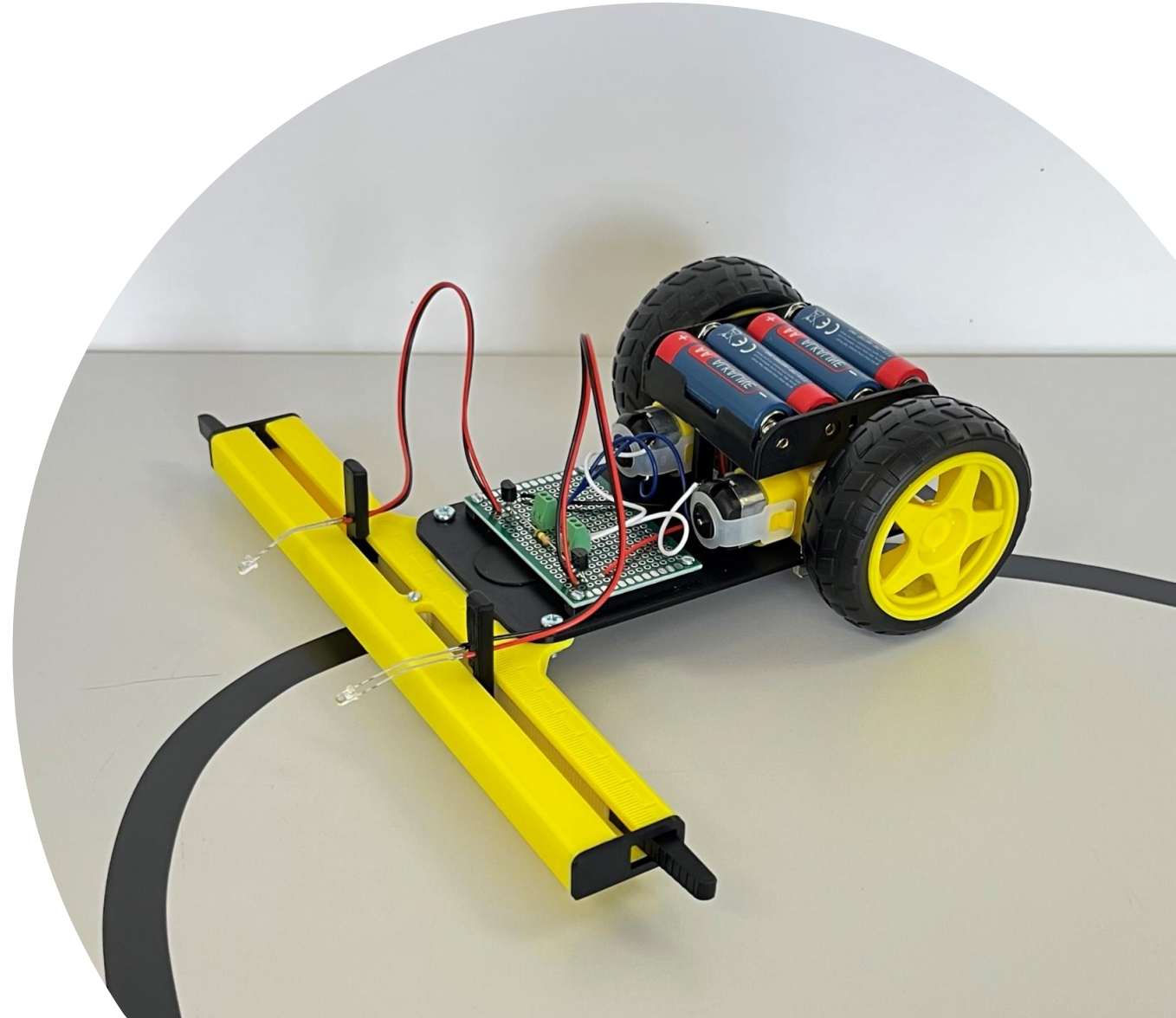
3. Activity: *Line-Following Robot (MT)*

- Experimental Question:
 - What is the optimal distance between sensors for line detection in order to complete a given track as quickly and accurately as possible?



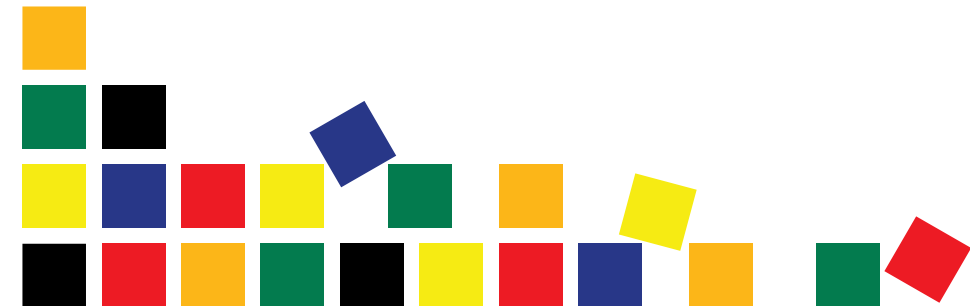
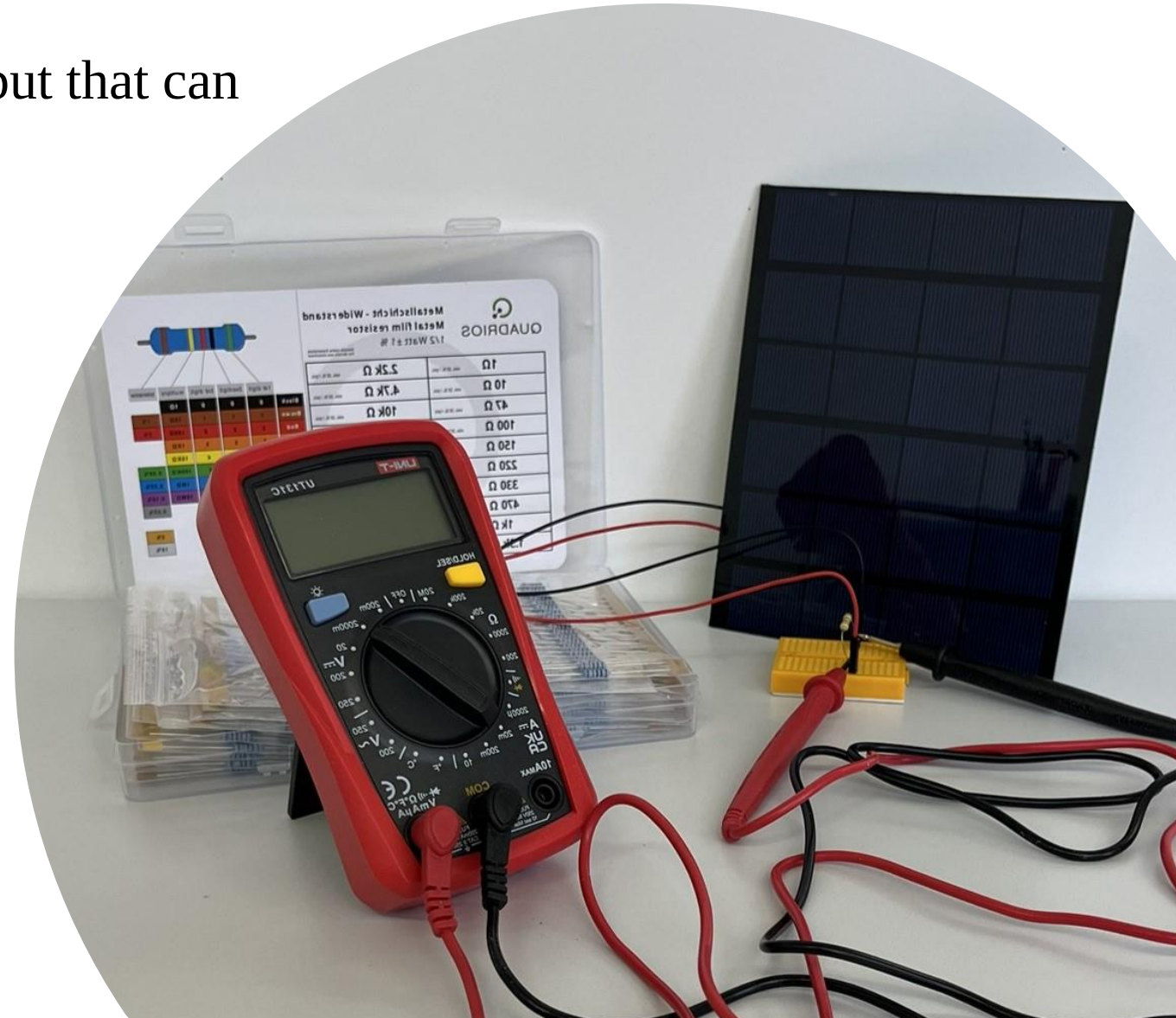
3. Activity: *Line-Following Robot (MT)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



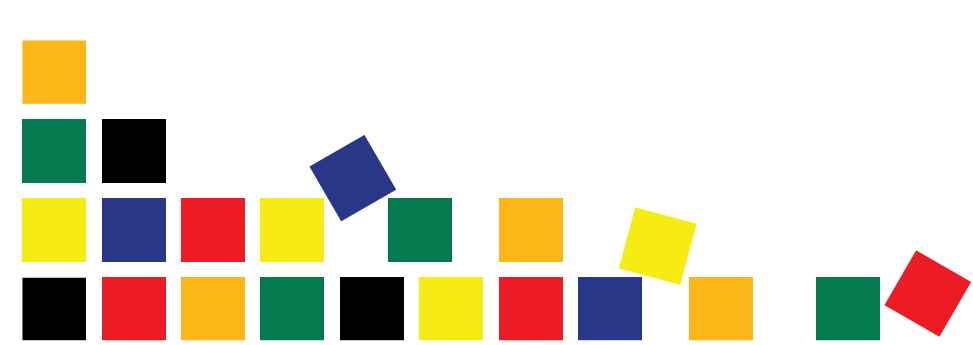
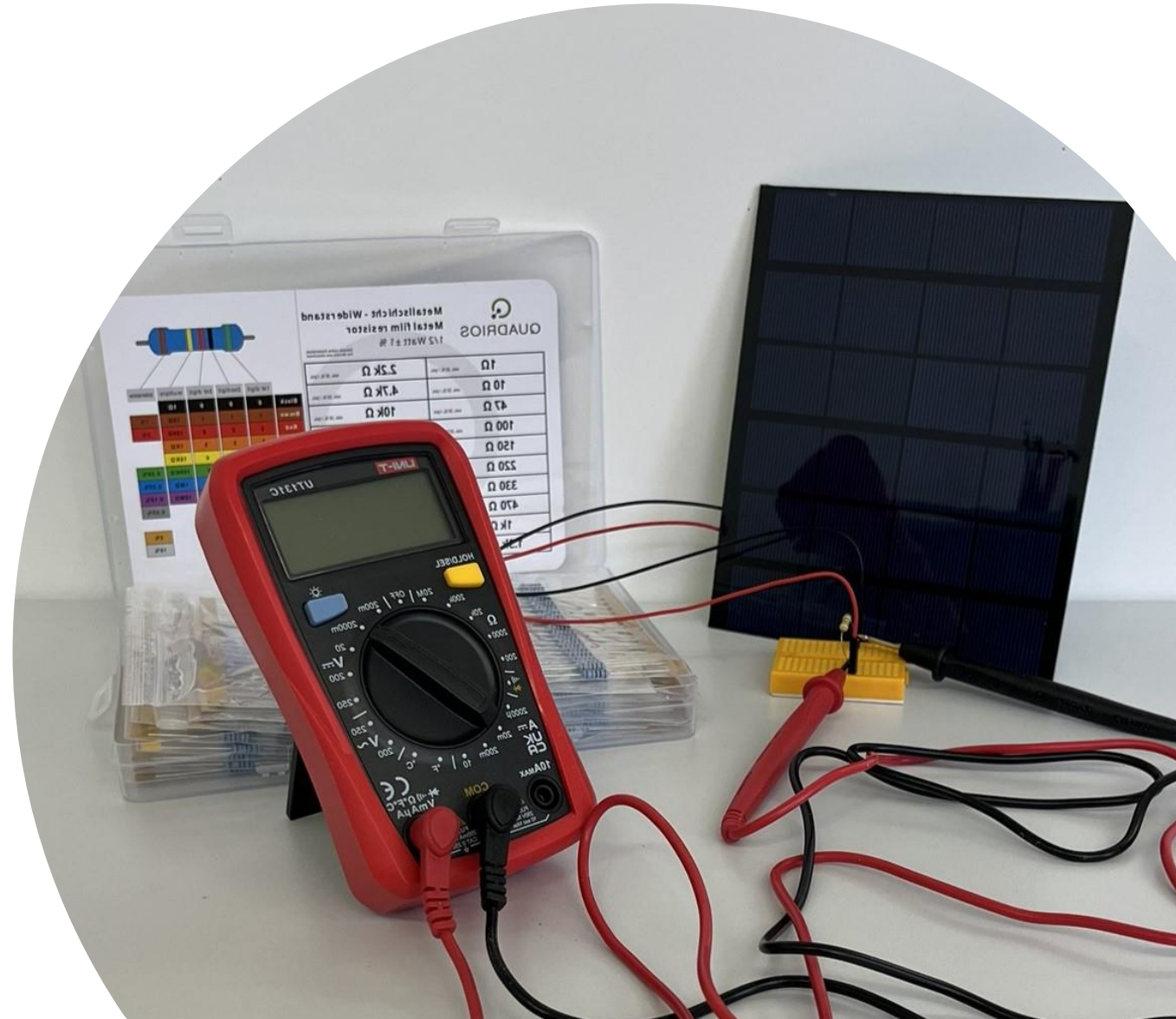
3. Activity: *Maximum Power Point (EWM)*

- Experimental Question:
 - What is the maximum power output that can be obtained from the solar panel?
 - $P = U \cdot I = R \cdot I^2 = \frac{U^2}{R}$
 - $P_{max} \rightarrow R_i = R_l$



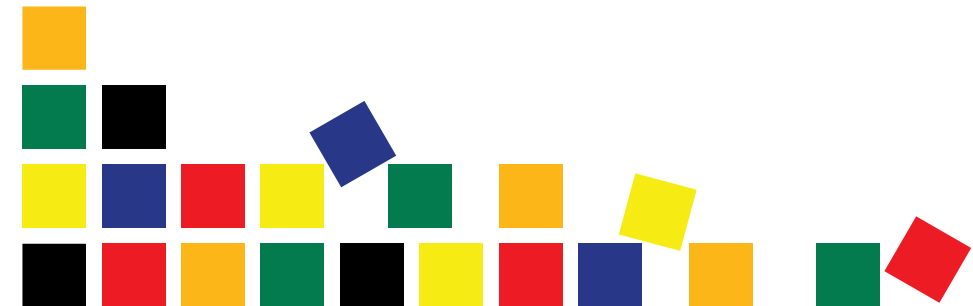
3. Activity: *Maximum Power Point (EWM)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



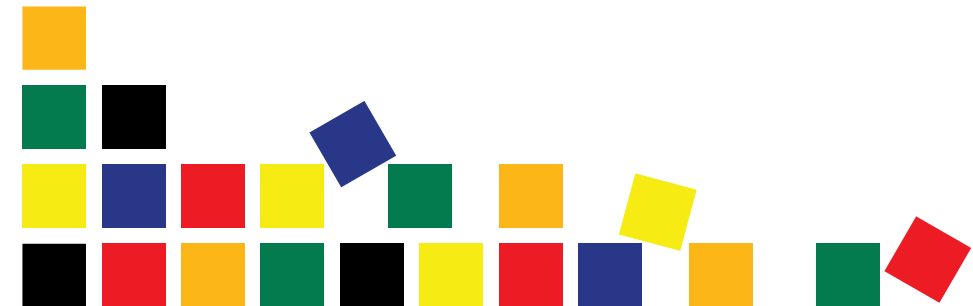
3. Activity: *Wind Turbine Geometry (RE)*

- Experimental Question:
 - What is the optimal wind turbine geometry to generate the most energy?
 - Consider number of blades, blade length, angle of attack



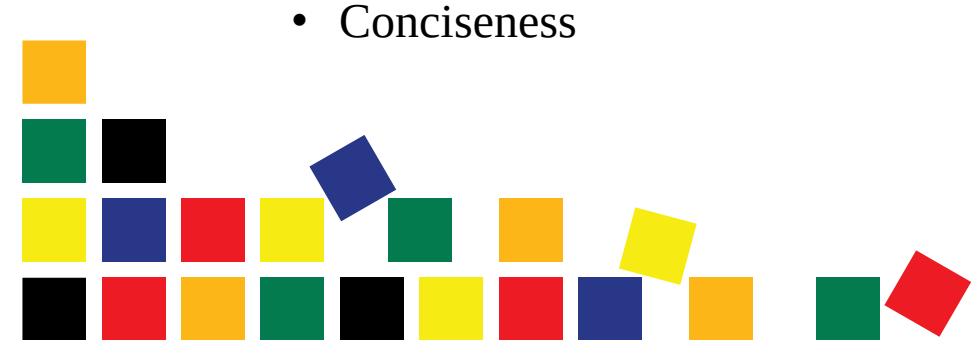
3. Activity: *Wind Turbine Geometry (RE)*

- Reflection
 - Integration into the syllabus
 - Learning objectives
 - Challenges
 - Possibilities for adaptation



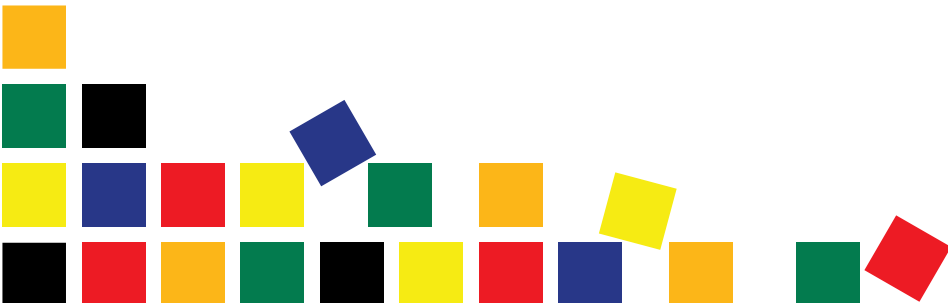
Theory: *State of Research, Effects*

- Teaching key skills through experimentation:
 - Attitudes: Diligence, sense of order, willingness to perform, friendliness, mobility, flexibility
 - Behaviors: Reliability, perseverance, personal initiative, openness, tolerance, determination
 - Skills: Communication, cooperation, ability to work in a team, assertiveness, decisiveness, creativity, ability to learn, organizational skills
- Advice for teaching practice (Kircher et al, 2000):
 - Structured layout
 - Good visibility
 - Focus on the essentials
 - Emphasis on important components
 - Critical analysis & discussion
 - Guidance
 - Structured process
 - Conciseness



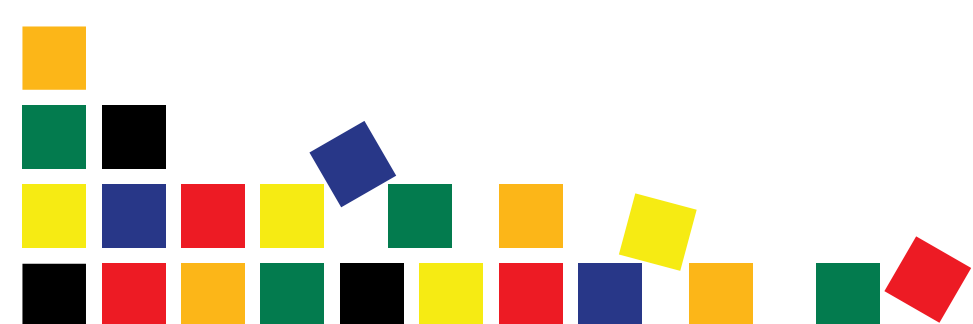
Summary and Conclusion

- Try an experiment of your choice



References

- Girwidz, R. (2020). Experimente im Physikunterricht. In E. Kircher, R. Girwidz & H. E. Fischer (Hrsg.), Physikdidaktik. Grundlagen (S. 263–291). Berlin: Springer. https://doi.org/10.1007/978-3-662-59490-2_7
- Kircher, E., Girwidz, R. & Häußler, P. (2000). Physikdidaktik. Braunschweig: Vieweg Verlag.
- Pahl, J.-P. (2013). Bausteine beruflichen Lernens im Bereich „Arbeit und Technik“. Band 2: Makromethoden - Rahmengebende Ausbildungs- und Unterrichtsverfahren (Bausteine beruflichen Lernens im Bereich "Arbeit und Technik" / von Jörg-Peter Pahl] /Franz Ferdinand Mersch], Bd. 2, 4. Aufl.). Baltmannsweiler: Schneider Hohengehren.
- Schmayl, W. (1982). Das Experiment im Technikunterricht: methodologische und didaktische Studien zur Grundlegung einer Unterrichtsmethode (Texte zur mathematisch-naturwissenschaftlich-technischen Forschung und Lehre, Bd. 11). Dissertation. Bad Salzdetfurth: Franzbecker.
- Walker, F. (2013). Der Einfluss von Handlungsmöglichkeiten auf den Wissenserwerb bei der Durchführung technischer Experimente. Dissertation. Universität Duisburg-Essen. Verfügbar unter urn:nbn:de:hbz:464-20131120-102416-1##, Stand vom 28.08.2024.
- Zinn, B. (2026). Didaktik des naturwissenschaftlichen, informatischen und technikwissenschaftlichen Unterrichts. Grundlagen und Denk- und Arbeitsweisen in interdisziplinären Fächern in Schule und Hochschule. Berlin: Springer Spektrum.



CONTACT DETAILS

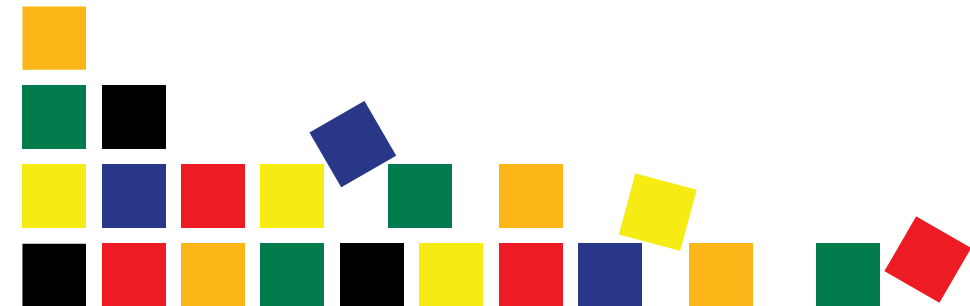
Simon Kammeyer

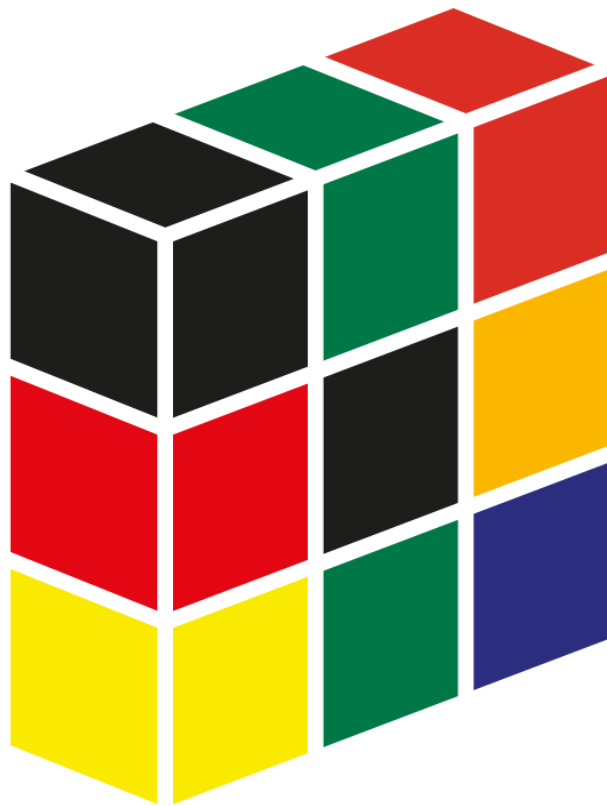
kammeyer@ife.uni-stuttgart.de

Prof. Dr. phil. Bern Zinn

zinn@ife.uni-stuttgart.de

Thank
You





TRAINME3

TVET lecturer training in mechatronics, energy & water management, renewable energies