How to integrate a makerspace in the regular classroom: Pedagogical design, implementation and assessment

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The MAKERSPACE project (INNOVATE/1221/0052)

- Research and Innovation Foundation
- ENGINO
- Research in Science and Technology Education Group
- 24 months; 2022-2024

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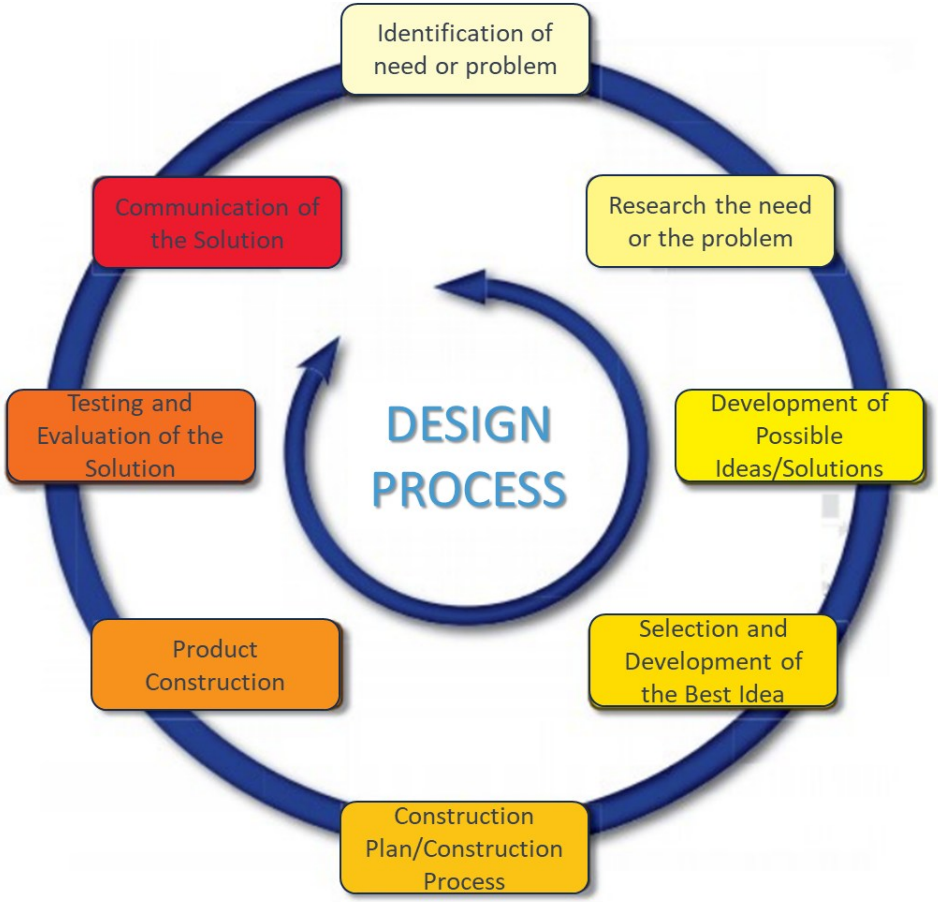
Pexels; Yaroslav Shuraev


Pexels; Skitterphoto

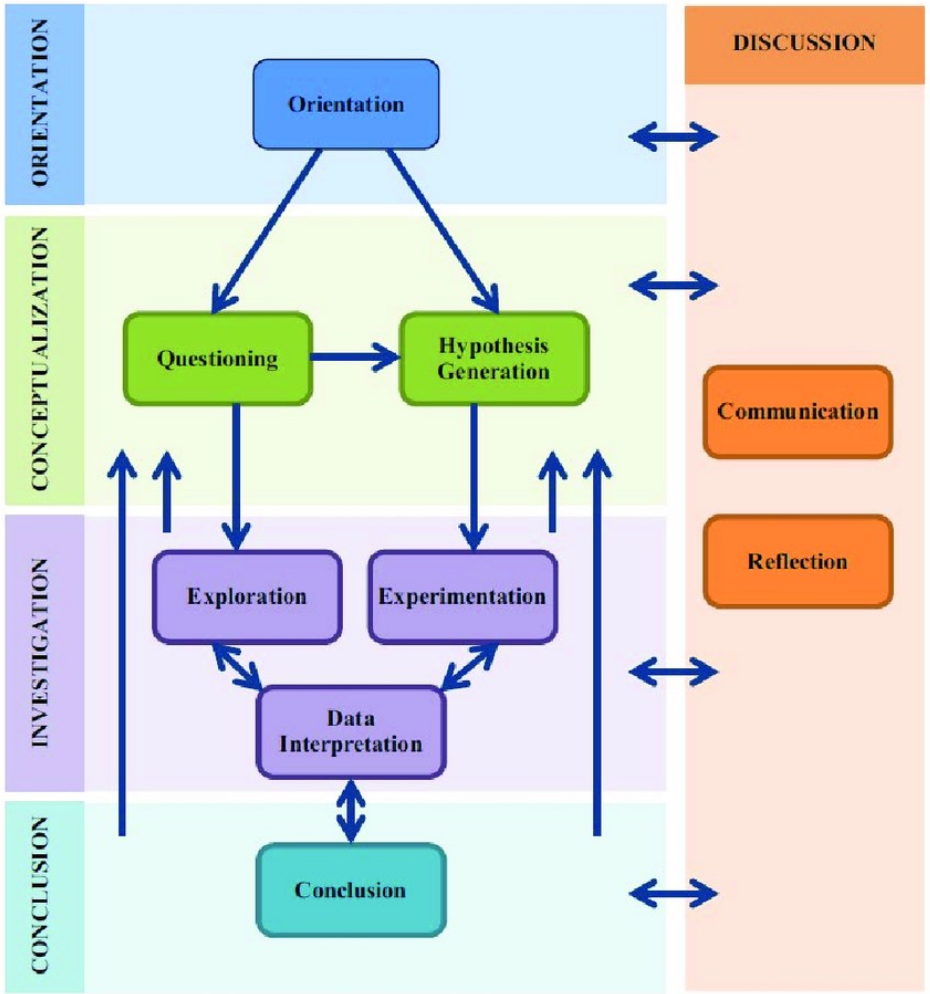

Pexels; Antoni Shkraba

Pedagogical design



Engineering design

Inquiry Cycle (Pedaste et al., 2015)



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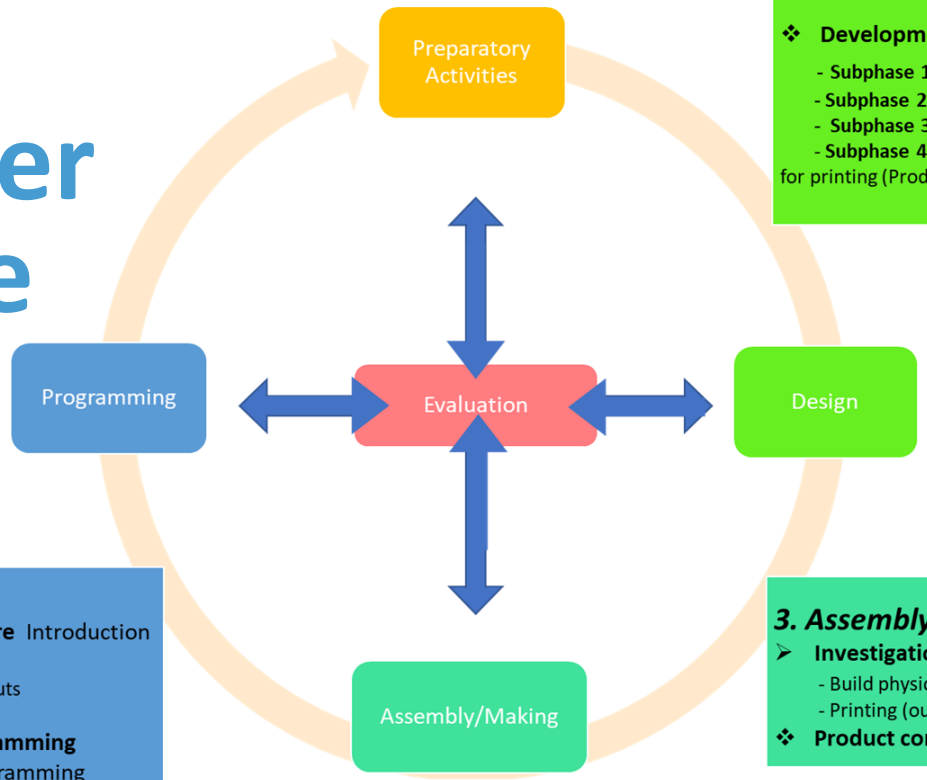
The Maker Cycle



1. Preparatory Activities:

- **Orientation**

The process of stimulating curiosity about a topic and addressing a learning challenge through a problem statement

- **Conceptualization**

The process of stating theory-based questions and/ or hypotheses

- Research (web quest)

- **Identification of need or problem**

2. Design:

- **Investigation**

Exploration and Experimentation of Software Design (Design Software)

- **Development of idea**

- Subphase 1: Blueprint
- Subphase 2: Selection
- Subphase 3: Software design
- Subphase 4: Final artifact ready for printing (Production)

3. Assembly/Making:

- **Investigation; Build**
  - Build physical artefact & model
  - Printing (out of office hrs)
- **Product construction**

4. Programming:

- **Investigation; Explore** Introduction to microcontrollers
  - Inputs (sensors), outputs
  - micro: bit
- **Investigation; Programming** Introduction to programming software (TinkerCAD)
  - Introductory tutorial
- **Programming (micro: bit/ Arduino)**
  - Light sensors
  - Display name tag

5. Evaluation **(Testing and Evaluation of the Solution)**

- **Conclusion; Evaluate**
  - Self assessment
  - Peer assessment
- **Discussion; Communicate**
  - Presentation of the final artefact for feedback
- **Discussion; Reflect**
  - Description, evaluation and discussion
  - Iterations: how do I make my product better?

1. Maker Cycle: Phase and Subphase

2. Learning goals: Curriculum standards

3. Teaching/learning material: Reference material given to students by the teacher

4. Learning activity: What students will do and deliver

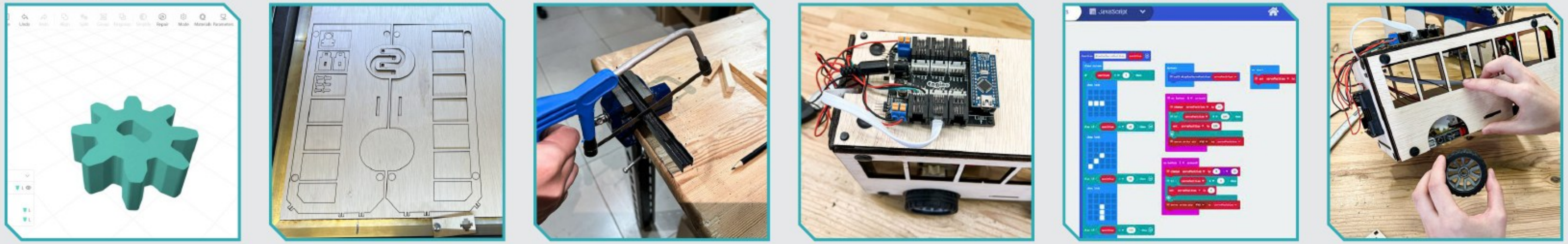
4. Time to complete: Duration, 5- 20 min

5. Class arrangement: Individual, group, whole-class activity

6. Learning artefact: Tangible outcome (physical or digital) produced by students during the learning activity

7. Assessment: Formative, peer, summative

› CAD Design & 3D Printing
› 2D Design & Laser Cutting
› Traditional Wood Work
› DIY Electronics
› Coding & Programming
› Assembly & Testing



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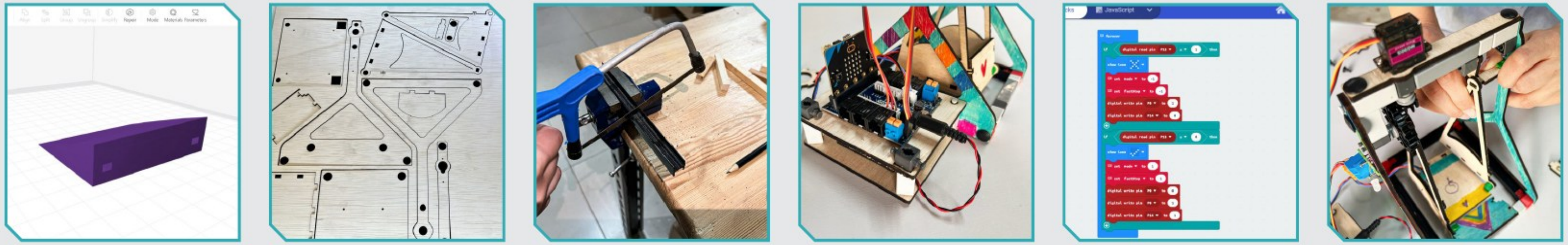

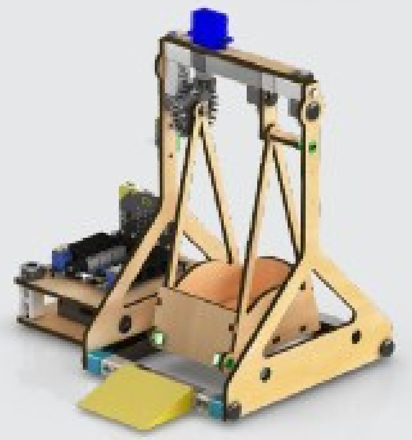

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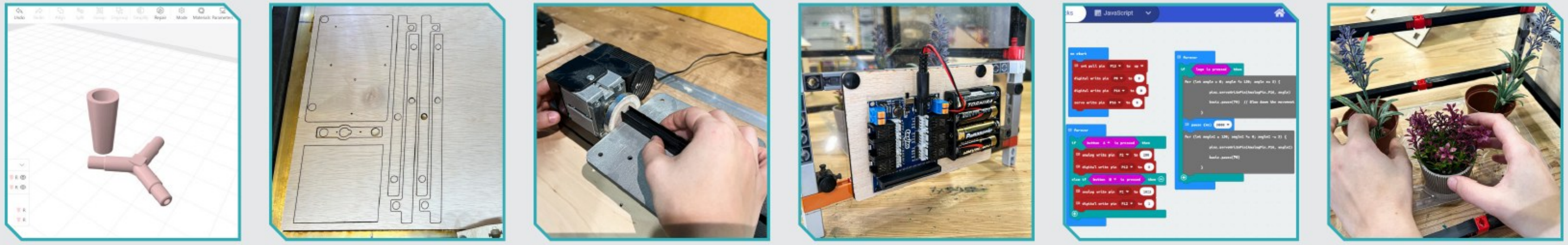

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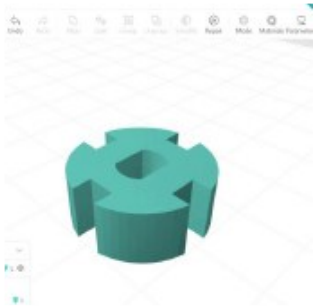
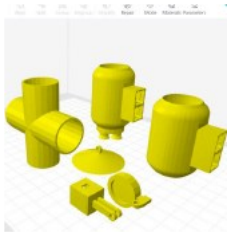
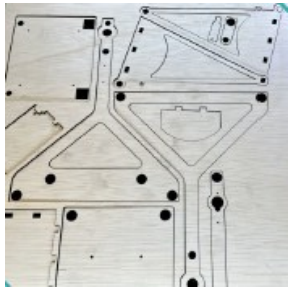
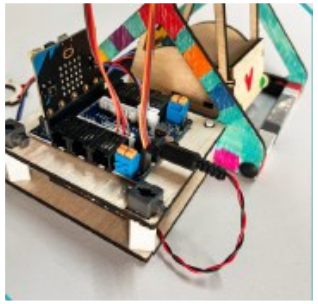
Pedagogical design, implementation and assessment

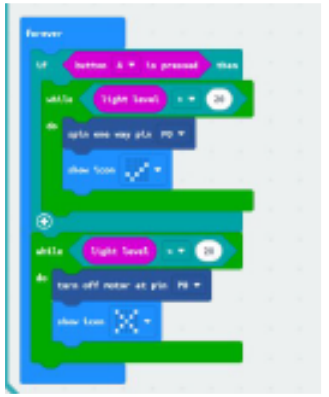
- Literature review
- Participatory pedagogical design
- Design iterations: (1) Basic scenario with the core artefact (scenario for learner engagement); (2) Maker Cycle Phases and subphases; (3) 8 X 80min lesson plans
- Implementations: Summer schools and real classrooms
- Project-based learning: Modular; curriculum anchors; teacher collaboration
- Educational levels: Lower primary; upper primary; lower secondary
- Assessment

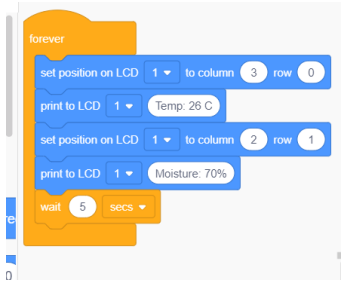












Learning products

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Lesson (duration)	Theme targeted	Related disciplines	Title of learning product
Lesson 1 (40 min)	Introduction to the greenhouse effect	Biology/ Science	1. Internal box temperature: predictions 2. Internal temperature after heating: explanation after experiment 3. Greenhouse effect
Lesson 2 (80 min)	Construction of greenhouse frame	Design & Technology	4. Technologically advanced urban agriculture 5. Safety Questionnaire for jigsaw and sanding
Lesson 3 (40 min)	Programming of the greenhouse's data screen	Computer Science	6. Difference of the block on start and forever 7. Wait command 8. Virtual program for the virtual screen 9. Revised Virtual program for the virtual screen
Lesson 4 (80 min)	3D Printer- 3D CAD software/ design	Design & Technology	10. Safety Questionnaire for 3D printer 11. Blueprints of the tubes' connector 12. Answers for the rubes' connector 13. Answers for the design of the "leg" of the tubes' connector and 3D design 14. Answers for the hole of the "leg" of the tubes' connector 15. 3D design of the final "leg" 16. 3D design of the final tubes' connector
Lesson 5 (40 min)	Design two experiments	Biology/ Science	17. Hypothesis 1 18. Design experiment 1 19. Hypothesis 2 20. Design experiment 2
Lesson 6 (80 min)	Programming of the greenhouse's moisture sensor	Computer Science	21. Moisture- variable 22. Program for the presentation of the moisture data on the virtual screen

Learning products

- Learning products are any (physical or digital) products created by students themselves during learning activities
- Learning products reflect key knowledge, skills and competencies necessary for their creation
- Learning products can be stored in portfolios to be retrieved and reused (reworked, revised, compared)
- Learning products can be used for assessment purposes (peer; formative; summative)
- Learning products can align pedagogical design, implementation, and assessment
- Learning products can be employed for a constructive dialogue between stakeholders

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Assessment

Open-ended learning settings (engineering design; inquiry-based learning)

- How to assess an open-ended learning environment?

Individual work vs. collaborative work

- How to assess learning outcomes, which have been largely based on collaborative work?

Disciplinary silos vs. interdisciplinary projects

- How to assess project-based learning, which builds on several disciplines (integrated STE(A)M)

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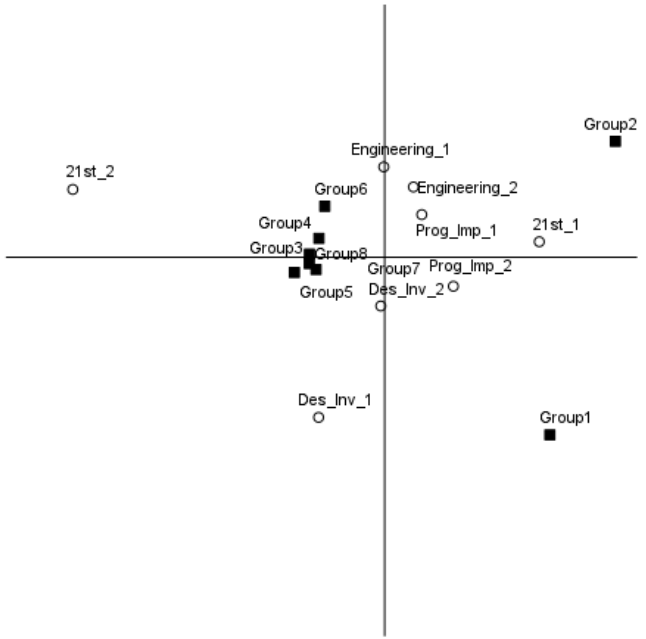
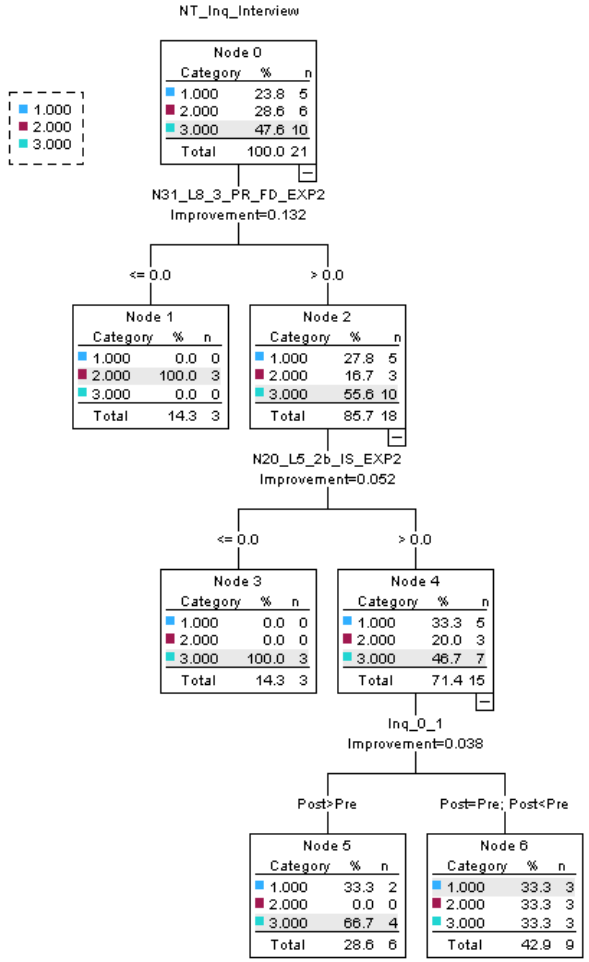
Data sources used for assessment

- Scales with attitude items (attitudes towards science and 21st century skills); self-reported items (e.g. programming self-efficacy) completed by each student in a pre-post test arrangement
- Learning products: Artefacts created by students as they undertook learning activities in groups, using tools and reference material given to them (outcomes of collaborative work)
- Near transfer tasks during interviews conducted with each student separately, which took place after the whole project was concluded

Data analysis: Opening up the “black box”

- Coding of near transfer tasks and learning products
- Pre-post differences between scales
- Group affiliation
- Non-parametric tests
- Multivariate statistics





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