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Interaction Boxes Promoting Scientific Interest in Non-Formal Learning Environments

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Abstract

In times of increasing scientific and technological challenges, fostering scientific education is essential for a scientifically literate society. Nevertheless, numerous studies reveal that interest in STEM subjects declines significantly among schoolchildren in early adolescence. [1]
Non-formal learning environments play a crucial role in science education by providing pupils with practical and motivating learning experiences. [2] Within this work, interaction kits were developed that were specially designed for the afternoon science program in school laboratories - addressing topics with motivating phenomena like magnetism, electricity and optics as examples. These kits contain hands-on experiments that can be carried out with low prior knowledge.
The offer is specifically targeted at middle school students (grades 6 to 8) and is designed to stimulate situational interest through an exploratory and playful approach. Based on current findings on the development of interest, motivation theories and didactic principles, the interaction kits promote a low-threshold and autonomous exploration of physical and chemical phenomena.
They represent a flexible, adaptable concept for developing scientific curiosity and offer methodically prepared materials for effective STEM promotion.
In our contribution, we present the structure of such interaction boxes, the design of which is primarily based on the principles of self-determination theory as well as the four-phase model of interest development. [3-5] The design of the experiments is aimed at promoting inquiry based and collaborative learning.

Keywords: *Scientific interest, interaction boxes, inquiry based and collaborative learning*

1. Introduction

Given the growing scientific and technological challenges, fostering scientific education is essential for a scientifically literate society. However, numerous studies reveal that interest in STEM subjects declines significantly among schoolchildren in early adolescence. [1]
One decisive factor for this decline is the lack of opportunities for active, independent exploration of scientific topics [6]. School laboratories, for example, offer a valuable addition to formal learning opportunities by providing an alternative approach to science via hands-on experiments. While they offer many pupils new learning stimuli, it can be a challenge for less motivated pupils to engage with the - often-complex – scientific content without prior knowledge. This is precisely where the interaction boxes become interesting with a low-threshold and playful approach to scientific phenomena.
Therefore, objective of this work is to develop an explorative educational format that is especially aimed at middle school students (can also be extended to students of higher age): Interaction boxes with hands-on experiments that can be used in the afternoon science program of school laboratories (or other non-formal learning environments). The boxes intend to enable a playful, independent and low-threshold exploration of scientific and, in particular, physical and chemical phenomena and thus create the basis for a long-term development of interest.

2. Theoretical Background

2.1 Interest and Motivation in MINT Education

Crucial for STEM education is to get learners sustainably interested in science, technology, mathematics and IT. Therefore, motivation and interest development play an essential role, as

learning processes are often challenging in these subjects in particular and a deeper understanding must be built up over a long period of time. [5-7]
Long-term interests can be developed if a person evaluates an object as significant on the basis of cognitive-rational considerations and if the positive emotional qualities of experience also predominate in the course of the object-related engagement. The positive qualities of experience relate to three basic psychological needs that have been identified within the self-determination theory of motivation [3,8]:

- **Autonomy**: Learners should have the opportunity to develop their own issues, carry out experiments and try out their own solutions. In STEM education in particular, this can be supported by open tasks, research-based learning and exploratory experiments.
- **Competence**: Scientific and mathematical concepts are often abstract and solving problems can be challenging. Therefore, it is important to provide positive learning experiences and a small sense of achievement to boost confidence in their own abilities. This can be encouraged through clear feedback, adaptive difficulty levels and interactive experiments.
- **Social Integration**: Cooperative work is particularly relevant in the STEM field, as scientific findings are often developed in teams. Exchange and discussion, for example in group experiments or joint problem-solving processes, can not only deepen understanding but also increase the motivation.

Recurring to these principles, the interaction boxes were considerately designed to facilitate meaningful engagement and enhance the pupils' learning experience. The interaction boxes enable independent and cooperative experimentation, give learners direct feedback on their actions and provide opportunities for social interaction. The aim is both to awaken enthusiasm for STEM subjects and to strengthen learners' expectations of self-efficacy by enabling them to actively investigate scientific phenomena and finally understand them.
In addition to motivation, the development of interest also plays a central role. According to the four-phase model [4], interest is typically developed in several stages, illustrated in Figure 1.

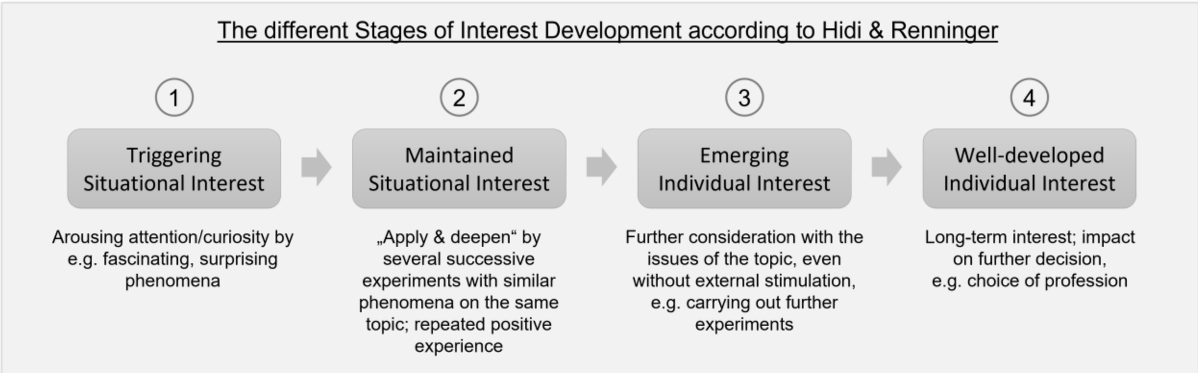

Fig. 1. Schematic illustration of the four phases for interest development according to Hidi & Renninger. [4]

1. **Triggering Situational Interest**: Initial curiosity is aroused by a fascinating or surprising experience, for example by unexpected physical effects, chemical reactions or interactive simulations.
2. **Maintained Situational Interest**: Repeated positive experiences with the topic stabilize the initial interest, for example, when learners carry out several consecutive experiments or are able to test their own hypotheses.
3. **Emerging Individual Interest**: Learners begin to engage with STEM topics voluntarily and self-directed, for example, through further reading or additional experiments.
4. **Well-developed Individual Interest**: The interest is deeply rooted and has a long-term impact on learning decisions and potentially also career choices.

As the first two stages in particular are crucial for the development of a lasting interest, the interaction boxes were deliberately designed in such a way, that they were initially intended to arouse interest by fascinating phenomena and then maintain this interest in the next phase. This is achieved by a combination of sensory stimuli, interactivity, direct feedback and playful elements that enable an immersive learning experience. At the same time, it is attempted to promote initial approaches to self-directed learning by leaving enough space for individual exploration during the experiments.

3. Design of the Interaction Boxes

3.1 Educational Principles

The interaction boxes offer a motivating and low-threshold approach to scientific topics and enable a sustainable learning experience due to their design. They are designed to promote explorative learning, to be understandable without barriers, to address different sensory channels and to enable alternative forms of documentation.

Explorative Learning

Instead of providing fixed procedures or ready-made instructions, the experiments encourage students to gain knowledge by their own observations, hypotheses and systematic experimentation. Open issues and variable experimental conditions support an individual exploration and creative problem-solving procedure.

Low-threshold Accessibility

The experiments are designed in such a way that they are understandable without specific specialist knowledge and provide an intuitive introduction to scientific physical and chemical concepts. The focus is on comprehensible language, everyday contexts and reduced technical complexity in the first encounter with the topic. This facilitates access, especially for pupils with little previous experience or initial uncertainty about scientific content.

Multi-sensory Approach

The experiments are designed to activate different channels of perception and thus promote multisensory learning processes. In addition to visual perception, haptic and acoustic stimuli as well as interactive elements are specifically integrated to enable a broader cognitive processing. Multisensory approaches have proven to be beneficial for understanding complex scientific concepts, as they address different learning preferences and facilitate the linking of new information with existing knowledge structures.

Alternative Forms of Documentation

Digital forms of documentation such as video recordings or dialogical reflection formats increase learners' motivation and promote sustainable learning. The active use of media enables a deeper examination of the experiments by individually processing and linking findings. These flexible methods support creative and independent exploration of scientific content.

3.2 Design and Structure

The concept includes ready-to-use interaction boxes containing hands-on experiments that the pupils can carry out independently with minimal instruction from a supervisor. A group of about four pupils works with one of the boxes. Each interaction box on a specific scientific topic contains a selection of approximately 4-5 experiments with the corresponding supporting material for each experiment. The experiments are designed to enable a step-by-step approach to the respective topic and can be flexibly adapted to different age groups and levels of prior knowledge. Each experiment follows a fixed structure, described in the following and illustrated in Figure 2.

Introduction: A short introduction places the experiment in an understandable context, often with reference to an everyday application or problem. This arouses the learners' interest and facilitates access to abstract scientific concepts.

Experimental Phase: Pupils experiment independently, develop hypotheses and vary the experimental conditions. The experiments are designed in such a way, that they offer scope for students to ask their own issues and enable explorative learning. Autonomous research is also supported by “question-cards” in order to avoid frustration during this phase if they don´t know what to do next.

Reflection and Discussion: After the experiment, the learners share their observations, formulate their own explanations and compare them with scientific explanations. This step serves to deepen the knowledge and helps to integrate the experimental findings into a larger subject concept.

Documentation: In order to make the learning process sustainable, various forms of documentation are offered. In addition to traditional written protocols, learners can record their results by videos, discussion protocols or photo stories. This enables more individual reflection on the experiments and promotes both media skills and the ability to communicate scientifically. The common structure of the interaction boxes is schematically illustrated in Figure 2.

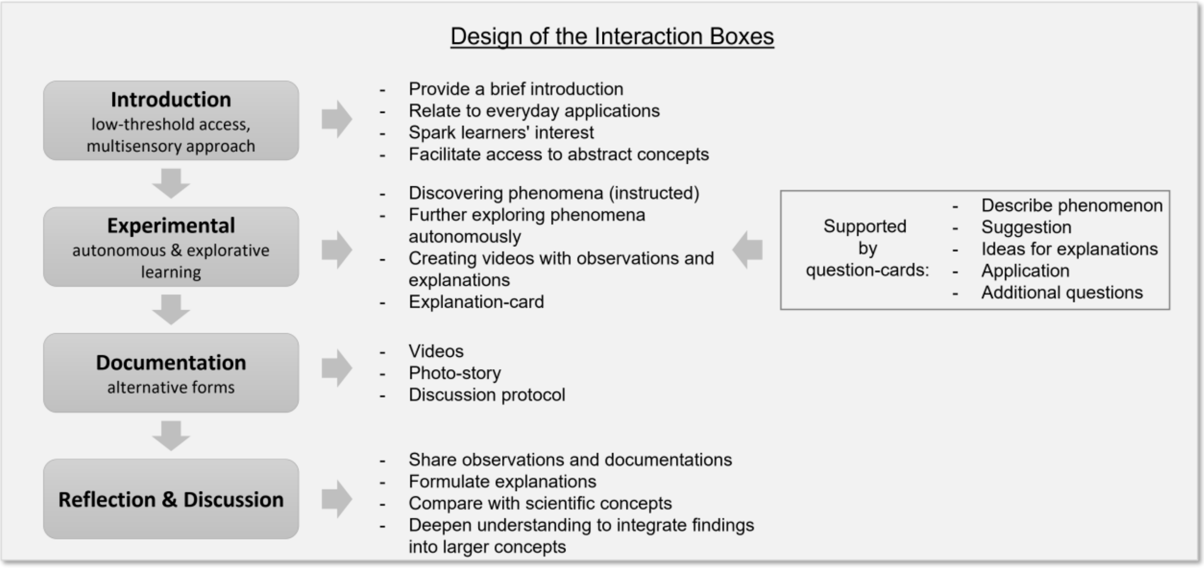

Figure 2. Schematic illustration of the design and structure of the interaction boxes.

3.2 Examples for Interaction Boxes

Interaction Box "Magnetism and Electricity"

The box with the topic "Magnetism and electricity" contains experiments on electromagnetic induction and on interactions between electric currents and magnetic fields. Figure 3, for example, shows a photograph of the experimental setup and supporting materials of this interaction box "magnetism and electricity". The various experiments included are listed below:

- Falling magnets: Magnets fall through metal tubes, inducing currents in non-magnetic metals.
- Magnet generator: A moving magnet in a coil generates electricity and lights up an LED.
- Mini-motor: Demonstration of the Lorentz force and its effect on a current-carrying wire.
- Magnetic track: It shows the same principle as in the "Mini-motor" experiment.
- Broken pendulum: It demonstrates the same effect as in the "Falling magnets" experiment, but with a directly perceptible effect.

Figure 3: Photograph of the interaction box on the topic "Magnetism and Electricity": experimental setup with the supporting materials.

4. Conclusion

The developed interaction boxes represent an innovative and didactically comprehensive concept for promoting scientific interests. The targeted combination of hands-on experiments, explorative learning and flexible documentation methods creates a low-threshold approach to physical or chemical questions. This approach takes into account central principles of modern STEM didactics by promoting self-directed and cooperative learning, addressing different cognitive approaches and supporting individual learning processes.

This concept provides school labs or other non-formal learning environments with an adaptive teaching and learning setting that is particularly suitable for middle school students whose prior experience and interests in the natural sciences are heterogeneous. The interaction boxes make it possible to explore physical or chemical concepts via active engagement and create positive learning experiences that can contribute to a stronger identification with STEM topics in the long-term.
In perspective, the described concept offers potential for expansion to include additional scientific subject areas, such as acoustics or mechanics, as well as for the development of an accompanying digital platform with interactive explanatory videos, simulation-based learning opportunities and further materials for in-depth exploration of the performed experiments.

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