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STEM DIGITALIS

EDUCATOR GUIDE

- INTERFEROMETRY -

PART OF THE INTELLECTUAL OUTPUT 3

Responsible partner: LUH

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Chapter 1: Introduction

This document serves as an Educator's Guide for the implementation of the Interferometry scenario.

It contains an overview of the Interferometry scenario structure and after that a detailed description of each individual unit and activity. Each activity is described in terms of a five-dimensional framework, providing information about the activity's timing, mode, approach, group synthesis and the types of media used (for more details please see IO2).

	Icon used to indicate information about the way of conducting each activity in terms of the 5-dimensional framework

Moreover the Educator's Guide includes hints for the instructors, indicating possible pre-service teachers' difficulties and ways to help them overcome them. These hints are indicated by a green frame, as shown in Figure 1.

Hint:
In the sense of a flipped classroom setting, the preservice teachers should first work out the basics of wave theory independently in order to be able to recognize individual problems, which can then be discussed together with the lecturer in activity 1.2.

Fig. 1 Example of a "Hint box"

Finally, suggestions of alternative ways to conduct each activity, for example if someone wants to look at different types of interferometers in more detail, are also provided. These alternatives are indicated by an orange frame, as shown in Figure 2.

Alternative:
If the lecturer considers the independent development of the basics of wave theory too demanding for the preservice teachers, he or she can of course also teach these basics in the traditional way. In this case, the modes of activity 1.1 and 1.2 would be reversed. That is, activity 1.1 would be taught face to face, and activity 1.2 would be conducted individually by the preservice teachers for a follow-up at home.

Fig. 2 Example of an "Alternative box"

Chapter 2: Why the topic of "interferometry"?

Interferometers in their various designs have long played a central role in the natural sciences. The negative outcome of the Michelson-Morley experiment in the 1880s disproved the ether theory and paved the way for Einstein's theory of relativity.

Today, interferometers can be used to investigate important material properties. Extremely precise measurements are also possible. In astronomy, enormous resolutions can be achieved with interferometrically arranged telescopes. Recently, it has even been possible to detect gravitational waves using interferometers, opening up completely new doors for astronomy.

In this way, interferometers make a significant contribution to expanding our scientific understanding of the world. Therefore, many curricula require the use of interferometers in the classroom.

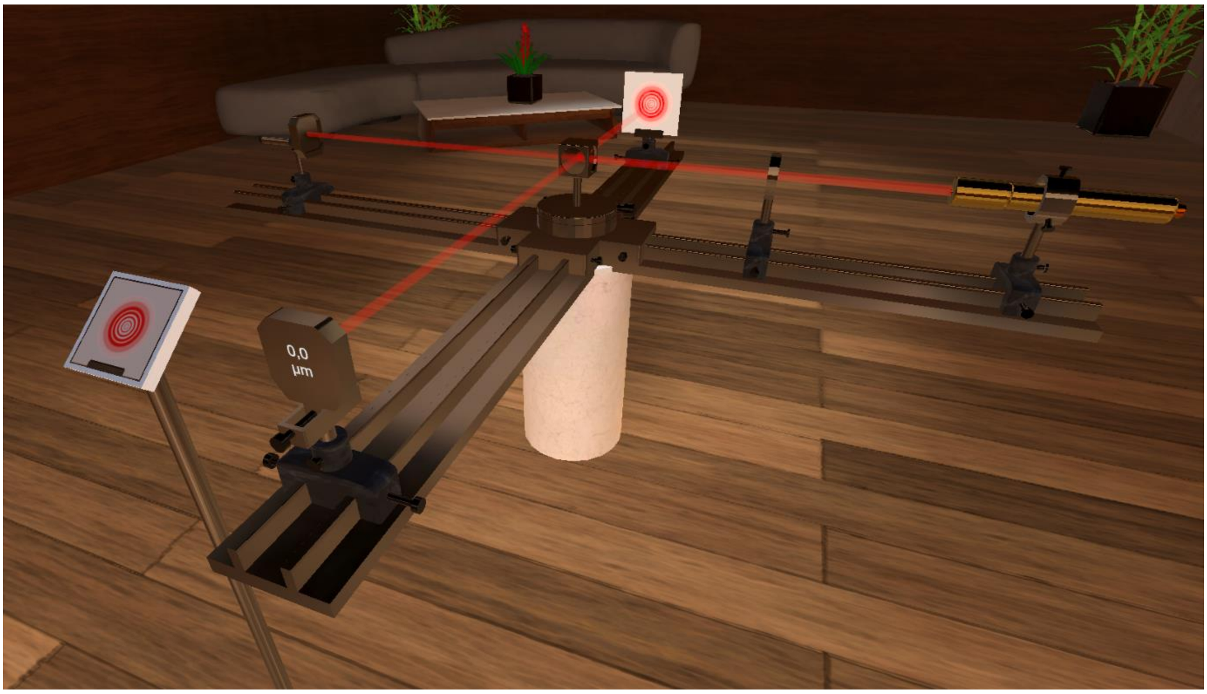

Fig. 3 Michelson Interferometer in a virtual reality surrounding developed by the LUH working group

Chapter 3: Structure of the Digital Scenario

The Interferometry scenario consists of three units:

- Unit 1: Introduction into Interferometry
- Unit 2: Applications of different Interferometer Types
- Unit 3: Detection of Gravitational Waves

In Unit 1 pre-service teachers are introduced to the wave model of light and the characteristic quantities of waves. They experience the effects of the superposition of waves and learn about the double-slit experiment and its results. The basics of the phenomenon of interference will be discussed in this context.

In Unit 2, pre-service teachers learn about the functioning and possible applications of the Michelson interferometer. They vary settings on the Michelson interferometer and thereby experience the effects of the superposition of waves. In addition to the Michelson interferometer, preservice teachers can also learn about other types of interferometers such as the Mach Zehnder interferometer and the Sagnac interferometer.

In Unit 3, pre-service teachers learn how Michelson interferometers are used in the search for gravitational waves from cosmic events and get to know the latest results in this area.

The three units comprise an extensive array of activities which are designed to be used and adapted by educators regarding to their needs. While all the activities may be completed in full, it is also possible to select a subset of activities, to reorder activities, to implement activities using different approaches and to supplement activities with your own. An example of a learning sequence are presented in Figure 1.

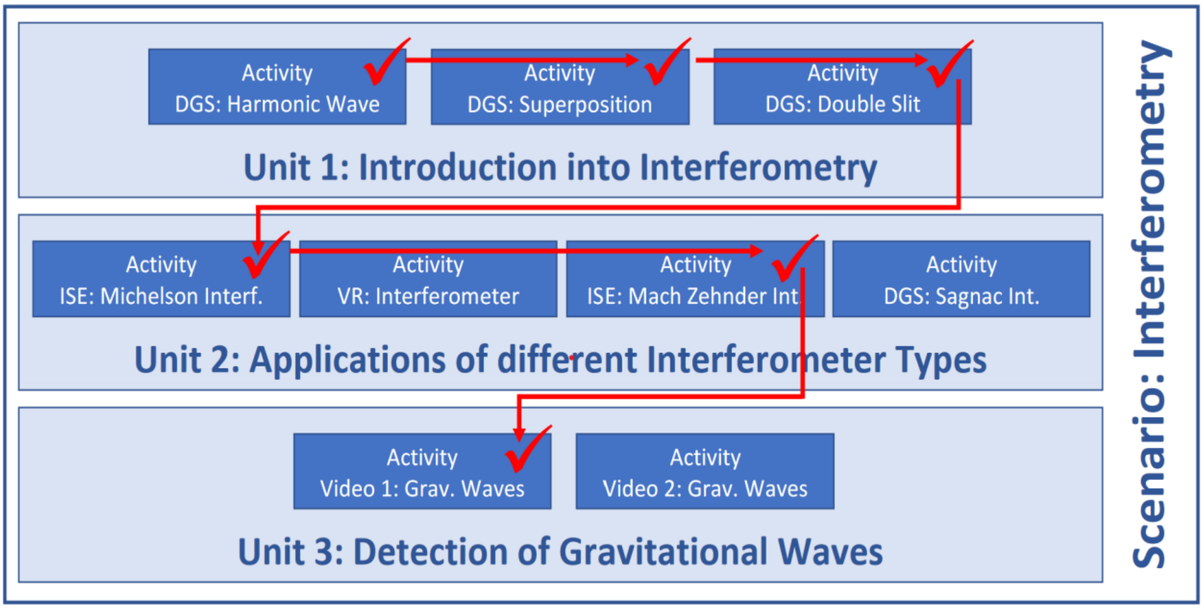

Fig. 4: Proposed sequence for Interferometry scenario Units & Activities

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Chapter 4: Implementation

Unit 1: Introduction into Interferometry

Activity 1.1

In this activity students become familiar with the basics of wave theory in a flipped classroom setting. This means that the preservice teachers work independently on the basic quantities and relationships of wave theory using digital interactive worksheets in a dynamic geometry environment in preparation for Activity 1.2.

Activity 1.1 is student led and it's suggested that it is run in an asynchronous, online session. Students work individually and develop their understanding through discussion and comparison of solutions.

Hint:
In the sense of a flipped classroom setting, the preservice teachers should first work out the basics of wave theory independently in order to be able to recognize individual problems, which can then be discussed together with the lecturer in activity 1.2.

Alternative:
If the lecturer considers the independent development of the basics of wave theory too demanding for the preservice teachers, he or she can of course also teach these basics in the traditional way. In this case, the modes of activity 1.1 and 1.2 would be reversed. That is, activity 1.1 would be taught face to face, and activity 1.2 would be conducted individually by the preservice teachers for a follow-up at home.

Digital media used during this activity include:

- https://www.youtube.com/watch?v=R8kCskG7hKI
- https://www.geogebra.org/m/eaqzrx5m

Activity 1.2

This is the follow-up activity to activity 1.1. Here, the problems that the preservice teachers had during their development of the basics of wave theory during activity 1.1 are discussed in particular. In this context, it is also possible to work together with digital media to illustrate these problems.

Activity 1.2 is suggested to be conducted in a synchronous, face-to-face setting. Students work in groups or all together with the teacher. In this sense the activity is mainly teacher-led, because even if the preservice teachers work in groups teacher input is important.

Hint:
At this point, it is important that the basics of wave theory and the characteristic variables that define a wave are understood by all preservice teachers in the course of the joint discussions.

Alternative:
If activity 1.1 is present and teacher led, activity 1.2 must be converted accordingly to an individual exercise session, preferably carried out at home.

Digital media used during this activity include:

- https://www.youtube.com/watch?v=R8kCskG7hKI
- https://www.geogebra.org/m/eaqzrx5m

Activity 1.3

In line with the flipped classroom setting, the preservice teachers now carry out this activity individually at home again. Here the findings about waves are to be applied to the question of what happens when waves overlap.

Activity 1.3 is presented here as an asynchronous activity which can be conducted as individual work with online material. In the case of students working together in groups, they could do so face-to-face or using an online platform. The activity is student led.

Hint:
As in the case of activity 1.1 the preservice teachers should first work out the content independently in order to be able to recognize individual problems, which can then be discussed together with the lecturer in the following activity. This corresponds to the idea of the flipped classroom setting.

Alternative:
If the lecturer considers the theoretical background of the idea of superposition of waves too demanding for the preservice teachers, he or she can of course also teach these basics in the traditional way. In this case, the modes of activity 1.3 and 1.4 would be reversed in a similar way as described in activities 1.1 and 1.2 respectively.

Digital media used during this activity include:

- https://www.geogebra.org/m/dg63j7m2

Activity 1.4

In this activity the teacher demonstrates the double-slit experiment, then the students work with a simulation to make themselves familiar with this experiment.

Activity 1.4 is presented here as a student-led discussion, which takes place in a face-to-face, synchronous setting. After having seen a (teacher-led) experiment students work individually first, before sharing their findings in small groups and then with the whole class (think-pair-share).

Hint:
At this point, it is important that the preservice teachers get to know a real-life experiment on the double slit. The use of visible light is ideal because this comes closest to Thomas Young's original setup and the splitting into the spectral components of light is particularly impressive.

Alternative:
Alternatively, a film of the experiment or a simulation could be shown. However, neither can fully replace the impression of a real experiment. In addition, the preservice teachers learn about a simulation in the following central exercise.

Digital media used during this activity include:

- https://www.geogebra.org/m/m7cqruz7

Unit 2: Applications of different Interferometer Types

Activity 2.1

Students choose from material of the showcase (see unit 1) to become independently familiar with the functioning of the Michelson interferometer. E. g.: ISE Michelson Interferometer, dynamic geometry applet (Brockmann-Behnsen, 2022):

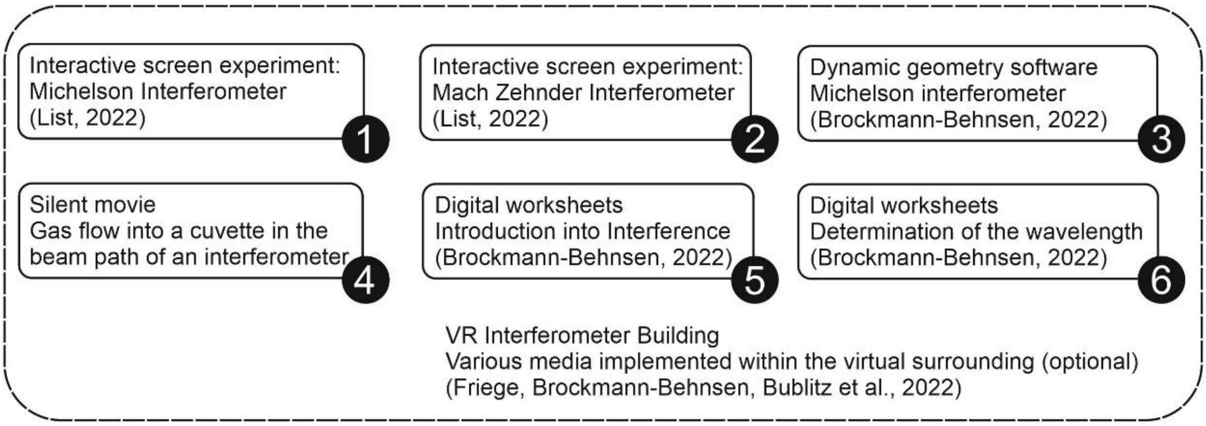

Fig. 5: *Showcase for unit 2 of the "Interferometry" scenario*

Activity 2.2 is student led, and is conducted asynchronously, in a online setting. Students work individually to familiarise themselves with the functioning of a Michelson interferometer.

Hint:
The preservice teachers have different possibilities to deal with the functioning of a Michelson interferometer. They can choose the one that appeals to them most from a collection of corresponding materials (showcase).

Alternative:
If it is possible to present a real Michelson interferometer, this is of course preferable. In this case, the digital materials of the showcase could be used by the preservice teachers for individual follow-up work.

Digital media used during this activity include:

- https://tetfolio.fu-berlin.de/tet/1748211
- https://www.geogebra.org/m/xnthawdb

Activity 2.2

This is the follow-up activity to activity 2.1. Here, the experiences and findings that the preservice teachers had while working with the digital materials of the showcase are discussed.

Activity 2.2 is conducted in an online conference or face-to-face, synchronously and is teacher led. Students work as a whole group together with the teacher. The teacher concludes the activity by facilitating a discussion and summarising the learning.

Hint:
At this point, it is important that the preservice teachers understand the structure and function of the Michelson interferometer so that they can experiment with the interferometer independently in the following activity.

Alternative:
Alternatively, the preservice teachers could explain to each other how the Michelson interferometer works and then present the results in plenary so that the teacher can get an idea of the preservice teachers' level of knowledge.

Digital media used during this activity include:

- https://tetfolio.fu-berlin.de/tet/1748211
- https://www.geogebra.org/m/xnthawdb

Activity 2.3

Students conduct experiments on the Michelson interferometer (in virtual reality).

Activity 2.3 is conducted asynchronously and in a face to face setting. Students work individually with ISEs or in pairs (one carrying der VR glasses, the other one taking care of him or her. The activity is student led, with the teacher acting as a minder and consultant.

Hint:
The simplest way of carrying out interferometer experiments is to use interactive screen experiments (ISEs). If the experiments should be carried out in a virtual environment half a class set of VR glasses must be available.

Alternative:
If the technical requirements, especially the VR glasses, are not available, the preservice

teachers can also carry out the experiment (determining the wavelength of the laser) using an interactive screen experiment (ISE) from the showcase (see Fig. 5). This has the advantage that it can also be carried out individually outside the classroom at any time.

Digital media used during this activity include:

- https://www.youtube.com/watch?v=i_cpK3-yZfU
- https://www.youtube.com/watch?v=TZnqYdUIV14

Alternatively: ISE:

- https://tetfolio.fu-berlin.de/tet/1748211 (Experiment 1)

Activity 2.4

As soon as the structure and function of the Michelson interferometer are understood and the first experiments with this type of interferometer have been carried out, the topic will be explored in greater depth in this activity. On the one hand, further experiments can be carried out with the Michelson interferometer, such as determining the expansion coefficient of aluminium. On the other hand, the preservice teachers can familiarise themselves with other types of interferometers such as the Mach Zehnder interferometer or the Sagnac interferometer.

Activity 2.4 is student led, and is conducted synchronously, in an online setting. Students work individually and choose the type of specialisation independently.

Hint:
In this activity, the preservice teachers should look for in-depth topics according to their own interests and work on them.

Alternative:
The individual selection of an in-depth topic already offers alternatives.

Digital media used during this activity include:

- https://tetfolio.fu-berlin.de/tet/1748211 (Experiments 2 to 4)
- http://tetfolio.de/web/1799622
- https://www.youtube.com/watch?v=pFWBfaM1OPU&t=77s (Silent Video to ensure understanding of the topic)

Activity 2.5

Students get together in topic-led groups and create posters on their findings. The posters are discussed together (method: museum-tour).

Activity 2.5 is teacher led, and is conducted synchronously, in a face-to-face setting. Students work in topic-led groups to complete the activity.

Hint:
The preservice teachers get together in groups depending on the in-depth topic and discuss their findings. They then present these findings on posters, which are displayed in the classroom. Together, the group goes from poster to poster and explains their content. The teacher moderates this process.

Alternative:
If this activity has to be carried out online, the presentations can also be made using a digital presentation tool.

Digital media used during this activity include:

- https://www.youtube.com/watch?v=pFWBfaM1OPU&t=77s (Silent Video to ensure understanding of the topic)

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Unit 3: Detection of Gravitational Waves

Activity 3.1

In this learn how Michelson interferometers are used in the search for gravitational waves from cosmic events.

Activity 3.1 is student led, and is conducted synchronously, in an online setting. Students work individually to inform themselves about the use of interferometers to detect gravitational waves..

Hint:
As part of this activity, the preservice teachers should familiarize themselves with factual films from the Internet about the topic.

Alternative:
If there is an institution nearby that deals with gravitational waves, an excursion to this institution could be organized. In Hanover, for example, there is the GEO600 gravitational wave detector and the Albert Einstein Institute.

Digital media used during this activity include:

- https://www.youtube.com/results?search_query=gravitational+waves (Example for an online video)
-

Activity 3.2

In Activity 3.2 students and teacher discuss the findings from Activity 3.1 in a present or online conference.

Activity 3.2 is conducted synchronously and in a face to face setting and is led by the teacher as a moderator.

Alternative:
This activity could also be facilitated in an online setting.

Digital media used during this activity include:

- No digital material required