CHAPTER 4
THE UNIQUE NATURE OF PHYSICS IN CHOOSING AND IMPLEMENTING PRINCIPLES OF ORDERING

As indicated in the previous chapters, when choosing and implementing principles of ordering, it is necessary to thoroughly consider the unique nature of the subject.

4.1 THE UNIQUE NATURE AND STRUCTURE OF PHYSICS

It is not possible, and also not the aim of this study, to give a complete exposition of the nature and structure of physics. Before meaningful ordering learning content, there must be an accurate indication of the unique nature and structure of the subject of concern. If this is not considered, a teacher's presentation easily can lead to a distorted appearance of the slice of reality being presented. Therefore, a few characteristics are indicated about the unique nature and structure of physics which can be important for didactics, in general, and for decisions about ordering learning material from physics. With the aim of ordering physics content for lesson situations, special attention is given to the following aspects of the subject:

Its field of study.
Its language.
Its validity.
Its typical methods.

4.1.1 Field of study

A physicist has the task of trying to arrive at valid conclusions about basic concepts and relations resulting from investigating natural phenomena. Thus, his/her field of study is comprehensive and difficult to delimit. In its broad sense, physics arrives at conclusions about the concepts of *matter* and *energy*. Consequently, phenomena such as time, space and movement also have relevance.

In the secondary school, the study of physics is directed mainly to the field of classical physics, in which there are formulations of causal laws for natural phenomena. At this level, however, a teacher must take care to not present these “natural laws” in a deterministic sense. Here, teaching involves less finding “the truth” or “ultimate reality”, and it must be directed to indicating the “immediate” validity of the conclusions which are drawn. In other words, the truth of a theory and the formulation of a law are only justified to the degree that it is valid with respect to the data available and interpreted. The unveiling of new insights and relationships might compel a physicist to modify or even entirely erase existing theories.[47] In this regard, from history, examples can be mentioned from optics, sound, electricity, and magnetism, where change and/or amplification became necessary. Mechanics, especially as developed by the insights of Newton, must be viewed as one of the cornerstones of the study of classical physics. However, before ordering specific physics themes meaningfully, especially because of their inherent structure-patterns and typical methodological approaches, it is necessary to indicate the actual problems which exist and with which a teacher can be confronted. We refer only to a few matters of which a teacher must have the necessary knowledge which might crop up in planning (also ordering) a theme such as quantum theory. Here it is important to know that the idea that energy exists as particular quantities or quanta and can be transmitted, first appeared in the 19th century. Max Planck had jumped at the idea, and further developed it. This enabled him to solve problems that classical physics previously could not. In linking up with quantum theory, Einstein formulated his well-know photon theory. This contributed to explaining certain phenomena which now are acceptable. These views, disclosures and findings regarding quantum theory brought about a complete revolution in theoretical physics. Compared with this, and about matters still opposed, de Broglie came to the revolutionary idea that matter must be described in terms of its wave characteristics. He further confirmed his view by making a mathematical argument for it. Experiments planned and carried out afterward have shown that a stream of electrons, which earlier were viewed only as particles, also produce a pattern of defraction, i.e., a typical wave pattern. This

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[47] Alberts, L., *Bulletin van die S.A.V.C.W.,*no. 21, January 1970, p. 15.

disclosure ultimately gave rise to an additional theory in which Schrodinger maintains that each electron must be associated with its wave function. This led to the general view that the probability is greatest that an electron will be found within a small area around the nucleus. According to Heisenberg, who worked more mathematically-logically, there is a definite limit to the preciseness of the simultaneous measurement of the position and momentum of an electron, with the assistance of any measuring instrument. This also, then, is the essential difference between the abstractness and exactness of the natural sciences and mathematics. The degree of exactness of the former always is in relation to the accuracy of the measures. The uncertainty regarding the position of the electron is expressed by the following connection: (uncertainty regarding position) X (uncertainty regarding momentum) = Planck's constant.[48]

From the above, the explanations and descriptions of phenomena by physicists continually are changing and, in a chronological ordering, the same theme will show itself in new attire. This knowledge, which asks for a new interpretation with each new insight, has relevance for ordering learning material. More specifically, we thimk of problems which are going to surface with the implementation of the various principles of ordering. This is attended to in detail later.

4.1.2 Its language

Among other things, physics is involved in the empirical verification, scientific evaluation, and systematization of knowledge about natural phenomena. Schematizing contributes to the scientific description and explanation of the "knowable" and makes it easier to bring about possibilities of actualization. There must be an attempt to name the concepts and, thus, be able to formulate a theory and state its validity beyond any doubt. Before the theoretical results about natural phenomena in physics can acquire validity for practice, they must be empirically verified. Any refined and scientifically correct formulation of a theory requires thorough knowledge and mastery of the specific "subject matter language". However, to point out the sense and meaning of quantitative

[48] Schutte, H.J., *Bulletin van die S.A.V.C.W.,* no. 7, December 1966, p. 178.

relations, which sometimes are necessary for understanding natural phenomena, and to be able to fully utilize them, mathematical manipulations often are used. By means of mathematical manipulations and methods, it is possible for a physicist to indicate mathematical-functional connections between separately measurable characteristics of a phenomenon of nature. The use of more exact and refined mathematical techniques gives physics a greater claim to a degree of validity and abstractness. It especially acquires validity in so far as it shows agreement with practice. Thus, each theory of physics has two moments:

- A formal mathematical moment.
- An empirical moment (i.e., an interpretation of the mathematical part in terms of experiencing nature itself).

From the above, the close connection between physics and mathematics is of great significance for any choice of teaching principles.

4.1.3 Its validity

Even though in physics there must and can be a form of exactness, still none of its findings can claim to be the complete "truth", to have unchanging validity or be lawful in a deterministic sense. Up to and including the beginning of the 20th Century, very few persons doubted this view about the absolute validity of the laws of physics because, at the time, physicists believed that "valid" explanations had already been found for most phenomena of nature. With the rise of quantum mechanics, and the success of the theories connected with it, the tendency then arose to endorse a more indeterministic standpoint.[49] However, today, both these standpoints are unacceptable. The acceptability of any physics theory always is dependent on the foreknowledge (knowledge) which contributes to the anticipation of a possible explanation (hypothesis). With the advancement of knowledge, new and qualified findings continually arise which, accordingly, increase or decrease a physicist's faith in the premise.

[49] Schutte, H.J., op. cit., p. 181.

To be able to formulate theories and laws for physics, physicists must work in specific and typical ways when there is a search for empirical verification. The form of this methodological work is significant for didactics, especially with the aim of ordering learning material. Therefore, this aspect is now attended to in detail.

4.1.4 Its typical methods

In most natural science subjects, the hypothesis-verification approach is so prominent that there is general reference to a natural science method. On closer investigation, the following typical characteristics are distinguished:

a) *The motivation and stimulation arising from a meaningfully stated problem*

There is always a clearly stated problem such as:

i) What relationships can be inferred among the pressure, volume, and temperature of a mass of gas in a closed container?

ii) Is there any relationship between the mass and volume of matter?

iii) Explain ebb and flow, etc.

b) *A preliminary empirical investigation with the aim of broadening experience (foreknowledge)*

For example, with a class discussion, clarity can be attained about the (quantitative and qualitative) nature of the foreknowledge the pupils have at hand. Then, there can be a corresponding choice of what experience must initially be brought forward to give them an opportunity to arrive at a solution to the problem.

c) *Classifying and schematizing*

The empirical data now are classified and compared to determine if there is any regularity. It is not always easy to inductively see a general law or relation among several separated examples and data. Often there will be a need for further analysis and comparison.

d) *Formulating a hypothesis*
From the regularity found, a hypothesis now is formed. Usually, this generalization, based on the earlier experiencing, is only a preliminary or possible explanation of the stated problem.

e) *Deductions from obvious characteristics of the hypothesis*

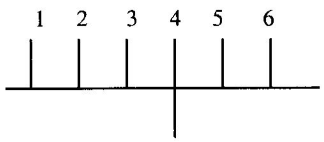
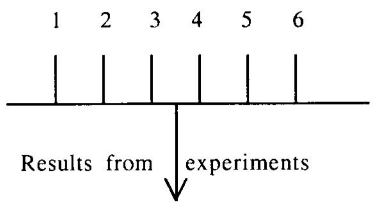
From the hypothesis, additional inferences and conclusions now can be made. Stoker also calls these additional inferences (conclusions) hypotheses, and says they are important for research, and for confirming or disconfirming the original hypothesis with additional research.[50]

f) *Final empirical verification*

The hypothesis, as well as the related inferences, now must be empirically verified once again. Thus, in verifying a hypothesis in physics, experimental work plays a particularly important role. Only after the conclusions of the various researchers have reconfirmed the hypothesis of concern can the original hypothesis, which is the basis of the other inferences, be accepted as a generally avowed theory or natural law. This method, i.e., from the example(s) to the general law, and again from the hypothesis (general) to further characteristics, expresses the typical forms of the inductive or deductive methodological principle.

In physics, it is found that such a method of "hypothesis verification" can be fruitfully applied to disclose causal relations between realities, and to unveil natural laws. Where at all possible, the activities also are directed to the quantitative relations

[50] Stoker, H.G., *Beginsels en metodes in die wetenskap*, p. 92.

Course of the hypothesis-verification approach	Corresponding steps in a lesson situation	Ordering principles	Methodolgical principles
a) A meaningful statement of the problem. b) Broadening experience (foreknowledge) by a preliminary empirical investigation. c) Classifying and schematizing data.  d) Formulating a *hypothesis*.	a) The problem must be meaningful to the pupils, therefore, linked to their experience and foreknowledge. The path is from the known to the unknown.	a) Symbiotic	a) Inductive
e) Deductive derivation of other hypotheses from stated one. f) Verification of stated and derived hypotheses, usually by experiments.  g) Generalizing from confirmed hypotheses with the aim of forming a general explanation or law.	b) Research is directed to the hypothesis with the aim of solving the problem. The expriment(s) (exemplar) now chosen and ordered for the child must already contain the essence of the phenomenon. c) From the results of the experiment the pupils must be able to synthesize and generalize.	b) Ordering in steps d, e and f largely punctual. c) Ordering is largely linear.	b) Deductive holds for steps d, e and f. c) Inductive holds for steps f and g.

between cause and effect by which the results can be summarized in mathematical formulas.

In teaching the natural sciences, e.g., physics, there must be thorough knowledge of this way of working regarding a problem. The hypothesis verification method (form of teaching) has relevance for didactics, especially for teaching physics. The relationship between this method and some didactic principles can now be represented schematically as follows.

4.1.5 Summary

From the discussion of the unique nature and structure of physics, now it is desirable to consider, from a methodological view, a way to follow that corresponds with the typical methods of the natural sciences in general. In connection with teaching physics, the following aspects must receive particular attention:

i) For motivating and linking the pupils up with content, they must be made aware of a problem which already has meaning because of their original experiencing of phenomena of nature itself. Such a linking will involve the pupils spontaneously discovering the meaningfulness of the problem. When the moment of their experiencing the sense of the problem arises, at this moment, there is a greater mobility and liveliness by which their questioning and venturing attitudes now become stronger.

ii) The fundamental place the practicum (experimental work) takes for investigating relations and laws in nature must be kept in mind. Experiments must be carried out by which the pupils can acquire experience and insights, and then interpret and schematize the learning content. Viewed from a methodological point of view, usually preference cannot be given to one way of learning. Schoene indicates that the deductive and inductive principles are equally important in teaching physics.[51] This is confirmed further because the inductive and deductive principles are

[51] Schoene, H., *Teaching physics to-day*, p. 17.

interchangeable, as was shown earlier in considering the hypothesis verification form of teaching.

Thus, the nature and structure of physics is a primary matter which must be thoroughly considered in choosing a principle of ordering in designing a specific lesson situation.

4.2 EXAMPLES ILLUSTRATING THE IMPLEMENTATION OF CERTAIN PRINCIPLES

4.2.1 Introduction

With several examples, the ways in which certain principles of ordering can be selected and implemented for teaching physics are shown. It always must be kept in mind that the choice of certain principles of ordering, in terms of the aim striven for, must lead to the presentation showing different forms. However, to maintain a coherence in further discussions

THEME: THE DUALISTIC CHARACTER OF LIGHT

***Core learning material*:**

Dualism

Particle nature

a) Linear movement
b) Reflection
c) Refraction
d) Photo-electric effect

Wave nature

a) Waves: Typical characteristics of waves
b) Types of waves:
   i) Longitudinal
   ii) Transversal
c) Wave movement:
   i) Linear
   ii) Reflection
   iii) Refraction
d) Diffraction and interference
e) Polarization
f) Dispersion-spectrum

Supplementary programs

a) Historical course of the nature of light:
   i) Newton's corpuscular theory.
   ii) Huygen's wave model.

b) Applications and uses:
   i) Mirrors
   ii) Lenses
   iii) Photo-electric effect
   iv) Polarization
   v) Spectroscopy
   vi) Color

a theme must be chosen as a point of departure, e.g.: The dualistic character of light.
In the following discussion, examples are given in terms of which several principles of organization can be manifested. There can be an ordering following the principle of core learning material, or by typical characteristics of the symbiotic, concentric, linear, punctual, and chronological principles. These examples are now dealt with separately.

4.2.2 Principle of ordering: core learning material

Theme: The dualistic character of light.

a) *Essence of the theme*

By reducing the above theme to its essence, certain inherent characteristics and fundamental relations become visible which also can contribute to a greater clarity about the concept of core learning material. For the aim of this study, however, a

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schematic exposition in table form will suffice in which there is an attempt to make understandable the differentiated core learning material and supplementary programs.

With the choice, compilation and ordering of the core learning material, the level of readiness of the pupils must have relevance as is clear from the following explanation.

b) *Level of readiness of pupils*
In accordance with the pupils' level of becoming, a teacher must answer the following two important questions beforehand:

- i) What foreknowledge (experience) do the pupils have?
- ii) Up to what level of difficulty can this presentation be planned?

Necessarily, there can only be a fruitful and meaningful choice of principles of ordering when the answer to the above questions is known. Thus, ordering the learning material in terms of the differentiated core learning material and supplementary programs constitutes a primary step in planning and preparing any lesson situation.

Now, to show further how the other principles of ordering also have a place and value in a lesson structure, each time a specific theme is chosen for the specific principle of ordering.

4.2.3 Principle of ordering: symbiotic

Theme: Wave movement – longitudinal and transversal types of waves

a) *Essence of theme*
As indicated, the reduction of learning material must always precede the ordering activity of a teacher. Only after this can a basic point of departure be given decisively. Until the essentials of the theme are ascertained, anticipations cannot be made regarding the guiding principles of ordering which must be chosen for the planning. The elementals [essences] of the theme "wave movements" culminate in the following two main moments:

Introduction of concepts with respect to wave movements in general

- Propagation and its direction
- Medium; particles of the medium.
- Wave pulses.
- Harmonious movement, periodic movement.
- A wave is a form of propagating energy.

Introduction of concepts with respect to longitudinal and transversal wave movements, in particular

- Parallel.
- Parallel movement of particles.
- Orthogonal.
- Orthogonal movement of particles.

It is important that the mutual relations among the concepts are not lost sight of.

b) *Level of readiness of the pupils*

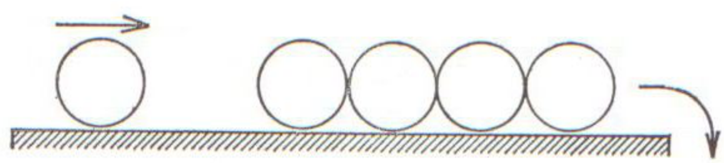
To meaningfully order the learning content, the pupils' level of being formed, and their standard [grade level] of teaching must be considered.

c) *Schematic explication of a plan following the symbiotic principle of ordering and its further course*

Ground form	*Methodological principle*	*Method*	*Ordering principle*
Conversation, example	Inductive	Demonstration	Symbiotic

The most fruitful way by which the pupils' learning intention can be aroused for a problem is by trying to bring about a meaningful link between it and the pupils' lifeworld. Therefore, one must not begin with themes such as wave phenomena, wave theories or wave movements, but rather with a theme such as water waves, which are directly within the experiential world of the pupils. Here, demonstrations of the most important wave phenomena in water must serve the aim of stimulating questions from a child. In addition to seeking connections with a child's at hand wealth of experiences, at the same time, he/she is offered an opportunity to directly perceive a representation (demonstration) of the phenomenon. This representation is important in a classroom [group] form of teaching because all the pupils do not have the same experiences at their disposal. In terms of planned experience, the pupils are enabled te easily see the essence of the theme because a teacher emphasizes it. The linking with the known, directly gives significance and meaningfulness to a child's lived experiencing and thus his/her [learning] intention becomes better directed. The symbiotic principle of ordering is of special value for this beginning phase of the learning event. However, when several examples are used, they must be related to each other and ordered. Some examples which can be chosen at this stage are:

- A locomotive whose cars are jolted when it is shunted.
- A billiard ball which collides with a series of other billiard balls.



- A door which is slammed and makes a curtain on the other side of the room move.
- An explosion in a mine tunnel, and the resulting shockwave.
- Water waves.

Thus, during this stage of the manipulation, the pupils are led from *known* matters to an awareness of a problem. A teacher's explication, therefore, already makes sense to a child, to the extent that his/her presentation can find a connection with a child's lived experiences of such a phenomenon. The initial problem is to find a near to life illustration of the phenomenon. Here one thinks of illustrating the wave phenomenon in different media such as air and water. The fundamental insights the pupil must acquire here are that, on the one hand, they must understand in which way the propagation of the wave occurred and, on the other hand, that it occurred in a uniform way. Concepts which can be presented clearly in this first stage are: propagation, direction of propagation, medium, particles of the medium. The concept "pulse" can only have meaning for a child at this stage if it is related to concepts such as "jolts" and "shocks" because the latter already are part of a child's everyday language usage and experiences. The most important task of a teacher during this beginning stage of the lesson is that he/she must try to order the content such that the pupils immediately get the sense of his/her explication.

4.2.4 Principle of ordering: concentric

Theme: Wave movements – longitudinal and transversal types of waves.

The essence of the theme as indicated in section 4.2.3 also holds for the additional planning according to this principle.

a) *Schematic explanation of a plan following the concentric principle of ordering and its further course*

Ground form	*Methodological principle*	*Method*	*Ordering principle*
Play-exemplary	Inductive	Self-experiment	Concentric

The form (ground-form) of this lesson plan is play coupled with the exemplary. Self-experimenting, as a method-form of actualizing play, implies that the pupils themselves look for a solution to the problem which emerges from the exemplar presented by a teacher. This exemplar must contain within itself the essence of the matter which is investigated (longitudinal and transversal waves) and, thus, can reflect the essence for the pupils. The essential concepts into which the pupils now must acquire insight are:

- Wave pulse.
- Harmonious or periodic movement.
- In a longitudinal wave the particles of the medium move parallel to the direction of propagation.

- In a transversal wave the particles of the medium move orthogonal to the direction of propagation of the wave.

The typical form of a concentric ordering is seen very clearly in the following table because, in a second phase, there is a building on and expanding of concepts which could not be fully dealt with in the first phase.

FUNDAMENTAL CONCEPTS

First phase		*Second phase*
Propagation and direction of propagation	⟶ ——	Concept such as velocity now can be presented, distance/time
Pulse or shock	⟶ ——	Wave pulse as a transitory wave
Medium and particles of medium	⟶ ——	Parallel and orthogonal movement of particles in the medium

These concepts must be ordered and presented in accordance with the pupils' level of readiness.

4.2.5 Principle of ordering: linear

Theme: Wave movements – longitudinal and transversal types of waves.

The aim here is to show how the same theme can figure in a subsequent lesson plan in which, from a qualified perspective on the matter, out of sheer necessity, other ground-forms and principles of ordering must be implemented. Thus, the ordering of the learning content must be brought into agreement with the changed learning aim. In this example, there is an attempt to present the theme in the form of a program which the pupils themselves can work through.

a) *Schematic explication and plan following the linear form of ordering and its further course*

Ground form	*Methodological principle*	*Method*	*Form of ordering*
Conversation	Deductive	Question and answer	Linear

Below is an example of an explication of the theme of wave movements as generally is found in a linear program.

Figure 1

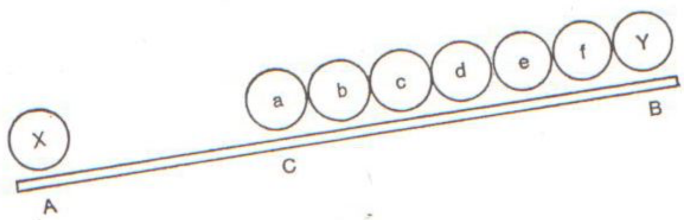


Figure 2

Figures 1 and 2 represent different ways in which energy can be transferred from position A to position B, and by which billiard ball Y is knocked off the edge. In figure 1, ball X is set in motion in the direction of B. To knock Y off the edge, X (the whole/a part?) must move across the interval between A and B.

the whole.
....

Figure 1 illustrates the transfer of energy from one position to another by means of the movement of a particle. The particle (moves/doesn't move?) with the energy it possesses.

moves.
....

In figure 2, ball X is set in motion in the direction of B with a velocity of V. X collides with a series of balls (a, b, c, d, e, f) that are placed between X and Y. Now Y rolls over the edge with a velocity of V. Thus, energy also is transferred from A to B (compare figure 1). In figure 2, X (moves/doesn't move?) the entire distance from A to B.

doesn't move
....

Figure 2 illustrates a way in which energy can be transferred from A to B. However, the only ball that moves after X has collided with the series of balls is .... Energy (is/is not?) transferred when X has come to rest.

Y
....

is
....

The phenomenon illustrated in figure 2 is known as a WAVE PULSE and this has moved from position C to B after the collision. Energy is (transferred/not transferred?) by this *wave pulse*; this is (just as/not as?) effective for setting Y in motion as is ball X in figure 1.

transferred
....

just as
....

4.2.6 Principle of ordering: punctual

Theme: The phenomenon of wave interference (light and sound waves).

a) *Introduction*

An important consideration for implementing the punctual principle always must be sought in the *complexity of the theme* or concept under consideration. From the additional discussion, greater clarity of this matter ought to be acquired. On the level of the secondary school, sometimes it is very difficult to teach one or another complex concept in a purely inductive way. For example, when the interference phenomenon is selected as the theme, this implies that the various forms of interference first must be elucidated for the pupils in terms of some examples. After this, it now is expected that they recognize and abstract the common characteristic from these examples. However, this is not always so easy, especially when the examples include aspects such as interference of water waves from two source points, sound waves by beats and the interference of light from a two-split. Such an approach (inductive) then easily can have the consequence that the child, especially at the beginning stage, can have the mistaken impression that this is purposeless work. The abundant detail and different examples all contribute to making the aimed for essentials less visible. If one consifers these factors, I say that a deductive methodical approach in interaction with a punctual principle of ordering cuts more directly and purposefully to the essence of the matter. Where a general law, hypothesis or definition is the point of departure for the presentation, it always is an indication that a punctual ordering of them might be successful. The exemplary form of teaching now strongly comes to the fore because there must be a search for the most appropriate exemplars to elucidate the different characteristics (aspects) of the general law from closer and various perspectives.

However, simply to only explain the phenomenon of interference, which is a complex concept, to the pupils will leave them unmotivated. To arouse the learning intention of the pupils with any success, the phenomenon must be placed within their life horizon as a meaningful problem. This requires that the learning event must be able to take its spontaneous course. Implementing the symbiotic principle as the basis for ordering the learning content can, at the beginning of the lesson, contribute greatly to such an attribution of meaning [learning]. This way of ordering will contribute directly to stimulating the pupils' wonder because they already lived experience a great deal of the phenomenon as known and, thus, as meaningful. Now, the child will enter the learning even more motivated.

In addition to the fact that initially connections must be sought with the pupils' experiential world, there also must be concern for a fruitful representation of the phenomenon. In presenting this theme, can the way be prepared for purposive learning in terms of a good exemplar such as the interference between two source points in a wave tank?

b) *Schematic plan for a punctual form of ordering*

Ground form	*Methodological principle*	*Method*	*Ordering principle*
Exemplary	Deductive	Demonstration	Punctual

However, to be in a position to choose a good example that reflects the essence of the phenomenon, the teacher himself must be sure about what constitutes the essence(s).

c) *Essence of the theme "interference"*
The meaning of the word *interference* easily can be traced back to its English origin, i.e., the word *interference* which means meddling or intervening. In physics, the concept of interference is used to describe what happens when two waves moving in the same medium interact with each other. This interaction can influence either the strength or weakness of this influence.

The concept of superposition or the succession of waves also must be clearly explained to the pupils.

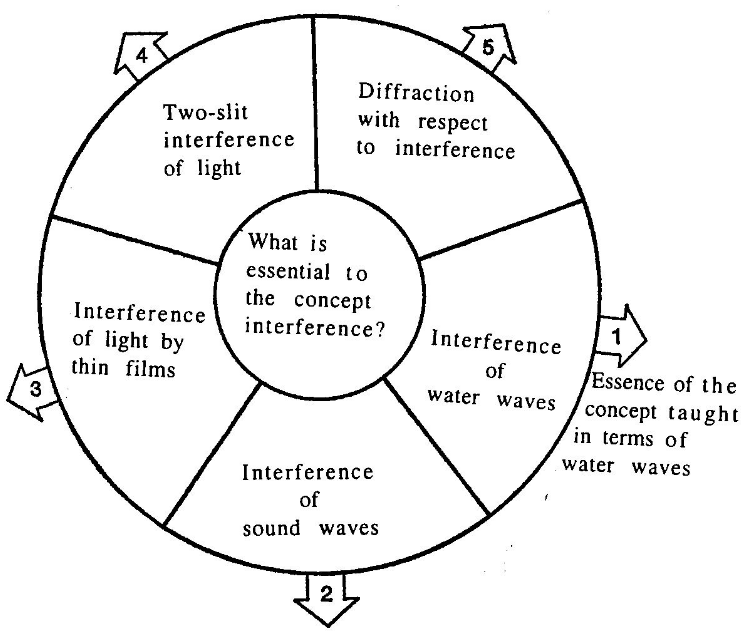
d*) Level of readiness of the pupils*
Here there must be clarity about the questions of the foreknowledge of the pupils, as well as the level to which the pupils can be guided (level of difficulty).

e) *Particular characteristics of the phenomenon*

The phenomenon of interference is manifested in various ways, and in each of them, several aspects can be distinguished. The following are the ways in which the phenomenon is manifested:

- Interference of water waves.
- Interference of sound waves – beats.
- Interference of light waves in a two-slit.
- Interference of light waves with thin films.

We have indicated that there is a close connection between the choice of the punctual principle of ordering and a deductive approach. In addition to the initial planning for stimulating the pupils' learning intention, the primary task of a teacher is the unlocking of reality. The learning aim now is to allow the pupils to acquire insight into the essence of the concept in terms of some characteristics and perspectives. After this, the pupils themselves, or with the help of a teacher, will investigate related and supplementary aspects of the phenomenon. Schematically, a punctual ordering of the concept "interference" is represented as follows:



4.2.7 Principle of ordering: chronological

Theme: Dualistic character of light.

a) *Schematic plan for a chronological ordering*

Ground form	*Methodological principle*	*Method*	*Ordering principle*
Conversation	Deductive	Narrate and Textbook	Chronological

b) *Essence of the theme*

- Newton's particle theory about the nature of light.
- Huygen's wave theory about the nature of light.
- A comparison of these two theories in terms of contemporary knowledge about linear movement, reflection, refraction and interference.
- The electromagnetic wave theory of Maxwell and its experimental proof by Hertz.
- Photo-electric effect.

c) *Readiness of the pupils*

The aim of the explication is to give the pupils a historical overview of existing theories about the nature of light certainly can be meaningful to most of them depending on the level of difficulty of the examples chosen, and the depth of interpretation required.

d) *The further course of a chronological ordering*

It is important to indicate here that this principle of ordering can be implemented most fruitfully only *after* the core learning material has been dealt with. The command of the core learning material concerns the fixed points by which a child acquires greater confidence regarding the nature of light. For further orientation, the insights can be acquired by a form of presentation in which the historical course of events about the nature of life contributes to allowing the pupils to acquire a better perspective on the theme and on the characteristic methods of the earlier great natural scientists. Thus, not only factual knowledge is mastered, but a child also becomes aware of the problems regarding the validity of the findings and general methods of the subject.

The insights acquired with respect to the influence and significance of the various principles of ordering in this study can serve as a warning to the natural scientist, so that he/she can reflect thoroughly on the validity of a statement such as the following: The inductive method and linear ordering are unique to the essence and nature of the subject and subject-didactics of the natural sciences. From this study, the natural scientist no longer can allow him/herself to be led by such a statement. In addition, it seems that the inductive and deductive methodological principles must be used interchangeably in teaching physics (the natural sciences). There also cannot be a preference for a linear form of ordering simply because of the matter of fact, logical character of the subject. Of equal or even greater importance are the symbiotic and punctual forms of ordering.