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 take into account the unique nature of the subject.

4.1 THE UNIQUE NATURE AND STRUCTURE OF PHYSICS

It is impossible and also not the aim of this study to give a complete exposition of the nature and structure of physics. Before being able to proceed to a meaningful ordering of learning content there must be an accurate indication of the unique nature and structure of the particular subject. If this is not taken into account the teacher's presentation easily can lead to a distorted appearance of the slice of reality being presented. Therefore, a few characteristics briefly are indicated about the unique nature and structure of physics that can be of particular importance for didactics, in general, and for decisions about ordering learning material. 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

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

In the secondary school the study of physics mainly is directed to the field of classical physics and there is an attempt to formulate causal laws for natural phenomena. At this level, however, the teacher must take care to not present these "natural laws" in a deterministic sense. Here, the teaching involves not so much findings of "the truth" or "ultimate reality" but it must be directed to indicating the "immediate" validity of the conclusions that are drawn. In other words, the truth of a theory and the formulation of a law only are 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 the physicist to modify or even entirely erase existing theories.[47] In this regard, from history a number of 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 being able to order particular physics themes meaningfully, especially on the basis of their inherent structure-patterns and typical methodological approaches, it is necessary to indicate the actual problems that exist and with which the teacher can be confronted. We refer only to a few matters of which the teacher must have the necessary knowledge that might crop up in planning (also ordering) a particular theme such as quantum theory. Here it is important to know that the idea that energy exists in 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 put him in a position 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 that now are acceptable. The mentioned views, disclosures and findings regarding quantum theory necessarily 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 produced a pattern of defraction or, more easily stated, it showed a

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

typical wave pattern. This disclosure ultimately gave rise to an additional theory in which Schrodinger maintains that each electron must be associated with its particular 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 it is clear that 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 that asks for a new interpretation with each new insight has particular relevance for ordering learning material. We think more specifically of problems that 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 and 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 particular 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 particular theory requires thorough knowledge and mastery of the specific "subject matter language". However, in order to point out the sense and

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

meaning of quantitative relations that 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 the physicist to indicate mathematical-functional connections between separately measurable characteristics of a particular phenomenon of nature. The use of more exact and refined mathematical techniques gives physics a greater claim to a particular 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, it is clear that the close connection between physics and mathematics is of great significance for any choice of teaching principles.

4.1.3 Its validity

Not withstanding the fact that in physics there must and can be mention of a particular 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 twentieth 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 already had 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 of the above standpoints are unacceptable. The acceptability, or not, of any physics theory always is dependent on the foreknowledge (knowledge) that contributes to the anticipation of a possible explanation (hypothesis). With the advancement of knowledge there continually

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

arises new and qualified findings that accordingly increase or decrease the physicist's faith in the premise.

To be able to formulate theories and laws for physics, physicists must work in particular 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 now is attended to in detail.

4.1.4 Its typical methods

In most natural science subjects the hypothesis-verification form of approach enjoys particular attention such that there generally is talk of a natural scientific 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) Give an explanation of ebb and flow, etc.

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

For example, in terms of a class discussion clarity can be attained about the (quantitative and qualitative) nature of the foreknowledge that the pupils have at hand. Then there can be a corresponding choice about what experiences initially must be brought forward to give them the 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, inductively, to see a general law or relation among the large number of separated examples and data. Often there will be a need for further analysis and comparison.

d) *Formulating a hypothesis*

On the basis of the regularity found a hypothesis now is formed. Usually this generalization, based on the earlier experiencing, only is a preliminary or possible explanation of the stated problem.

e) *Deduction on the basis of obvious characteristics from the hypothesis*

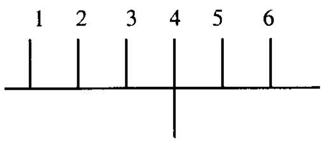
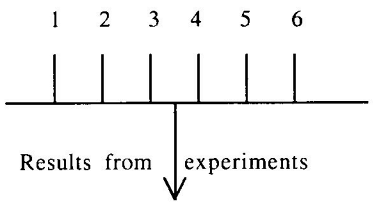
From the hypothesis additional inferences and conclusions now can be made. Stoker also calls all of these additional inferences (conclusions) hypotheses and says that they are important for research and for confirming or disconfirming the original hypothesis with additional research.[50]

f) *Final empirical verification*

The hypothesis as well as the related inferences now must be empirically verified once again. Thus, it is clear that 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, namely, from the example(s) to the general law and again from the hypothesis (general) to further particular 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 particular 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, in particular physics, there must be thorough knowledge of this way of working regarding a particular problem. The hypothesis verification method (form of teaching) has particular relevance for didactics, especially for teaching physics. The relationship between this method and a number of didactic principles now can be represented schematically as follows.

4.1.5 Summary

In light of 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 up the pupils must be made aware of a problem that already has meaning on the basis of their original experiencing of phenomena of nature itself. Such a linking will entail the pupils spontaneously discovering the meaningfulness of the problem. When the moment of experiencing the sense of the problem by the pupils becomes actual, at the same time this is going to be paired with a greater mobility and liveliness by which the questioning and venturing attitudes now come more strongly to the fore.

ii) The fundamental place the practicum (experimental work) takes regarding the investigation of relations and laws in nature must be kept in mind. Experiments must be carried out by which the pupils can acquire experience and insights in order to arrive at an interpretation and schematizing of the learning content. Viewed from a methodological point of view usually preference cannot be given to one particular mode of learning. Schoene also indicates that the deductive as well as the inductive principle equally are very important in teaching physics.[51] This statement is

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

confirmed further because the inductive and deductive principles so clearly can be interchanged with each other as was shown earlier in the hypothesis verification form of teaching.

Thus it is clear that the nature and structure of physics is one of the primary matters that thoroughly must be taken into account before there can be a choice of a particular principle of ordering in designing a specific lesson situation.

4.2 EXAMPLES ILLUSTRATING THE IMPLEMENTATION OF CERTAIN PRINCIPLES

4.2.1 Introduction

There is an attempt to show by a number of examples the ways in which certain principles of ordering can be selected and implemented for teaching physics. It always must be kept in mind that the choice of certain principles of ordering on the basis of the aim that is striven for must lead to the fact that the presentation is going to show different forms. However, in order to try to maintain a coherent connection in the further discussion, a central theme is chosen as the point of departure: The dualistic character of light.

In the following discussion examples are given in terms of which a number of principles of organization can manifest themselves. There can be an ordering following the principle of core learning material or on the basis of typical characteristics of the symbiotic, concentric, linear, punctual and chronological principles. These examples now are 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 that at the same time can contribute to a greater clarity about the concept of core learning material. For the aim of this study, however, a

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

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 necessarily must have relevance as is clear from the following explanation.

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

i) What foreknowledge (experience) do the pupils already have?

ii) Up to what level of difficulty can this presentation be planned?

Necessarily, there only can be a fruitful and meaningful choice of principles of ordering when, among other things, the answer to the above questions is known. Thus it is clear that ordering the learning material on the basis 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 already indicated, the reduction of learning material always must precede the ordering activity of the 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 that must be chosen for the planning. The elementals [essences] of the theme "wave movements" culminate in the following two main moments:

Introduction of a number 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 a number 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.

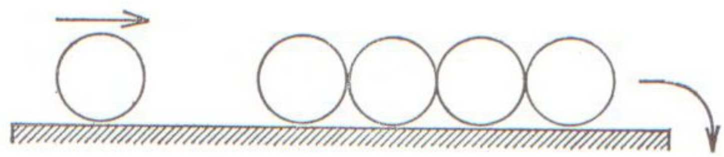
b) *Level of readiness of the pupils*
To meaningfully order the learning content the pupils' level of being formed and their standard [grade level] of teaching must be taken into account.

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 particular problem is by trying to bring about a meaningful link between it and the pupils' life world. 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 that 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 the child's at hand wealth of experience, at the same time he is offered the opportunity to directly perceive a particular representation (demonstration) of the particular phenomenon. This representation is especially important in a classroom [group] form of teaching because all of the pupils do not have the same experience at their disposal. In terms of planned experience, the pupils are put in a position to more easily see the essence of the theme because the teacher emphasizes it more. The linking with the known directly gives significance and meaningfulness to the child's lived experiencing and thus his [learning] intention becomes better directed. The symbiotic principle of ordering is of particular value for this beginning phase of the learning event. However, when a number of examples for the pupils are dealt with they necessarily must be related to each other and ordered. Some examples that can be chosen at this stage are:

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



- A door that 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. The teacher's explication, therefore, already makes sense to the child to the extent that his presentation can find a connection with the child's lived experiences of such a phenomenon. The initial problem is to find a close 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, he must understand in which way the propagation of the wave occurred and, on the other hand, that it occurred in a uniform way. Concepts that 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 the child at this stage if it is related to concepts such as "jolts" and "shocks" because the latter already are part of the child's everyday language usage and experience. The most important task of the teacher during this beginning stage of the course of the lesson is that he must try to order the content such that the pupils immediately get the sense of his 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 that emerges from the exemplar presented by the teacher. This exemplar must already contain in itself the essence of the phenomenon that is investigated (longitudinal and transversal waves) and thus can reflect the essence of the matter 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 can be seen very clearly in the following table because in a second phase there is a building on and expanding of concepts that 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 necessarily 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, on the basis of 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 that 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.

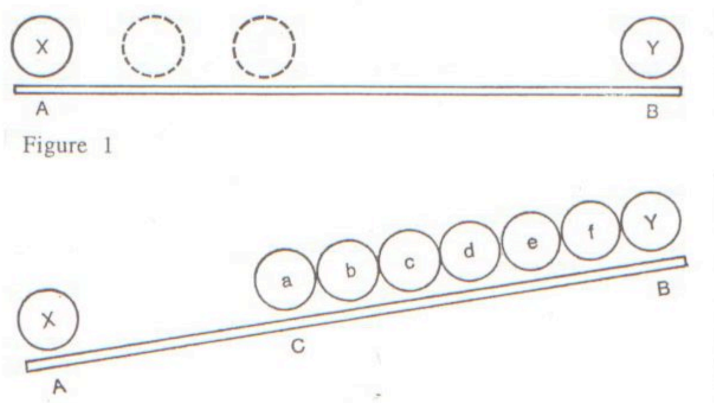


Figure 1

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 to be dealt with, this implies that the various forms of interference first must be elucidated for the pupils in terms of a number of 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 takes these factors into account, 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. In order 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, namely, the word *interference* that 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.

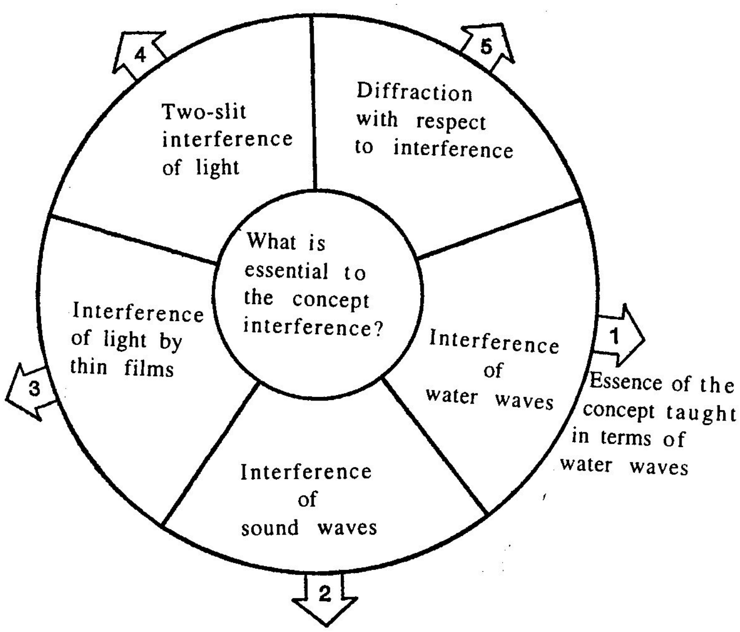
The concept of superposition or the succession of waves also must be clearly explained to the pupils.

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 manifests itself various ways and in each of them a number of aspects can be distinguished. The following are the ways in which the phenomenon manifests itself:

- 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 already 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 the 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 a number of characteristics and perspectives. After this, the pupils themselves, or with the help of the 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 light 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 try 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 the 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 the 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 can reflect thoroughly on the validity or invalidity 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 it is clear that the natural scientist no longer can allow himself 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 on the basis of the matter of fact, logical character of the subject. Of equal or even greater importance are the symbiotic and punctual forms of ordering.