UNIVERSITY OF HELSINKI REPORT SERIES IN PHYSICS

HU-P-D124

Need and possibilities of astronomy teaching in the Finnish comprehensive school

Irma Hannula

DEPARTMENT OF PHYSICAL SCIENCES
P.O. BOX FIN-00014 UNIVERSITY OF HELSINKI
HELSINKI, FINLAND

Academic Dissertation

To be presented, with the permission of the Faculty of Science
of the University of Helsinki, for public criticism
in the Small Auditorium E204 of the Department of Physical Sciences,
on July 29th, 2005, at 12 o'clock.

Helsinki 2005

ISBN 952-10-2103-9 (printed version)
ISSN 0356-0961
ISBN 952-10-2104-7 (pdf-version)
http://ethesis.helsinki.fi/
Photo: Aurora Borealis /Irma Hannula
Yliopistopaino
Helsinki

Daniel

my dear first-born grandchild

you are

joy and blessing

for my life!

I. Hannula: Need and possibilities of astronomy teaching in the Finnish comprehensive school, University of Helsinki, 2005, vii, 250 p., University of Helsinki, Report Series in Physics, HU-P-D124, ISBN 952-10-2103-9 (printed version), ISSN 0356-0961, ISBN 952-10-2104-7 (pdf-version), http://ethesis.helsinki.fi/.

Classification (INSPEC): A0140D, A0140E, A0140G, A0140J, A0190
Keywords: astronomy teaching, worldview, attitude, conceptual and processual structure

Abstract

The purpose of this work is to create a research-based foundation for planning the structure, content and methods of astronomy teaching in the Finnish comprehensive school.

At first, a critical analysis of the significance of astronomy teaching from the point of view of the educational aims was made, in order to verify the need of it and to find significance factors, which would offer a basis for defining principles of astronomy teaching. The significance of astronomy teaching is defined to consist of all such factors through which astronomy teaching can promote the educational aims of school. They were searched from a selected set of writings by prominent cultural authorities, relevant from the viewpoint of astronomy teaching, and a covering set of extracts from them was taken as the basic material. This material was first divided into four subject groups, culture, school, teaching and worldview and then classified into twelve aims categories based on a critical interpretation of the curriculum and a thorough reading of the material. The essential contents of each category was summarised in form of an essay-like description, and finally crystallised into five leading common themes: worldview, observation, existence of life, space technology, and culture which would serve as the basis of the detailed planning of the contents of astronomy teaching.

Secondly, the conceptual structure of astronomy, which forms the core of teaching, was analysed in view of extracting principles for astronomy teaching. Construction of the pupil's world picture requires that teaching must follow the line of 'creation of meanings' in the development of astronomy. This was analysed in terms of the principles of the perceptional approach. It was noted that stepwise progress in the chain of structural hierarchy of nature, starting from the scale of man towards the larger structural units, is the core line characteristic to astronomy. Moreover, two hierarchical lines of conceptual development were pointed out, the generalisation-unification development and the progress in quantification hierarchy. It was concluded, that the structure of teaching should follow the progress in the structural hierarchy and that none of the two lines of conceptual hierarchy should be violated without loss of understanding. Particularly, the essence of meaningful learning is the qualitative perception of empirical meanings of concepts, and the quantitative generalisation process is a key to understanding the use of physical concepts in astronomy.

Thirdly, the preconditions for astronomy education were searched by a query sent to teachers, plus overviews of present textbooks, curricula and teacher training programmes, supported by own experiences from over twenty years at school, from teacher education and international work in preparation of recommendations for astronomy teaching. The teachers’ attitudes were positive. They felt uncertainty about their competence but were willing to take part in complementary education. The pupils were interested in astronomical subjects. The scant facilities of school seemed not to produce essential difficulties, although a lot of special wishes were expressed, but the time available was a subject of worry.

Finally, the principles resulting from the studies of significance and conceptual structure were gathered and concretised into a suggestion for planning guidelines of astronomy teaching.

The research strongly suggests that astronomy is needed in the comprehensive school. Some increase of it is seen to be possible even in the present situation, but textbooks, curricula and teacher training programmes are obvious targets for revision. A more permanent arrangement would require that the position of astronomy is confirmed in the national curriculum, so that structural and methodological principles presented in this research can be realised.

Preface

My personal interest in astronomy was aroused at the beginning of my studies, so the basic course of astronomy was part of my study program already in the first year. At the same time I began also active observation, first by identifying constellations. With the help of a star map, the night sky started to take shape increasing my inspiration. The overall picture of the universe was formed in the basic course, and later, with continuous interest still remaining, the picture deepened all the time.

In my own teaching, astronomy has always belonged to the contents of science. In physics and chemistry courses, astronomical subjects have provided appropriate application examples. The physics course in the ninth grade I have usually started with astronomy. Pupils have been well motivated in learning astronomy. It is true, in the comprehensive school there are always pupils with less interest, not only in astronomy, but in the school as a whole. However, even among them there are some who have become interested in physics through astronomy, not to mention an interest in astronomy itself. Of course, over the years I had also to face opposite cases, where a pupil has become 'depressed' and I have taken it as a problem related to my way of teaching – often as a too quick conclusion. Because the question is about pupils in the upper level of the comprehensive school, it is easy to see connections to their age of puberty, and general learning problems related to that age. Generally, teachers have to be honest about their own teaching and professional development, and admit the difficult situation, as far as it concerns problematic pupils. The majority of them have experienced astronomy as a thrilling subject and they have been willing to get more of these exciting experiences as a contrast to the overall syllabus that is often regarded as quite theoretical. Mysteries about life and death have always been of interest to man. The most important reason for the interest in astronomy is, probably, the mystery of the origin, purpose and future of life, and it is likely to remain as a mystery regardless of new discoveries about the universe.

As a member of the Finnish graduate school in mathematics, physics and chemistry education I got the opportunity to study this problem field, for a couple of years even on a full-time basis. My participation in several in-service and advanced teacher training courses, as well as international connections related to the development of astronomy teaching, have contributed essentially to the specification of the subject of my research. Especially, my responsibilities in the annual international summer schools of astronomy education, organized by EAAE (The European Association for Astronomy Education), in the three-year project within Socrates-Comenius program provided by EAAE, and in the workshop courses of astronomy in the Department of Physical Sciences in the University of Helsinki, have been of great significance to me in this work.

I praise my Lord for the great gift He has given to me in allowing me to carry through this work!

I express my deep gratitude to my supervisors Professor Kaarle Kurki-Suonio and Professor Maija Ahtee for their guidance, support and inspiring advice. My gratitude is further extended to Professor Heimo Saarikko for all his advice and encouragement. My warm thanks go to Professor Jari Lavonen and Professor Esko Valtaoja for reviewing the manuscript and suggesting important corrections, clarifications and improvements.

I am grateful to Professor John Percy and Ms Joanna De Gouveia, Alan C. Pickwick MSc, Ms Cindy McCabe, Martti Sloan MSc and Ms Raila Järvinen for revising the language and for their detailed remarks about the terminology. Any errors left in the text are totally my own responsibility.

My thanks are also extended to several colleagues and friends at the Department of Physical Sciences. Especially, I wish to mention Tuulikki Pitkänen, Head Secretary of the Department, because of her untiring and patient assistance in the practical arrangements. I thank Mervi Hyvönen-Dabek, Aino Vahvaselkä, Ari Hämäläinen and all colleagues in the group of didactical physics for their kind support and understanding.

I wish to express my gratitude to my relatives and friends for the interest in my work and for the support, which have helped me so much. I thank my dear relatives for their help in the translation work.

The care and the support received from my family are never forgotten. I thank my son Jani Jukka and my daughter Heidi with their families, my parents and also my sisters and my brother with their families. Especially my beloved husband Vilho has been so helpful and supporting. Without his support, this work would never have been completed. I dedicate this thesis to him.

Irma Hannula
Helsinki, July 2005

List of acronyms

A.D.	Anno Domini
B.C.	Before Christ
CERN	Conseil Européen pour la Recherche Nucléaire
CCD	Charge coupled device
EAAE	European Association for Astronomy Education
FINISTE	Finnish network for schools
IAO	International Astronomy Olympiad
IEA	International Association for the Evaluation of Educational Achievement
INSET	In-service teacher training
LHC	Large Hadron Collider
LUMA	Science and mathematics
MAOL	The Finnish Association of Teachers of Mathematics, Physics, Chemistry and Informatics,
MFK	Mathematics, Physics and Chemistry
NGC	New General Catalogue
OECD	Organisation for Economic Co-operation and Development
OTAVA	www.otava.fi, the Finnish publisher
PCK	Pedagogical Content Knowledge
PISA	Programme for International Students Assessment
POPS	The framework curriculum for the comprehensive school
STS	Science, Technology and Society
VESO	Collective bargaining contract
WSOY	www.wsoy.fi, the Finnish publisher

Contents

Part I Background

Part II Literature research

II A Mapping of the significance

II B Mapping of conceptual structure

II C Overview of pupil's astronomical worldview

Part III Planning of astronomy teaching

III A Preconditions

Part I Backgrounds

1 Introduction

The background of this research goes back many decades. The weak position of astronomy in school education has been a common concern for many years. In talks and writings it has been clearly pointed out that astronomy would have to be included more often and at a larger scale in curricula.

Since ancient times people have been interested in phenomena in the sky, they have looked at the sky and tried to figure out how the surrounding universe looks. They have developed many kinds of observation tools, measured things and analysed results, and based on those results, tried to interpret the surrounding mystery.

When looking at the history of astronomy and the whole mankind, astronomy seems to be connected to life and events in society in all times. Especially during periods of great revolutions, the impact of astronomy has been very strong. It has changed people's conception of the whole universe. The exploring and pondering of mysteries in the universe has shaped the basis for the development of physics and given impact and impulse to other sciences as well as culture. These impacts reflect also into the school - other disciplines have got inspiration, background and applications from astronomy. Astronomy seems to provide a rousing inspiration especially for the arts. It is easy to claim that it feeds man's imagination and raises his mind into distant spheres, touches man's divine nature and gives a feeling - and for many an experienced confidence - of the existence of God.

It is quite a general experience of teachers, coming often out in discussions, that the pupils are surprisingly interested in subjects relating to the universe. They follow the news about new ‘conquests’ in astronomy. During remarkable celestial phenomena a class or even the whole school may be following those astronomical events and the news in the media related to them. Those kinds of events include solar eclipses, eclipses of the Moon or the appearance of planets. In recent years bright comets have inspired pupils even to overnight observations. The pupils' interest in astronomy has also been stated in many research contexts. For instance, in a study by Lavonen *et al.* (2005) 3626 of 4954 pupils on the ninth grade of the Finnish comprehensive school responded a query about their interest in various science subjects. It was verified that, amongst all astronomical subjects suggested, there were several which were definitely found interesting and none, which would have been non-interesting. Moreover, both boys and girls found similarly the astronomical subjects interesting, see also Krapp (1992).

Why is astronomy then not included more into elementary education? Reasons have been considered and listed in many fields, especially in public discussions and seminars. As a common concern in those discussions, there has been raised the small amount or even lack of astronomy teaching, as well as teacher training and educational readiness.

The Department of Astronomy in the University of Helsinki, the Finnish Astronomical Society and URSA Astronomical Association organized at the University of Helsinki a seminar concerning the school teaching of astronomy in 1974 (Anon. 1974a). Most essential subjects in discussion were the position and importance of astronomy, the astronomy teaching in the comprehensive and high schools, and the organizing of astronomy teaching in teacher training and post-graduate education. The Finnish

Astronomical Society and URSA Astronomical Association have been worried about the missing basic information about astronomy and the small amount of astronomy teaching in schools. According to them, astronomy has many links to the other disciplines, and those links are of considerable help when figuring out the whole picture of science. In the seminar it was also pointed out that astronomy is included by many countries in science teaching, either within science or as a separate discipline.

In the notes sent to the Ministry of Education (Anon. 1974b) the significance of astronomy in physical research had been underlined. There astronomy was considered as good and maybe the only possible field of application in the research of universal, often very special circumstances. In addition the basic information in astronomy is seen as a necessary component that people need when figuring out their own picture of the world. In the notes were also mentioned the aims of physics teaching in the upper level of the comprehensive school, those were presented by a committee planning curricula for the Finnish comprehensive school, including among other things ‘familiarising pupils with most essential natural phenomena and regularities in them' as well as a motive 'to inspire for pro-active scientific studies and provide with ideas for constructing a picture of the world' as examples. The aims of environmental studies in the lower level of the comprehensive school and physics in high school are pretty similar. Finally the notes mentioned a concern for the status of astronomy in teacher training and its impact on the quality of astronomy teaching. As an option the notes suggested including astronomy courses into physical, geographical or environmental studies.

A few decades ago, astronomy was not included in physical studies at all in Finland. In the textbooks there were some references to astronomy as an application of particular subjects, but there were no coherent themes about it, not to speak about coherent teaching periods. Teachers who have given special attention to astronomy in their teaching often report in discussions that this has given them joy and satisfaction in their work. Despite of these almost-always-positive teaching experiences, the question still remains: why astronomy is not more taught in schools? Discussions with colleagues, articles in magazines and papers, discussions on television and radio have all brought up similar kind of questions. In the seminar in 1974 (Anon. 1974a) it was pointed out that the same question had been already under discussion in 1926.

In the eighties and early nineties, when the insufficient role of astronomy within the Finnish school system became more and more evident to me in my work as a physics teacher, practically no research was done on the subject, as is obvious also from the recent review of astronomy education research by Bailey (2003). This was still true in 1995 when the Finnish national Graduate School In Mathematics, Physics And Chemistry Education was founded giving me the opportunity to start this research, at first beside my teaching work and later for a couple of years as a full time researcher. My ambitious plan was to examine the problem as a whole, to create a scientific basis for the need of astronomy teaching in the Finnish comprehensive school and to build up a research-based foundation for planning its structure, content and methods.

The work would start with a wide critical analysis of the significance of astronomy from the point of view of the educational aims in order to verify the need of astronomy teaching and to enable setting of well-defined significance factors, which would offer a basis for defining principles of astronomy teaching and for selecting themes to be included.

Because the target of this research was the Finnish comprehensive school, the school laws and curricula must be taken into account as necessary boundary conditions. Therefore an overview of the legal foundations was the natural first step in this analysis. The educational aims as defined in the school laws and in the curriculum valid in that time (Anon. 1994) became, thus, the formal starting point for classification of possible significance factors, as presented in chapter 3.

It is true, the curriculum as such does not offer a scientific basis for research, because it results from a political decision procedure. The aims setting therefore reflects the prevalent ideologies and values of the society rather than up-to-date scientific results and arguments and are, thus, subject to changes whenever new curricula are decided. In principle, the curriculum prescribes the anticipated direction of development of teaching, but in practice it, more or less, just verifies the nature of development already occurring. However, this may also be a circuitous route for the educational research to affect the curriculum. As a specific example, there is a strong new emphasis put in the next curriculum on the experimentalism and the nature of science (Anon 2004). One can interpret this as a verification of such a development, which has occurred in the field as a result of a vivid professional discussion evoked by the increase of such an emphasis in the science of education, (*cf.* Hodson 1998). On the other hand, the general classification of aims implied in the school laws and curricula is rather invariable and generally acceptable.

As presented in chapter 4, the ordinary analysis of the significance was based on a literature search of statements referring to the significance of astronomy as a science in the history of mankind, social life and school, and in the development of the worldview, relating them to the educational aims. Through an interpretative classification-reduction procedure the message included in the accumulated material was concentrated into themes, which would serve as the basis of planning the structure and contents of astronomy teaching in school. Basing on features perceived in the inspection of the material this procedure breaks the limitations of the curriculum as the starting point. In this way, although the curricula or their development is not an actual object of this research, this mapping would be able to suggest also modification of the aims setting of the curricula.

On the basis of the study of learning process it is obvious that understanding of concepts and laws, learning of skills of experimental work and perceiving of the nature of science are essential aims of science teaching (Hodson 1998). As basis of astronomy teaching, it would be appropriate to take, for instance, the theory of meaningful learning by Ausubel (1968). According to the theory, pupils should learn to know the logical structure of the field being taught. To make this possible, the teacher should understand the structure of pupils' knowledge and learning methods. Shulman (1987) has developed the construct of ‘Pedagogical Content Knowledge’ to structure some of the problems of teaching and teacher education. He states that there is a close connection between content knowledge and pedagogical knowledge in science teaching. To help pupils to understand scientific concepts and things, science teachers have to be taught contentual and methodological skills, *cf.* Tobin (1994). Hence, the conceptual structure of astronomy and its relation to the development of pupils’ astronomical worldview is another cornerstone of the astronomy teaching.

This leads to the second basic item of this research, a study of the conceptual structure of astronomy (chapter 5) in view of extracting principles for planning the structure, contents and methodology of astronomy teaching. This was approached from the point of view of creation of meanings as the basis of concepts because this was seen to be the factor, which connects learning to the development of science. This study was largely based on the ideas about structured physics teaching developed at the Physics Department of Helsinki University since early eighties and which have proved successful in physics teacher education, *cf. e.g.* Lavonen *et al.* (2005). Additional support to this approach can be obtained from the philosophical analysis by Nersessian (1984) of the nature of formation of meanings in science, particularly from her emphasis of the empirical content as the core of scientific terms, and theory construction as a part of the conceptual aspect of experience. These ideas were developed further with a special reference to astronomy and reduced into principles concerning astronomy teaching.

A literature review of the development of the pupils' astronomical worldview was found necessary (chapter 6) to be able to connect the principles 'derived' from the structure of astronomy to what is known about the natural development of the pupils' learning facilities.

The development of the content structure of disciplines and the improvement of teaching has been considered from many points of view. In his research on reformations of education Fullan (1991) categorises factors of educational reformations in three groups: properties of reformations (the structure of astronomical knowledge, its nature and teaching methods), preconditions in school (teaching tools, resources in school, former knowledge, skills and beliefs, teacher training possibilities) and factors from outside of school (local and national education system, legacy, national strategies and curricula, astronomers' way of thinking, international situation). The changes in school world are difficult to realise. As Tobin *et al.* (1994) state, 'many of the reform attempts of the past have ignored the role of teacher beliefs in sustaining the status quo. The studies … suggest that teacher beliefs are a critical ingredient in the factors that determine what happens in classrooms'.

To complete this research of the foundations of astronomy teaching it was necessary to make a critical study of the preconditions (chapters 7, 8). The preconditions for organising astronomy education were searched by a query sent to teachers, deepened by interviews, plus overviews of present textbooks, curricula and teacher training programmes.

As the conclusive phase of this work (Chapter 10) the principles resulting from the studies of significance and conceptual structure were gathered and concretized into a suggestion for research-based guidelines for planning astronomy teaching in the schools. To support this concretizing interpretation of the research results and the evaluation of the significance of the observations concerning the preconditions, this was preceded by an overview of my own teaching experiences from over twenty years and those of other teachers in Finland and in some foreign countries (Chapter 9).

Along with the progress of this work, the research on astronomy teaching has revived also internationally. In the literature review by Bailey (2003), more than hundred references on this subject are listed, categorised and summarised. However, most of the problems discussed are dealing with rather specific details. Research on student understanding, effectiveness of instructional methods and mixed-methods approaches occupy a large part of the literature. Bailey states that the connection between this kind of research and its effect on classroom instruction is lacking. Also, the problems are studied mainly from the viewpoint of the science of education only. There is a lack of research on understanding concepts, concept formation, conceptual structure and the scientific nature of astronomy, which form a central starting point in the present work.

Now, after ten years of work, at the time of presenting the outcome of the research, there is still no comparable comprehensive study of the foundations of astronomy teaching. It is, thus, justified to suggest that the present work is filling a definite hole in the field.

2 Background

2.1 The background of schools

During my teaching career of over two decades, my understanding of situations at schools – especially astronomy education – has developed significantly. In addition to my own experiences that have been affected by discussions with colleagues, training days, theme seminars and opinions expressed in public media, I have developed my own sense of the circumstances on astronomy school education.

A clear controversy between two important factors has caused me amazement. Almost without exception, people think that astronomy and things related to the universe are of extreme importance to be taught to all pupils and also to adults. From this subject there have not been any objections. What cause the controversy at school are the often-heard comments 'money matters' and 'time is money'. ‘Lack of money’ in the school system and the whole society is an every day phenomenon, so it is easy to hide behind that reason. Instead, 'lack of time' is something that causes amazement, because teachers in the Finnish school system have quite an independent position in regards to their own teaching methods and schedules. In these situations it has been easy to say – as with the other colleagues teaching astronomy – that ‘it is only a matter of organisation'.

Previously, the contents of astronomy courses have mainly been attached to the curriculum of physics education. Presently, they have been incorporated more and more to the curriculum of geography. Fortunately in the physics textbooks there is still – and should always be – astronomy, either as its own chapter or linked to applicable chapters according to the practice selected by a current series of books. In most, especially in the oldest series of books, astronomy has been included in the last chapter of the textbook. In such cases, it is easily is not taught at all because of the lack of time.

Telescopes have definitely been associated to belonging to the education of astronomy, though buying one usually becomes the major barrier to begin teaching it. Every school may have binoculars, at least for biology and geography education, though they are seldom regarded as sufficient tools to explore the sky. Question of time was related to old teaching methods, where a teacher followed strictly the contents and structure of the textbook, and there was not much astronomy in those.

2.2 Instructions and materials

In past years, the school world has had to face many changes, all happening in a relatively short term. These changes have been related to social matters, values and curricula. In addition to social changes, the necessary renewal of school has also been affected by the rapid scientific development in different fields (*cf*. Tobin 1994). Overview of curriculum I have made both in chapter 3 and chapter 7, but in the different point of view. In chapter 3 the main purpose is to investigate curriculum on the base of school laws being a starting point to the planning of astronomy teaching. In chapter 7 I have made an overview of two curricula and my intention is to investigate contents of astronomy in them. This contains closely to the investigation by questionnaire. That is why it is placed in chapter 7.

According to *The framework curriculum for the comprehensive school 1994* (Anon. 1994) by the National Board of Education the need for renewing the curriculum is raised from three changes: social change, change in values and curriculum theoretical change.

Social changes include government, political and economical changes. Internationalisation has brought many new aspects and ideas both to social and individual lives. Also, the school system has been developed due to the mentioned changes. Delegating decision making more and more from the central management to communes has affected a lot of the diversity of education. Students have been able to plan their education program according to their own needs, thanks to the flexibility of the study programs and their lengths. A possibility to study some of the courses elsewhere adds to student's chances to build up his or her own individual education.

Changes in values are related to the large-scale international activities, where ability to accept different cultures and ways of living is needed, including the capability to change one's own life according to the conditions. During the last decade, international education was well present in schools as many schools made co-operation agreements with foreign schools. The influences and experiences from abroad have added to our own traditional foundation of values.

According to the curriculum theoretical change, the curriculum is constantly developing a set of instructions, cultivated by experiences and environmental impacts. For teachers to follow that, they require flexibility, co-operation skills and the willingness to develop their own work. The former curriculum guided by the central management was too detailed in its list of contents. However, in the last few years when the responsibility was given to the communes, the curriculum has included more generic guidance based on the commune's own special characteristics and importance.

Textbooks reflect fairly well the trends of ideas in a society. They also follow the contents of the curriculum and other guidelines of the society. From the astronomy education point-of-view, these trends do not have great importance. This is because the textbook series have always contained at least some basic information on astronomy, and conversely, the importance of other references is better without underestimating the astronomy contents of the textbooks.

As a basis of astronomy education in my own school, an individual plan had to be created. This is because in the official curriculum – both in the one given by the central management and the one specific to communes – there had been only a reference to subjects related to the universe and space research. The situation is obviously the same in all the schools where there is a teacher interested in astronomy. On the other hand, every teacher has had to participate in creating the communal curriculum, so in that respect there has been a possibility to include all needed instructions and course contents also from astronomy.

2.3 Teacher training

In the teacher training of mathematical subjects, the study program has been filled by the studies of compulsory subjects. The compulsory subjects have included mathematics, physics, chemistry, and currently computer sciences. Astronomy courses can be included in optional studies, or they can be studied in addition to other studies for one’s own interest. Lately, courses from very different subjects have been approved to be included in examinations, and furthermore all three subjects are not necessarily required to get a position as a schoolteacher. Currently, many kinds of mathematical subject combinations can be found from the application announcements for offices. Astronomy courses have included mostly lectures and exercises. Less emphasis has been put on observation because of today's information technology, modern measurement and photographic tools.

In the class teacher training, the curriculum has included more astronomy, mostly in environmental and natural science course contents. However, the set of subjects is quite small including, most typically, the subjects of the Earth and space, as well as the most common daily and seasonal phenomena. The schedule of class teachers' study program is very tight, so getting additional studies to fit in the weekly study program is a sign of the evident personal interest.

Through these overviews of the items in schooling, I have made the questionnaire (chapter 7 and 8) on this basis by grouping the questions according to items of education, teaching activities, materials and tools, curriculum and teacher training. In additional subject I intend to examine teachers' attitudes to astronomy and astronomy teaching.

3 Structure of the study

3.1 Starting points of the teaching

As the target is to study organisation of astronomy teaching in Finnish elementary school, educational law has to be taken as a starting point. Laws concerning elementary school define for the school the aims and values set by society. Practical instructions for planning teaching are given by orders. Based on these have been those created by national and communal curricula that contain detailed aims for school teaching (*cf.* chapter 2 and 7). In addition to current legislation, previous legislation is also studied for comparison. Following these are different reports that show the opinions and interpretations as bases for the legislation.

3.1.1 Mission of school according to laws and orders

The wording of laws and orders set in different years, especially in decades, is in an interesting way different, even if the basic idea of the mission and values of school is the same. For that reason, references from school legislation of two different decades have been included in this study.

In the Law for Elementary school from 1983 (School laws 1993; Anon. 1983. Law for Elementary school 476/83), the mission of the elementary school is defined as follows: “elementary school shall aim to raise a pupil to be well-balanced, in good condition, responsible, independent, creative, co-operative and a peace minded person and member of society.” (2§). Teaching in the elementary school has to be organised so that “it gives the pupil necessary capabilities for many-sided development of personality, ... protection of environment and nature, ... enrichment of national culture and national values as well as development of international co-operation....” (2§).

In 30§ of the same law are given the instructions for the curriculum: “In a commune there has to be the curriculum for an elementary school” and ”National Board of Education gives the curriculum bases, where the national aims and contents for teaching are given...” and further on “For the annual organisation of work a working plan has to be accepted, a plan based on the curriculum”.

In the Law for Elementary education from 1998 (Anon. 1998. Law for Elementary education 628/98; Ranta 1998; Anon. 1996. Committee report 1996, 92-94 and 161) the following is said of elementary education: “Aims of teaching. In teaching that this law refers to the aim is to support pupils’ growth to humanity and ethically responsible membership of the society, as well as give them necessary information and skills for living” (2§). In addition it is required that “teaching has to promote education and equality in the society as well as pupils’ talents to participate in education and otherwise develop themselves during their life” (2§).

In 15§ of the same law, it is required from the teaching organiser that “the teaching organiser has to accept the curriculum for the teaching mentioned in this law”.

By taking a look at the laws, it can be seen that in defining the aims for the Law for Elementary education, more generic concepts have been used than in its ‘list’ of aims. However, the basis of the aims and value are similar.

3.1.2 Thinking behind aim setting

The development and renewal of school is a continuous process that is based on discussions and interpretations of values and aims. These discussions reflect the thinking methods of each era. They have had their impact also on contents of laws and orders. Also in this context, it is interesting to get familiar with the thinking in different decades and to learn how far sighted – and now even realised – ideas the legislators of that time had.

In the report I of the elementary school curriculum committee (Anon. 1970a. Committee report 1970:A4), the problems in setting aims for education are debated. According to the report in planning, the future of a school also has to be taken into account, as well as the present. In addition to the school, pupils are also strongly affected by the surrounding society. Thus, it would be important to create a continuous relationship between the school and the society for all the school days of the pupils. Aim setters are everywhere. They can be – in addition to traditional ones like teachers, pupils, parents and educational authorities – also communes and non-profit foundations, as well as smaller interest groups. It is underlined in the Committee report that in aim setting, it has to be taken into account ‘pupils’ harmonic overall development’. Special focus is on familiarising with traditional culture, meaning that people have to know their own history and cultural background.

In the report II of the elementary school curriculum committee (Anon. 1970b. Committee report 1970:A5), it is mentioned that the target for environmental studies is to teach pupils to observe, categorise their experiences, enrich their store of concepts and use of different work methods. As a target for teaching physics, it is mentioned familiarisation of pupils with the most essential natural phenomena and the regularities in them, as well as work methods of physics. In addition, schools should arouse interest in natural sciences among pupils and provide them with the elements in developing their worldview. Targets of teaching geography include, among others, giving pupils information about the Earth and the structure of the universe.

In the intermediate report of the committee concerning the basic education in mathematics and science (Anon. 1988. Committee report 1988:30), the status and importance of the basic education is examined. According to the report the basic education in mathematics and science includes “knowledge of the natural phenomena and laws controlling them and their application in the astronomy, physics, chemistry and biology” (p. 5). As a target for teaching physics, the report mentions, among others, extending pupil’s basic knowledge about sciences and developing his personality. In addition, the target is to arouse interest in collection of information by observation and to enable pupils to shape their worldview. Mentioned as a target for teaching geography, is to “enable shaping a realistic worldview by teaching in innovative and alternative solutions studying way” (p. 54).

In the final report of the committee concerning the basic education in mathematics and science (Anon. 1989b. Committee report 1989:45), it is mentioned that a person needs information in order to shape his worldview, use the tools provided by the culture as well as co-operate with other people. He must also understand ethic questions related to his skills and knowledge. According to the report, education should provide qualifications for collecting and utilising continuously changing and renewing information. Reaching these aims needs new capabilities from teachers, so the report requires starting further educating them.

In the report of the committee concerning the all-round education in humanities and social sciences (Anon. 1993. Committee report 1993:31), geography is regarded as a nature and human oriented subject that builds cultural identity, and studying it gives ‘geographical ability to read’ and tools to build a worldview. The committee emphasises extending teachers’ complementary education to the improvement of the humanistic social all-round education, in addition to educating their own subject and teaching methods.

3.1.3 Aims according to the curriculum

All school levels (elementary, high and vocational schools) have their own curricula, which are still quite parallel. Differences are usually in the practices of how the programs are realised. However, the aims are very much alike between the degrees, as well as the value basis. For this reason the aims are studied quite centrally based on only one curriculum (*The framework curriculum of the comprehensive school,* Anon. 1994), where the application of ‘aim and value’ is presented in detail.

Aims have been divided into three categories that are examined separately in the following.

Social aims

School is a part of society and therefore changes in society reflect unavoidably also to school. School community cannot ignore that. It has to be able to react to new situations and trends of ideas in a way that is most suitable for school. As typical for the present time, the changes have expanded into an international phenomenon; therefore in educating the young people the schools are facing bigger and bigger challenges.

On the other hand, school also has something to give for the society. It can help people to build and edit their worldview and act like a pioneer for exploring new information.

> In regards to the future, we are in a more open situation than before on almost all fields of human activity. Thus the schools now have a possibility to become a significant pioneer and implementation of change. (p. 9)

School wishes to raise its young people to become open minded, in terms of thinking issues from different perspectives, and respectful for the values accepted by the society. Therefore, it is important to have both public and school internal discussion about ethic questions and values. The contents of common value basis come up not only from the present worldview, but also far from the past meaning the history of mankind. Development phases of mankind, especially social and scientific periods of transition, have developed the worldview and left a good legacy for the future.

> In changing the world, what is needed is wide, different perspectives used in ways of thinking. Clarifying and structuring the value basis of school requires ethical thinking and discussion around values. (p. 9)

Daily routine work in schools is directed by the suggestive national guidelines for all activities and curriculum that is an ever-changing dynamical process reacting to surrounding changes. On the local level, however, the curriculum leaves a possibility for teachers to influence the contents and methods of their own teaching. A teacher himself is the best developer of his own work and he knows his school society better than a distant administrative authority.

> Studies show that a teacher's own participation in creating the curriculum is a relevant pre-condition for real changes in the internal operations of the school. (p. 9)

Forming an individual's worldview is based on receiving and processing the information. According to the current learning conception, a pupil himself is the cultivator of his own information structure.

> Current understanding of learning underlines a pupil's active role in outlining his own information structure. A pupil's understanding and expectations direct where he wants to focus his observations, what information to receive and how to apply it. (p. 10)

The teacher's role has become more like a background player, learning instructor and learning facilities' creator. Therefore working habits also have changed. It is important to think carefully about the teaching methods to be used and thinking also that the learning content is as important and significant. Together, these influence the quality improvement of both learning and teaching.

> Amount of information grows rapidly, so controlling it by traditional methods of school is difficult. Important is on which bases the contents of study subjects are chosen, so that studying would promote developing organised information structure. A precondition for this is that the pupils will have an understanding on information sources, ability to search for and create new information and estimate the reliability of it. Critical attitude towards information and its reliability will be emphasised, and as the studies of different fields progress, the old information becomes invalid faster all the time, along with additional developed study results. (p. 10)

Applying information requires studying its reliability, which is criticism towards new information. The school's mission is to arouse the interest of pupils in information and help them to apply it across the subjects in different situations.

Individual educational aims

The main aim is short and clear: promote the development of pupils' personality. Along with technological development of society, technological skills are also required. They are seen to belong to the all-round education. Furthermore, a task of school is to develop a pupil's studying possibilities, such as learning different ways of finding information, information processing skills and independent working. Teacher's role as instructor and encourager should grow. The school should aim to raise the children and young people so that they will have a positive attitude of human nature, a clear multi-dimensional worldview and a healthy value basis.

> As a basis for the teaching and educational work in elementary school is a positive attitude of human nature, of which the starting point is a curious, motivated to learn and active child and young person. (p. 12)

> Young people's worldview as a whole – its phenomenal, functional, social, cultural and mental extent – is an important starting point in planning the educational and teaching work of school. (p. 12)

> In specifying the value basis, an important tool is ethical thinking. Starting point for thinking of values are the basic values of ancient times: goodness, truth, and beauty. (p. 13)

A communal curriculum guides practicalities of teaching, where aims and contents of each subject entity are specified based on national guidelines. All possible materials related to teaching including suggestions for practical realisation can be included in that program. <u>Evaluation</u> is a significant part of the teaching and educational work of a school, because via that a pupil builds his <u>self-identity</u>.

> In the communal curriculum are specified the aims and contents of each subject entity, subjects and subject groups based on the national curriculum. Also, questions related to teaching methods and ways of working in schools are examined.
>
> In curricula the principles of schools' self- evaluation as well as pupil evaluation are decided. Creating the curriculum is an active and continuing development process. It is necessary to start creating the curriculum by defining the values, as the other solutions can be derived from them. (p. 16)

The contents of the curriculum should be connected to the pupil's own normal life and nature. Especially emphasised is <u>integration</u> between different subjects, theme events or co-operation <u>projects</u>. A pre-condition for these activities is that a pupil has <u>communication</u> skills. Communication skills are one of the most important virtues of the pupil in shaping one's picture of the world or self-image. Knowing one's own <u>cultural environment</u> and becoming a part of it are important targets of environmental education.

> What is important is to attach the subject entity to children's and young people's own experiences and things actual and important to them. (p. 32)
>
> Communication can be defined as mental, esthetical and ethic interaction via messages. Thus communicational education means teaching to create, manage and develop that cultural interaction. (p. 35)
>
> In communication a pupil obtains material for build up of his worldview and self-image, and he creates a relationship between himself and the world. Communicational education diversifies this process through experience, action and analysis. In communicational education the pupil's development in expressing himself, experimenting, participating in and affecting the communicational environment as well as information searching and researching is supported. (p. 35)
>
> A target of environmental education is to preserve the diversity of the nature and promote the continuous development. A starting point for environmental education is a sensitive and experimental experience of the nature and cultural environments. (p. 36)

<u>Subject related aims</u>
Studied first are <u>the sciences related to astronomy</u> mentioned in the curriculum, and their input and influence on the development of a pupil's <u>worldview</u> and <u>mental growth process</u>. At the same time, both content related and methodological aims are included in order to plan teaching astronomy.

Mathematics
Mathematics and astronomy have been linked for ages, but even since their separation (*cf.* Lehti 1996, 131), mathematics has an important position for both astronomy studies and an overall development of a pupil.

> Mathematics provides tools for promoting logical and precise thinking, perceiving the space and resolving many practical and scientific problems.
>
> Mathematics can be seen as a basis for scientific development and modern technology.
>
> Mathematics studied in elementary school has to be seen, therefore in a wider scope than only learning certain calculation methods. It has an important impact on a pupil's mental growth process. (p. 74)

With the help of mathematics, a pupil's ability to model the situations in the surrounding world, explore them and apply them by means of mathematics can be developed. For the pupil, it is important to have the possibility to create concrete models in order to shape real visions and concepts.

Environmental and natural sciences

Teaching the environmental and natural sciences (grades 1-6 POPS, Anon. 1994) has a target to familiarise the pupil with simple research methods of natural sciences. At the same time, a basis for the development of natural sciences oriented thinking is created. Learning proceeds from observing phenomena to outlining the basic concepts and application in different situations. Especially one's own active attitude and co-operation with the others are emphasised.

> An essential target of environmental and natural sciences is to support and lead a pupil's growth as an exploring and acting citizen, who is interested in nature, exploration and protection of it.
>
> A target of studying is that a pupil… learns to observe his living environment and its phenomena, and also makes simple measurements and tests by self-made tools, …based on his own observations he can make questions and conclusions, explain his results as well as discuss them. ...learns to build an outlined picture of the Earth as a heavenly body and geographical entity… (p. 78)

In addition, the target is to teach the pupil to search for, criticise and apply information. In that he needs skills to use different sources, the pupil would also have to learn to produce information on his own.

> In addition, the written sources, statistics, pictures, videos, films, fairytales, stories, drama and music that are used in teaching help the pupil to shape his own visions on people's lives in different conditions on the Earth. (p. 80)

Geography

Teaching geography (grades 7-9 POPS, Anon. 1994) has a target to make the pupil to observe, in addition to his natural environment, his cultural environment, because geography also helps the pupil to shape his global picture of the world. The content of geography courses includes viewpoints of both natural and social sciences.

> A target of studying geography is that a pupil ...learns to observe natural and cultural environment, ...learns to understand the position and special features of the planet Earth... …learns to search for actual information in different ways, by also using information technology, ... (p. 83)

Physics and chemistry

Teaching physics and chemistry (grades 7-9 POPS, Anon. 1994) has a target to familiarise the pupil with natural scientific thinking and research methods as well as applying information in different situations. The research focused on observations, aims to understand the phenomena of the nature. Teaching has to support the pupil's development of personality and his worldview as well as help to understand the position of the natural sciences and technology in the culture.

> Teaching has to be inspiring and appropriate, and it has to start from the methodological and informational level that the pupils have reached in their earlier studies.
>
> Teaching physics and chemistry has to support forming the entities across the subjects. Entities can be formed in different ways, for example: structures and systems, interactions, energy, processes and experimental method. Typical for teaching physics and chemistry is proceeding by making observations and measurements in order to understand the dependency and interaction relationships of the nature. (p. 85)

Especially in studying physics, there can be defined two general target levels that suit especially well also to targets of astronomy. These targets are presented here word by word due to their coverage and preciseness:

> On qualitative level the target is that a pupil * can make observations, classify and apply them and make proper conclusions about them, * learns the basic concepts connected to the physical phenomena, principles, laws and models and * can discuss the things and phenomena of the field of physics as well as apply physical information in questions related to the nature and environment, problem solving and decision making.
>
> On quantitative level the target is that a pupil * can make measurements and compare the orders of magnitude, present, apply and make conclusions, * can create simple models, especially based on graphical presentation, and use them in explaining the physical phenomena and * can plan and make simple researches also by using self-made tools, as well as estimate the research process and reliability of the results. (p. 85)

Emphasised especially about these targets are making observations, understanding the conceptual structure, experimentalism and modelling. An experimental and inquiring approach supports the pupil's development of personality. The aims also include educating the pupils to criticise and estimate the reliability of the results.

The themes of entities across the subjects and their contents have to be chosen so that they support reaching the aims of teaching the natural sciences. Five themes mentioned in a previous reference (structures and systems, interactions, energy, processes and experimental method) have been presented in more detail in appendix (p. 87). Learning has to proceed towards figuring out these entities.

Therefore, starting points of teaching physics include an experimentalism that is based on experimentally found information of the surrounding world. Teaching physics include different working methods, that all support outlining the phenomena and understanding the basic concepts. Thinking and understanding the concepts can be tested for example by means of discussion.

> Outlining the phenomena of physics and chemistry, understanding the basic concepts and developing the thinking require of teaching a wide range of working methods. Absorbing and understanding the concepts of physics and chemistry can be supported by working methods that give the pupils a possibility to discuss and be in interaction with each other.
>
> Observations, measurements, tests and experimental research are used as a starting point in creating and implementing classifying and outlining concepts, quantities, laws and theoretical models and in examining the applications of the information. Experimentalism can be one's own activity, laboratory work, demonstrations, educational visits, activity carried out with the help of audiovisual tools or telling. (p. 88)

A common target of the working methods of physics is to direct the pupil into experimental procurement of information in all possible ways and critical estimation of found information and application in practice.

3.2 Research problems and methods

In order to use the aims set for teaching as a basis for planning the teaching of astronomy, the importance of teaching astronomy has to be evaluated from a perspective of aim categories presented in chapter 3.1.3 (social, individual educational and subject related aims). How and to what extent does astronomy support and enforce the set of aims? How can astronomy realise these aims? The significance of teaching astronomy consists of factors by which astronomy can realise the set of aims. These significance factors are searched from the history of mankind by the help of literature, from school world via guidelines and opinions as well as social life via its cultural impacts. It is also important to examine the role of astronomy in the development of mankind's picture of the world and an individual's picture of the world development process. Astronomy has had a role in the history of mankind, so it can have a role also in the development of the pupils. The pupil's natural development is similar to the historical development of science. Considering all this, it is reasonable to get familiar, rather extensively, with the history of astronomy from various perspectives.

Operative teaching has to be based on the conceptual structure of astronomy based on meanings of concepts. The target of the examination is to study how this structure fits into the structure of empirical science's concept formation and how quantitative concepts are connected to the quantity and law system that is the basis for teaching physics. This way the targets of teaching astronomy would be closely related to the targets of teaching the other natural sciences – especially physics – and thus would be specified with all their special features. Drawing a parallel between the sets of aims has an impact on the selection of contents and method as well.

In planning the teaching of astronomy, it has to be taken into account the structure of the learning process so that the subject matter will be aligned to the phases of the pupil's own development process. It was already mentioned earlier that the science (here has to be thought the structure of the entire contents of astronomy) and the natural development of the pupil following similar paths. Examining the learning process has a target to switch the contents and methods of teaching to the factors that are known to impact the pupil's personality and development of his worldview. The pupil is continuously involved in a social process, in interaction with the other pupils, teachers and surrounding society. In this process, the educational target of the school is to aim to promote the common understanding especially within immediate surroundings, that is the pupil's school community (Kurki-Suonio, K. & R. 1994). In this respect the education and teaching methods, by which the targets of teaching related to the content knowledge and the development of personality can be achieved, will be in an important position.

Which kind of possibilities are there to realise a teaching that takes into account the importance of teaching astronomy, conceptual structure of astronomy and development phase of the pupil's astronomical worldview? These possibilities are searched for by an inquiry for teachers, from the points of view of learning materials, guidelines and teacher training as well as estimating one's own teaching experiences.

The main problem of the research is

How should astronomy teaching be organised in the comprehensive school on the basis of the significance of astronomy teaching, the conceptual structure of astronomy and the development of pupil's astronomical worldview?

My intention is to study how to organise a systematic, structural-based and extensive astronomy teaching in the comprehensive school. The problem will be explored from many different points of view, both using literature and empirically.

The main problem will naturally break up in the sub-problems, from which the structure of the research will be formed.

Which are the essential significance factors of astronomy teaching?

In mapping the significance in Chapter 4, the significance of astronomy teaching will be searched from the selected textual material contained in the social life, in the school life, in the development of worldview and in the great turning points of the history of astronomy. The history of astronomy will be considered on how mankind's conception about the universe has changed and developed from that point of view. From the times B.C.E. until the recent days, those turning points will be searched, in which astronomy especially has been an impressive factor or a target of application. In addition to that, the interaction between astronomy and other sciences or sectors of culture will be considered.

Discovered passages of text related to the aims are itemised and classified into categories of aims (presented in Anon. 1994, see chapter 3.1.3) and further in subcategories (will be presented in chapter 4.1). The main themes of the textual materials in these categories will be interpreted as themes of astronomy teaching as a condensed presentation of the significance factors. These themes will be taken into account in the planning of the contents and methods of astronomy teaching in Chapter 10.

What is the conceptual structure of astronomy like?

In mapping the conceptual structure in Chapter 5, structures of empirical concept formation of astronomy will be searched in literature in comparison with empirical concept formation of physics and other sciences. The generalisation and integration development of astronomical concepts, empiricism and applications, as well as the special position of astronomy compared to physics will be searched. Also, considerations about teaching are going to be done in accordance to approaching methods used in teaching and the conceptual structure of astronomy.

What do the significance and conceptual structure require of the contents and methods of astronomy teaching?

On the basis of the concluded significance of astronomy teaching and the conceptual structure of astronomy, the astronomical contents and appropriate teaching methods will be discussed. In order to build up a basis for planning of contents and methods, as well as the order of subject matters as for the development of the structural picture of world, a founded proposal will be prepared on the basis of the themes of significance.

What kind of preconditions are there in planning astronomy teaching, which takes into account the significance of astronomy teaching, conceptual structure of astronomy and the development of pupil's astronomical worldview?

Present preconditions for astronomy teaching are explored (chapters 7 and 8) empirically, using a questionnaire and an interview, and by an overview of curricula and textbooks. In the questionnaire, the recent situation of astronomy teaching and teachers' qualifications and attitudes are examined. Results are interpreted mainly in an essay-like form; a few of them are analysed by statistical methods. The survey of preconditions is deepened using an interview.

In chapter 9 I will discuss my own experiences on selection of subject matters and application of various teaching methods. In building up my founded proposal for astronomy teaching they have been valuable support. I also wish to bring out experiences of other teachers, because one may get some ideas from them for planning astronomy teaching. Since many practical questions have to be solved before the implementation of teaching, an exploring of practical possibilities of implementation belongs to the exploration of preconditions.

How do the preconditions affect on the implementation of the proposed astronomy teaching? How can the conditions be improved?

The possibilities to implement astronomy teaching along the lines of the founded proposal are discussed. On the basis of the research results recommendations about curriculum, proper timetable and teacher training will be made, as well as proposals for further improvement of astronomy teaching.

Part II Literature research

II A Mapping of the significance

4 Searching significance of astronomy teaching

4.1 Outline of the research method

The planning of astronomy teaching has to be based on the significance of astronomy teaching. The significance can be interpreted to consist of such factors or features through which teaching of astronomy would promote fulfilment of the educational aims of the comprehensive school. Significance factors can be searched in the cultural effects of astronomy on different areas of social life both in the present and in the history. In this work such *significance factors* were searched from a prominent set of texts selected from literature, relevant from the viewpoint of astronomy teaching.

A necessary primary phase of this part of research was a wide overview of literature where astronomy was discussed from the general cultural viewpoint in relation to the development of culture, school, teaching and worldview. In reading through the literature it became obvious that many of the texts repeated the same arguments and views just with different personal tones. Therefore, a good coverage of possible significance factors could be reached through a purposeful selection of a restricted set.

A set of *books, writings and articles* by Finnish scientists and cultural authorities were selected, because, in the first place, the intention was to plan astronomy teaching for the Finnish school. In order to cover the history of astronomy and its effect on the development of human culture worldwide, a set of texts by international authorities were selected. The set includes not entire books or articles but relevant extracts as listed in App. 4.1. These extracts form the *text material* to be analysed

In order to perceive the most essential features or arguments included, the text material was *divided into four groups* according to the four different viewpoints mentioned: culture, school, teaching and worldview. Each group was then examined separately reading the text material through over and over again, until an idea of a proper *subdivision into special topics* was found and a fair description of each topic could be written. In the fourth group, material relating to the development of astronomical worldview, it was found appropriate to arrange the text to make the description *proceed in chronological order.* In the development of conceptions of worldview, one can concentrate on the great revolutions, because they are unique turning points, where the significance of astronomy for the mankind is most clearly emphasised. The exploration of history in this sense can be identified with exploration of the development of astronomical concept formation. It would, thus, also give a basis for defining contents and methods for astronomy teaching.

This *essay-like interpretation* of the contents of the text material is presented in chapters 4.2.1-3 and 4.3. It is a preparatory step, which yields, besides the educational aims, an additional basis for the definition of categories and sub-categories of text excerpts, and gives a background for the ordinary analysis of the material in terms of the categorisation.

Categories for data analysis

For the ordinary analysis the text material will be reduced into a set of text items, statements related to the problem of planning astronomy teaching. This reduction is based on a basic categorisation, which enables one to verify the relevant text passages and to classify them. This was based on three principles.

The first basis of the classification was formed by the three aim categories of the curriculum, (a) social aims, (b) individual aims for education and (c) aims of content knowledge (web 4.1). In order to deepen and specify this classification and to find a wider viewpoint, each of them was yet divided into three sub-categories (coded as a1-a3, b1-b3 and c1-c3), on basis of a closer examination of the aims setting in the curriculum, as specified in Table 4.1. Perception of proper sub-categories was also supported by the sub-division of the text material in special topics.

Table 4.1. Aims categories a, b, c based on the curriculum

a = Social aims

a1 = aims contained in social life and actions
In the sense of this sub-category the society has several roles, such as maintenance of school, reviser of general attitude, field of public discussion, designer of value basis and critic of society.

a2 = aims contained in guidance of society
In guidance of society belong instructions for schools, including the bases of curriculum, criteria for evaluation, subject contents and definition of value bases.

a3 = aims from society to individual
Society has expectations to individual in different sections, like in accordance with education, life values, culture and general opinion. An individual is expected to have a strong self-image, tolerance of critics and structured picture of world.

b = Individual aims of education

b1 = development of personality
In properties of personality belong self-image, development of worldview, own dignity, learning abilities, strong self-awareness and tolerance of critics.

b2 = development of personal knowledge
In stages of the development of personal knowledge belong discovering of learning abilities, searching for information, analysing and adapting it, construction of worldview, formation of constructivist information structure, assuming both scientific method and learning by doing.

b3 = social development

An individual has social manners, like behaving in groups, conversational talent, interaction, approving each other, tolerance of dissimilarities, co-operation and empathy.

c = Aims of subject content knowledge

c1 = scientific process, acquisition of knowledge, assuming and applying it, development of conceptual understanding

c2 = technological process, acquisition of knowledge in using tools, ability of using tools and influence on society.

c3 = social process, process of community for acquisition and use of knowledge, aid in implementation of scientific and technological processes, development of understanding and ability of using tools by the aid of people's mutual interaction.

Planning of astronomy teaching forms the second basis of the classification. This gives rise to two additional categories, coded in the analysis as

s = subject or subject matter appropriate in contents of astronomy

m = method appropriate in astronomy teaching

Development of the worldview forms the third basis of the classification. This yields just one more single category coded as

mk = events influencing in worldview (**m**aailman**k**uva in Finnish).

Data analysis

In the analysis all groups of the text material were treated similarly. The text was read carefully through several times in search for sentences and expressions that would belong to any of the categories or subcategories defined above. For the aims categories a set of keywords picked from the relevant passages of the curriculum was used to support the identification of the sentences and their proper sub-category (Anon. 1994, see chapter 3; see also web 4.1). Statements in the text material referring to contents and methods of astronomy teaching belong naturally to the categories **s** and **m**, respectively. All such statements in the text material, which were related to factors having effects on proceeding strategy in the development of pupil's astronomical worldview, were placed in the category **mk.** All such sentences and expressions were underlined and marked with the category codes **a1-a3, b1-b3, c1-c3, s, m** or **mk**.

The underlined and categorised version of the original text material (in Finnish) is given in the web page (web 4.2). The following, in the context of the discussion of each category and sub-category the relevant part of the text material is given in English translation - without underlining and codes.

The set of underlined and categorised expressions and sentences form the data in the research of the significance of astronomy. They were listed in accordance with the categories they belong by their meaning. There were thus twelve lists to be handled in the analysis. Within each list, the expressions and sentences were grouped according to topics, which arose in the interpretation of the set. In addition to that, an essay-like interpretation of each topic was made in all categories, except for the categories **s** and **m**, where just the resulting lists of contents and methods were collected. A detailed example of the complete analysis of one category is given in Finnish in web page (web 4.3).

Finally, the interpretations in each category were concentrated into those significance factors indicating themes on which the planning of astronomy teaching will be based. The interpretations of the categories are presented as summaries in the chapter 4.4.

In the same context, it is important to consider in depth the evidence concerning the significance of this research.

4.2 Astronomy in social life and culture

The next chapters will draw the attention to the role of astronomy in different areas of human life. An overview is presented covering the "best known" events where astronomy has played an important role. Many of these events are still current today in the era of modern technology. The different aspects do not form a chronological chain but are rather glimpses" from several, largely overlapping, areas of emphasis.

4.2.1 Social influence

Conception of the world in the history of mankind

Pannekoek seeks the origins of astronomy by surveying the history of natural sciences. Astronomy has existed in the history of mankind already long before other natural sciences. The needs of everyday life have simply created demand for the knowledge and services of this branch of science. Other branches of science were developed mainly in the universities and laboratories during later centuries. After the collapse of the classical world science sank into the darkness of the Middle Ages. It was not until the social changes of the 1500's that also astronomy gained a remarkable status due to a new conception of the world. In the next century natural laws of motion controlling the universe, instead of philosophical theory, were accepted in human thinking. Astronomy had also proclaimed itself to be the cradle of theoretical knowledge producing predictions and maxims that control and guide mankind – besides the requirements of society. The astronomical theory was a main part of the religious and philosophical conception of the world and it was reflected to social life. The predecessors of the modern physicist have been physicists, whereas the astronomer finds Babylonian priests and magicians, Greek philosophers, Moslem princes, monks from the Middle Ages as well as noblemen and priests from the Renaissance era in the history of his branch of science. It is not until the schools of the 17th century that he finds modern citizens like himself. To all these astronomy has meant the whole conception of the world. That is why the history of astronomy can also be regarded as an evolution history for human's conception of the world. The current astronomical research is more and more directed to the construction of theories of the universe instead of empirical observations. After the technical revolution stars have no more had a similar meaning in human life as before. Astronomy is, however, still a science, which explores the entire universe, and its history is a remarkable part of the history of mankind. (Pannekoek 1989, 13-15)

Social influence in early history

Farrell describes in his article the rise of astronomy into an influential background of the modern culture and science. "The Greeks, the Persians and the Indians each developed astronomy and astrology during antiquity, but the astronomical observation almost ended in the second century A.D., when the mystical sciences and astrology gained ground" (Farrell 1996). The Muslim and Arabian culture spread all the way from India and Arabia up to Spain. Astronomy with its interesting research objects and efforts to explain the universe had a vast influence on the society of that time. The significance of astronomy was recognized among monarchs and war generals as well as the scientists. The leaders, the caliphs, took astronomers and astrologers with them to the war fields and discussed scientific themes with them. The monarchs were interested in secrets of the universe and phenomena of the surrounding world. That is why they provided the scientists with better and better measuring equipments. They gathered versatile scientific information from around the world and had that translated. In about 800 A.D. scientific researches started increasingly to be written down, due to the Chinese know-how in making paper.

International activities

The heavenly phenomena were a vital part of the life of Greeks. The geographical area was too tiny for agriculture. That is why sailing became, by trade with the overseas countries, an important source of livelihood. Astronomical knowledge was needed for sailing. This new way of life had an influence also on people's conceptions of the surrounding world. Connections with the foreign countries and peoples broadened the sailors' and travellers' conception of the world. It was easier for them to assimilate new ideas and manners, and thus criticize the traditional beliefs.

In Greece economy and politics were blossoming in 600-400 B.C. It is true, astronomy was developed gradually; already in the fourth century B.C. Among other things, some planets and their orbits were known. But everyday duties did not leave room for astronomical hobbies and so accurate observation of stars was given less time. (Pannekoek 1989, 95-105)

In Singer's opinion trade was developed along with different needs and experiences as the construction and the activities of society became more versatile. Things needed were no more always available as they had been when the society was self-supportive. They had to be purchased either from craftsmen or from other countries. Mercantile trips and expeditions broadened the people's worldview. (Singer 1996, 4-5)

Controlling time

The practical astronomy arose, as Pannekoek describes, from the needs of travelling and chronology. When sailing on the Mediterranean, it was only during the night that the stars were used to show direction and time. The time was defined by observing especially rising times of the zodiacal constellations. The earlier lunar calendar was adjusted to the solar year by adding a thirteenth month. The solar calendar supported everyday life better than the lunar calendar, especially as to agriculture and sailing. Local authorities made changes in the calendar. That is why the periods could be somewhat different in different places. To define the start of a year exactly, the time of summer solstice was defined when the Sun was at the highest at noon. At that instant the points of sunrise and sunset on the horizon were nearest to the north. When defining the vernal and autumnal equinoxes or the summer and winter solstices, it was noticed that there were differences between the lengths of the seasons. It was concluded that this is due to the speed of the Sun varying in different quarters! A clock based on regular oscillatory motion became a new device for measuring time (Pannekoek 1989, 106-112 and 278)

Measurements and calculation

Astronomers developed, along with their astronomical calculations, spherical trigonometry and algebra. When sailing in the Near East in the 12th century, the merchants used astrolabes and different kinds of protractors made of metal, and guidebooks and maps in which the degrees of longitude and latitude were written down. It was not until the 13th century that the astrolabes came to Europe. At that time they were quite a revolution. Then the sextants, chronometers and clocks took their place in everyday use. (Farrell 1996)

Still in the 17th century the sailors on the oceans needed accurate astronomical data. They used astronomical measurements to map the ports, coasts and islands of the distant continents. On the open sea the sailors had to determine the longitude and latitude of their geographical position. The latitude was easy to determine on the basis of the latitudes of the Sun and the stars measured on the meridian. For this purpose good catalogues of those values were necessary. Kepler's catalogues were made for the Sun, the Moon and the planets and Tycho's catalogues for the northern stars. But as the requirements increased they were no more good enough, thus, the aid of astronomers was needed again. Determination of the longitude was based on disparity in time between the site and the zero-degree meridian. Due to the needs of the French economic and political life, Paris acted as the zero point of the catalogues in the 17th and 18th centuries. Later on, when England became the leading seafaring country, the Greenwich observatory became the place of zero- meridian. (Pannekoek 1989, 276-277)

Pannekoek tells, the rise of science consists also of improvement of practical working methods besides the development of ideas and theoretical explanations. An astronomer had to calculate values of astronomical quantities from the numerical values obtained in his observations. Thus for example in the 15th and 16th centuries, building of mathematical equipment was as important in the scientific process as construction of technical gadgets. Positions of planets were defined earlier in terms of ecliptic coordinates, longitude and latitude, but in the 16th century the equatorial system gained support. It was easier to determine the equatorial coordinates, the right ascension and the declination, and to calculate the ecliptic coordinates from them with trigonometric equations. (Pannekoek 1989, 199-201)

Technology and new sciences

Settling down to cultivate land required tools. Development of technology can be said to have started as early as at the shift from the Stone Age to the age of metals. Research was required also for owning and splitting land. Landowners' rights and common regulations had to be defined. This gave rise to the development of land-measuring leading further to geometry with its mathematical forms. Slaughtering of sacrificial and edible animals made man acquire information of their anatomy. This led further to exploration of human anatomy. As a result, the branches of science like metallurgy, mathematics, anatomy, *etc.* as known nowadays, were developed. The findings and inventions promoted development of different fields of science. *E.g.* inventing fire, clay-wares, wheel, bow, metals and ways to produce metals showed mankind the 'way to science'. Finally, Singer boasts of that "The great thinkers have had a strong influence on the development of philosophy and, thus, also on the development of science. The science is namely a part of philosophy." (Singer 1996, 1-5)

Inner beliefs

Pannekoek states that the 16th century was an era of a great social and spiritual revolution. New religious conceptions gained space. Lutheranism, Calvinism and reformation of the Catholic Church shook up the silent life of the former authoritarian church. At the same time also belief in astronomical predictions increased more and more. The sovereigns hired "mathematicians" to predict the future (at that time "mathematics" meant "astrology") for them. So, astronomy prevailed in everyday life on the 15th and 16th centuries more than any other science. (Pannekoek 1989, 186-187)

Crowe views the significance of astronomy from three viewpoints: scientific, historical and philosophical. From the scientific point of view, studies of astronomy will provide the pupil with basic knowledge about the starry sky, referring, thus, also to the area beyond the solar system. The historical point of view emphasizes examination of the evolutionary phases of astronomy as science. In addition, surveying phases of development of some special subject, for instance, those of the observation tools during the last three centuries, belongs to the historical viewpoint. This includes two subject matters: the product of science and the developmental process of this product. Such an approach gives a fresher and a more human vision about science. We are exploring not only the creatures but also the creators. On the other hand, the philosophical viewpoint includes many ideas and themes. The ideas, which led to the modern conception of the universe, created many possibilities for philosophical and theological beliefs. Exploration of the history of stars involves also methodological questions concerning nature, meaning and reliability of observations. Crowe states when learning natural science, it is important to study also its historical development and to get acquainted with the connected philosophical thoughts. (Crowe 1994, pf-1)

New scientific conquests

A couple of Pannekoek's examples show how astronomy could be a field for applying physics or could make good use of the new discoveries of physics.

Pannekoek continues astronomy of the 19th century did not limit its discoveries to the surface of the heavenly bodies but penetrated also inside. The gravity extended down to the centre. As the first new piece of knowledge, Pannekoek tells about determination of the mean density of matter. For example, when the masses of the planets are known relative to the mass of the Earth, either on the basis of their satellites or disturbances in their motions, and their volumes are determined by measuring their diameters, the mean densities relative to the density of the Earth are obtained. As another new conquest Pannekoek mentions a gift offered by physics to astronomy on the 19^{th} century, namely the spectral analysis. The light of the Sun reflected by a planet goes twice through its atmosphere, that is why its spectrum has to be like the spectrum of the sunlight, the absorption of the planet's atmosphere excluded. At the end of the century the angular velocity of the rotation of the planet could be determined on the basis of the wavelength shifts of the reflected light. (Pannekoek 1989, 383-389)

The science of the universe

Pannekoek notes finally that the solar system is just a little particle in a huge galactic system, many million times bigger, with milliards of suns. We know that outside of our galaxy there are some objects, for example globular clusters of stars. The space explored by the astronomy has widened immensely; the number of galactic systems may be hundreds of milliards. They are neither evenly nor randomly distributed, but are for the most part condensed into groups or clusters. Thus, they also have a structure. In Pannekoek's opinion astronomy is now confronting new problems, not astronomical in the first place but problems of space and time or universe and science, connected with physics, mathematics and astronomy. It is now realised that the problem of infinity is a versatile object for a new science, which is a combination of astronomy, physics, mathematics and epistemology, and is named the cosmology. In this fusion with other sciences, astronomy or the science of stars has become the science of universe. (Pannekoek 1989, 483-490)

4.2.2 Astronomy in school life

During the last few years, the situation of the teaching of natural sciences has been a subject of pondering especially among the subject teachers. The reason is the decrease of lessons of natural sciences in the national reorganization of the lesson schedules. In a proclamation delivered 18.2.2000 to the minister of education Maija Rask, the Finnish Association of Teachers of Mathematics, Physics, Chemistry and Informatics (MAOL, web 4.4) states among other things "A good mastery of the natural sciences gives a person an understanding of nature and its phenomena, qualifications to understand the importance of technology and technique in nature conservation and in sustainable development". According to the proclamation, it is necessary for our society that the education of its citizens secures the competitive ability of industry and the means of solving environmental problems. To reach the aims the general education must have resources to give high enough education in mathematics, physics and chemistry. The proclamation states that "Studying of these subjects should be started as early as possible due to the child's natural curiosity to wards natural phenomena and technical solutions", and emphasizes that good expertise in teaching physics and chemistry arouses a lasting interest in natural sciences. (Web 4.5)

There has always been some astronomy included in the subjects taught at school, especially in physics. In the early times it has offered a basis for the development of physics (see Chapter 5), one could claim that it has inspired researchers to empirical examinations. Observing new phenomena and objects has forced people to invent still better equipment and improve old equipment. The possibility offered by the telescope “to leap” from the Earth to space must surely have increased research of the starry sky phenomena. Predictions created by theoretical ponderings or mathematical methods can be tested by measurements and observations. This co-operation between physics and astronomy has certainly promoted the development of both, with an accelerating speed one might say.

'Why should astronomy be taught?' asks Tuomi and gives also some answers already at the beginning of his article (Tuomi 1999). He states that astronomy fascinates people at all ages and leads easily to the ultimate fundamental questions. At the same time, the pupil gets acquainted with the scientific method. Astronomy is a key to the natural sciences and it is amusing to teach it. The possibility to teach in the natural environment and in real situations makes astronomy special. Pupils may use their own senses to observe an entire world of phenomena, to gaze at the dark sky with its twinkling stars, to listen to the silence and to feel the coldness. Pupils’ enthusiasm can start already in the Kindergarten and it may continue through the whole life, but a wrong sort of teaching may also extinguish it. In Tuomi’s opinion, the exploration of celestial phenomena must proceed to theory through observations and positive experiences. The role of the teacher is remarkable in creating this kind of learning situation, but many restrictions and problems arising from the practice can prevent its realization. For instance, school transport, light pollution, the price of a telescope and various compensations can be these kinds of hindrances. An enthusiastic teacher will, though, find the way to carry out the teaching in his own way.

Exploring astronomical phenomena helps pupils to perceive the surrounding world and construct their conception of the world (West 1996). Pondering together events they observe in their environment and questions occupying their minds is often very fruitful and even educative to scientific thinking. Such conclusions West has drawn from his teaching experiences. He tells further that he has discussed with his pupils questions related to the origin of seasons, the inclination of the Earth axis relative to the orbital plane and its effect on the angle of incidence of sunlight in different parts of Earth, so that we see the Sun shining high up on the sky in the summer and low down in the winter and that the sun rays have in winter a much longer path to go through the atmosphere, which all results to a wide variation of the distribution of the incident radiation energy on the Earth surface in the course of a year. He also tells to have discussed how the inclination of the Earth axis makes the path of the Sun on the sky look like a lying narrow number eight. This kind of a graph, the analemma, can be observed if the position of the Sun is determined every day at the same time. This phenomenon is well known, at least, by the sailors, who had to know where the Sun would rise on the local horizon.

Noll thinks that astronomical phenomena serve well as examples in teaching physics (Noll 1996). For example Kepler’s 3rd law for circular orbits can be generalized to describe motions on elliptical orbits in general. In his opinion, because the circular orbits are special cases of the elliptical orbits and rare in our solar system, it would be more reasonable to turn the process around and start with the elliptical orbits. Then Kepler’s 3rd law for the circular orbits would come out as a special case. When dealing with the case the pupils would need to know from physics just the conservation laws of angular momentum and energy. Noll presents the excellent co-operation between astronomy, physics and mathematics in derivation of this law. It starts from the area swept by the position vector and the orbital angular momentum of a planet, it makes good use of the equation of an ellipse and conservation of energy, ending finally up to Kepler’s 3rd law for elliptical orbits. When starting from the circular orbits pupils should accept that the radius is replaced by the semi major axis. Then the validity of the law also in this case would be more difficult to demonstrate to them. (It should be noted, however, that this theoretical approach is not suitable for school since it turns the natural direction of learning upside down, *cf.* Chapter 5.)

A peculiar example of the significance of astronomy teaching is found in the curriculum and subject contents of the Naval Academy of the Finnish Defence Forces. The naval cadets are taught to orientate themselves by stars, to determine the position co-ordinates and to carry out also other navigational tasks by old methods used in ancient times. The teaching brochure (Star navigation 1992) is intended for use on a course where the cadets shall study stellar navigation and especially constellations and stars of the northern hemisphere. The cadets are also taught to show round the planetarium of the Naval Academy when needed. Mythological stories of constellations are included, based on A. I. Henriksson's book "The stories of the antique". The brochure presents with pictures mainly such constellations, which include navigational stars. Also, some other constellations are presented on the basis of their interest. In addition, the planets are introduced. The constellations of the Zodiac are presented as horoscopes or star signs. Towards the end the brochure seems to lose its hold on astronomy also in other ways and turns to astrology.

4.2.3 Astronomy as an inspirer of science and culture – a philosophical-scientific viewpoint

Raimo Lehti ponders in his book ”Stars and people” over the significance of astronomy for other sciences and culture (Lehti 1996, see also Lehti 1992). His thoughts take a deep look at science and culture seeking mutual interaction. This chapter presents an exceptionally wide range of thoughts from this book because of the many-sided, profound and, as to the scope of the present work, a very rich discussion of the significance of astronomy.

The significance of mathematics and astronomy to science and culture

The rise of the scientific-technical culture has been provoked by certain series of events called 'great revolutions'. Lehti states 'the revolution of sciences' in the 17^{th} century and 'the technical revolution' in the 18^{th} century are this kind of changes. The European scientific-technical culture spread in the 19^{th} and 20^{th} centuries everywhere and it is now global. The revolutions mentioned, as well as 'the scientification of technique' in the middle of the 19^{th} century, were, thus, European phenomena. The mathematical knowledge gathered during the previous centuries amplified on its part the effects of the 'scientific revolution'. But at least some philosophers and theologians pondering over the astronomical world systems suspected the possibilities of mathematics, especially in the theories of planetary motions. They thought that the mathematicians should not regard their models of planetary motions as corresponding to the reality. The breakthrough of 'Copernicanism' together with the researches of dynamics by Galileo and his successors increased the significance of mathematics for other sciences. The mathematical analysis of astronomical phenomena produced more reliable knowledge on the structure of the world than mere pondering of causal relations.

Separation of mathematics and astronomy

In the latter part of the 19th century mathematics and astronomy were no more joined into the tight *mathesis* combination. The rise of spectroscopy created a new subject area for astronomy, the physical research of fixed stars, to replace the dynamic theory of the planets. Lehti tells ‘the middle of the 19th century meant in many ways a new deal in the world of sciences’ (p. 131). At first thermodynamics and electrodynamics, later the new theories of the structure of matter and elementary particles, rose to the level of mechanics. Also the biological sciences, overshadowed earlier by the ‘scientific revolution’, are now gaining an important position.

Effects of celestial bodies on the earthly life

Some celestial phenomena have a remarkable influence on our living conditions and circumstances. The heat of the Sun, the alternation of seasons and the light and dark periods of day and night as well as the tide are earthly phenomena driven by celestial causes. The influence of the universe outside the Earth on the life of the creatures down here is, however, mostly indirect. The physical and chemical circumstances of the surface layer of our planet, the planet’s rotation around its axis and revolving around the Sun create an environment for people, animals, plants and all creatures to live. The circumstances of the environment have shaped their activities and achievements; they have had an effect even on the rise of the human culture and the sciences.

Observing stars

The night sky gives often an impression of something ’super mundane’. Seeing the starry sky had a different meaning to a man of the antiquity than to a modern man. The ability to use deliberatively the knowledge gained from observing the starry sky has been one of the characteristics, which distinguishes man from an animal. It has, thus, been embarrassing to discover that also some animals make good use of the stars. For instance, some birds use stars to orientate themselves during their migration.

Early cultural effects of the starry sky phenomena

Although the old mythological impressions may have had a certain effect on the rise of astronomy, the effect of ‘the regular rotation’ of the starry sky has been even stronger. Man has utilized it by creating a calendar and developing equipment for orientation, like a clock and a compass. Indications of earlier utilisation of the starry sky combined with various rituals can be seen for instance in Stonehenge and in other similar constructions of the Stone Age. Likewise, the Mayan calendar shows that they have made observations of the motions and phenomena of heavenly bodies.

In many cultures the world of the stars has been regarded as a home of divine powers higher than the earthly world, but ‘only in the chain of the cultures from the antiquity through the Latin Europe to our modern world they have been combined with astronomy and cosmology’ (p. 141).

Astronomy in the development of modern science

Noteworthy events in the 'revolution of sciences', which ruined the medieval cosmology, are the Copernican heliocentric system, Kepler's more accurate version of this system, Galileo's dynamic researches proving the rotation of the Earth together with his observations by telescope, which showed the similarity of the planets. Newton combined the laws of motion and the theory of gravity (Fig. 4.1), and created a basis for theoretical astronomy and physics.

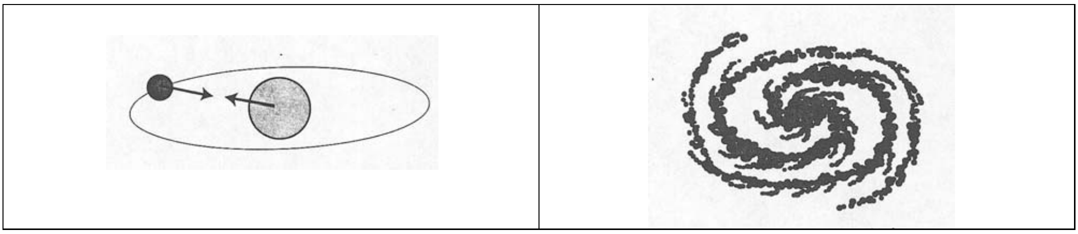


Fig. 4.1 Gravitation controls the motion of the heavenly bodies and keeps the galaxy together.

In some events of the 17th century, astronomy has had a stronger effect on the evolution than the revolution of science. This impact is mainly materialistic. For example, the instruments designed for seeking the secrets of nature have been developed for the needs of astronomy in the first place. Also the scientific societies, which form a community solving scientific disagreements, have needed more efficient means for communication. That is how books, scientific magazines and also the present modern means of communication were developed. *The Royal Society of London for the Improving of Natural Knowledge*, for which the King confirmed the rules in 1662, is one of the very first of such communities. The French Royal Science Academy was founded a little later in Paris. These societies contributed to the foundation of an astronomical observatory both in Paris and in Greenwich near London. They were the very first institutions financed by the society, which were doing research work systematically. As a result of John Flamsteed's work in the Greenwich observatory the famous star catalogue was composed. On the other hand, the work of Picard, Cassini and others in France led to the 'measurement of degrees' needed for determination of the size of the Earth.

Newtonian astronomy as a paradigmatic 'normal science'

Newton's theory and the ever more specific tools developed after Brahe raised astronomy again into a leading science in the 18th century and at the beginning of the 19th century. William Whewell describes in his book of 1837 the progress of science, presenting how "the combination of Newton's dynamics and observing astronomy has led to a top-level science, which is a valid model for all other physical sciences" (p. 149).

Thomas Kuhn has stated that collection and analysis of details within the framework of existing theories is the backbone of science practicing and a factor, which largely explains the development of science. He calls this form of research, which dominates over the everyday science practice, as normal science. (Lehti 1996, p. 151; *cf.* Kuhn 1962/1970, p. 34). In Kuhn's opinion, mere rejection of old scientific theories replacing them with new ones is not sufficient in science, but it is the cultivation of normal science which reveals the flaws in the existing theory. Such changes of the theory Kuhn calls scientific revolutions.

Effect of astronomy on other sciences

Invention of the spectroscope made possible clarification of the structure and development of stars. On the other hand, study of the motions of stars led to an understanding of the dynamics of star systems. Galaxies, called nebulas, were found to be star systems. Pondering the first moments and the future of the expanding universe and search for explanations are shaping our astronomical worldview. Lehti emphasises that the significance of astronomy for the science and culture lies in that "intellectually as well as emotionally, living a life worthy of a human being presupposes understanding to some extent of the world the human race is born into and acceptance of it" (p. 152).

Gazing at the starry sky has helped people intellectually and widened our conceptions. Why, due to the development of science we have better opportunities for that than those who studied the starry sky two thousand years ago. The broadening of our worldview is mostly due to the fact that our knowledge about the physical world has grown wider than the Newtonian celestial mechanics, which is counting on gravity and classical dynamics. Astronomy is no longer the basis of the physical science like in Newton's time. The modern physics explores mainly the effects of electrical, magnetic and various microphysical forces.

In the overall development of the *physical science*, the significance of astronomy has been in giving the initial impulse to a certain series of events. According to this view, "mathematical formulation of the basic natural laws is a fruitful method for interpretation of the external world leading to new insights" (p. 153). Astronomy gave an impulse, for example, to the rise of electrostatics: Coulomb's law has the same form as the gravitation law.

The concept of potential, originating from the celestial mechanics, and the series expansions of the Kepler motion, which have led to the development of Fourier's series and, further, to the theory of complex power series, are examples of impulses of astronomy to *physics and mathematics*. Astronomy has also influenced, on its part, in studies of the solutions of the three-body problem.

Astronomy has influenced also the writings of thinkers and poets. In the European history there are several thinkers and poets concentrating on cosmological themes. Their astronomical interest can be clearly seen in the European culture. One cannot understand the cosmic fears of John Milton and other metaphysician poets without knowing the contents of the revolutionary reformations of Copernicus, Brahe and Galileo and their influence on people. Epicures, among others who supported the atomism, opposed the *religious* interpretations of heavenly motions. "Christian cosmologists had added in the world, constructed by the astronomical and physical views, theological and ethical aspects, which Dante describes in his poems" (p. 155).

Besides the great thinkers, also *the writers* have interpreted thoughts aroused by astronomy. The language used in the writings was Latin, the language of the scholars and the universities. Common people were, thus, left outside these discussions. On the other hand, writings about the conception of the world had been published in vernacular language already long before ‘the revolution of sciences’: “The writings of Brunetto Latini, Ristoro d’Arezzo and others in French and Italian disseminated new ideas on cosmos among people already since the 13th century” (p. 157). Also Alessandro Piccolomini, an Italian writer, in his books about ‘the universal globe’ and the fixed stars, dedicated the frame stories on the construction of the world to a beautiful lady. It is true, his world still was pre-Copernican and geocentric.

Also the conceptions of those who are interested in *astrology* or are looking for flying saucers have certainly been influenced by astronomical knowledge. The research methods of an astrologer differ completely from those used by the astronomer in his researches and interpretations. For instance, there are not many astronomers who would believe in flying saucers at all. Astronomy is fascinating people even today. It nourishes their imagination with mysterious ‘heavenly’ matters (Fig. 4.2).

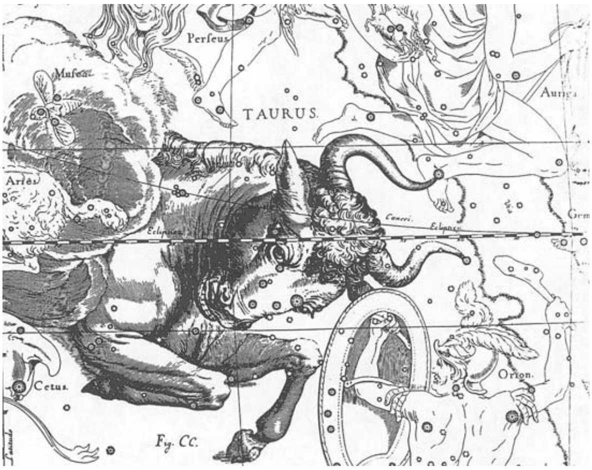


Fig. 4.2 Mythological features on the background of the constellations – an imaginational inspiration

Three theses on the significance of astronomy

The conception of the physical world, which is controlled by mathematically formulated laws, can be regarded as a product of the European culture. Is it then correct to speak about the significance of astronomy to the European culture, although, for example, the theory of the motion of the planets was a central theme in the ponderings of the 17th century? At the end of his presentation, Lehti is encouraged to present three theses on the significance of astronomy (p. 161):

1. The course of history shows that the attempts to clarify the external world mathematically have their origin expressly in the examination of the heavenly phenomena, and that these attempts have been extended from there to other kinds of phenomena.

2. The effect of the mathematically formulated world explanations on the intellectual world of a European is mainly caused by astronomical and cosmological problems.
3. It is not just a historical accident that this has happened, but the research of the physical external world by mathematical methods could never have been started in any other way than as launched by astronomy in the way described above.

Our planetary system revolving round the Sun is a laboratory built by nature. This system obeys simple natural laws, *i.e.* the laws of dynamics and the law of gravitation. The motions of the Sun, the Moon and the planets in the sky prove that a mathematical world explanation is possible. Lehti concludes in the end: "The planets almost forced man to realize the mathematical character of the basic natural forces", (p. 164).

4.3 Astronomical worldview in history

4.3.1 What is a worldview?

In everyday thinking the worldview simply means the mental image a person has about the world. Often more restrictive and specifying attributes, like natural, physical, cosmological, geographical and astronomical, are added. The geographical worldview is exceptional of these, since it mostly is associated with the globe itself and the objects nearby. The other four include also the objects of the universe.

Encyclopaedias define the worldview much in the same way (Tietosanakirjaluettelo). According to *Otavan iso tietosanakirja* (OTAVA 1963), the worldview is "a theoretical total image of the universe obtained with help of the results of different sciences." *Facta* 2001 (WSOY 1984) declares it to be "an illustrative general conception of the world based on scientific facts." *Nykysuomen tietosanakirja 3* (WSOY 1993) and *Iso tietosanakirja* (WSOY 1996) give two definitions: "1. An illustrative total picture of the world based on scientific facts" and 2. "The entirety of an individual's conceptions and beliefs concerning the world, that directs his thinking, beliefs and action." *Nykysuomen sanakirja 2* (WSOY 1988) expresses this more widely: (Worldview is) "an illustrative conception about the entirety of the world formed by a person for himself; in a wider sense = a conception of the world.

Differing clearly from these definitions *Otavan suuri ensyklopedia* (OTAVA 1978) describes the worldview widely from many viewpoints:

> "Worldview, a conception about the entirety of the being, is based on results of different sciences and other bases regarded as facts and experienced particularly important and generally valid …. Worldview may be an image of different things according to the cultural circle or individual, or to the aspect of the being, which is regarded as fundamental in the cultural circle or by the individual in question. In addition, the worldview varies depending on those theories and fundamental conceptions on which its construction is based.
> Often the worldview means purely the total conception about the universal space or the 'container' where we are, about its bodies and their motions as well as about the development and history of this entity. …
> …Traditionally one has tended to use the expression 'worldview' only in the context of such overall conceptions based on scientific results, which can be regarded as neutral, in distinction from the so called '*conception of the world*', which includes also ethic selections. …

> … Also one speaks of an *individual's worldview*, meaning the total conception constructed by the individual about the life and world, starting from such bases which he regards as invariant and which he has experienced essential and important, most often since the early childhood. Correspondingly, one may speak about the worldview of an ideological, religious or political group or of a scientific doctrine, which has become popular, such as materialism, evolution, Marxism and Catholicism … .
> The worldview varies according to the viewpoint and it changes with time. It reflects at the same time the things regarded as true by people in different times."

According to an astronomer, astronomy has a significant role in construction of the picture of the world (Karttunen 2000):

> "Shaping of the picture of the world from a geocentric picture emphasizing the importance of man, into the present enormous universe, including man and the Earth only as an insignificant part, has followed the development of astronomical research. Astronomy has taught man the true dimensions of the surrounding nature. Astronomy has a significance of primary importance in the creation of a scientific picture of the world. The picture of the world means a model of the universe based explicitly on observations, thoroughly tested theories and logical reasoning. The ultimate criteria for the model are always the observations. If the model is in conflict with observations, the model will be changed and no philosophical, political or religious preconceptions and beliefs must limit this process."

The geographical picture of world

"Traditional geography studies the Earth as the home of man", states Rikkinen in her article (Rikkinen 1994). In geography also the relation between man and his environment is defined. The oldest geographical research tradition, or the spatial tradition, defines spatial relations and movements of phenomena.

J. von Wright is plumbing from the external world to an individual's inner worldview in claiming that the picture of the world can be understood as "an inner representation of the world building up for an individual along with his development, the total structure of his conception system concerning the external world and the self, where all what he has learned, thought and felt in the course of his life is reflected as crystallised" (von Wright, J. 1982). In a more narrow sense the worldview means, as Rikkinen states, a picture about the external world, whereas the educationists are speaking of "inner representations of the geographical substance of the external world." The idea of a geographical space surrounding the individual is an important part of the geographical worldview. This can be thought to consist of a space, of which the individual receives knowledge through his own senses, and, on the other hand, of a macro-space, too distant and wide to be known in detail. As an example Rikkinen mentions perception of the outlines of the continents and the locations of countries. (Rikkinen 1994)

Rikkinen states further, that "there develops to every human, along with the age and experience, an individual geographical picture of the world with both ego- and ethno-centric features. The farther off we move from the individual's everyday environment, the more superficial and random will the spatial ground of that picture become." Especially, in mental images connected with the globe, strongly valuational substance is mixed with the knowledge concerning different areas, their nature and culture. Teaching geography in schools has a central importance in shaping the geographical picture of the world. "Therefore it is also important to know how the spatial basis of the worldview develops with the age of pupils." (Rikkinen 1994)

Takala is marvelling, when analysing the results of her research on the worldview, that the pupils “have understood the ’worldview’ so, that the question is about ideas concerning the reality outside the human” (Takala 1982 a). None of them mentions the ego-conception. About the same thing von Wright has presented the view that the ego-conception is a developmentally ’late-born construction’. (von Wright, J. 1982)

In Takala’s opinion a geographical worldview enables ’an intellectual mobility’. A human interprets what he has seen and experienced, on the basis of his own constructed worldview. The geographical worldview includes an idea of one’s own country with attitudes towards other countries and nations. The purpose of the internationality education is to guide pupils ”into international understanding, cooperation and peace as well as into respect for human rights and basic liberties.” Geographical knowledge includes a lot of nominal and numerical data. Instead, the world events are more difficult to perceive and they are experienced in a very individual way. Things that change most slowly form the basis of the geographical worldview, and in this respect our world is a part of the universe. (Takala 1982 b)

The scientific worldview

Virrankoski states that the reality has been regarded, since the classical antiquity, to be composed of a material and a spiritual part. According to the natural philosophers, nature, manifesting itself as the activity of matter, represented the for-us-invisible spiritual world. The relation of the material and the spiritual essence has long been a major issue of controversy. As Plato saw it, they were connected by the human soul. Aristotle thought that all being was composed of matter and shape, represented by the nature of the inanimate objects and the soul of the living creatures. After the discovery of Newton's general law of gravity, the objects needed no more any 'mover', so the soul was freed from this task. Explaining the spiritual things in terms of material concepts led to mechanisation of the worldview. (Virrankoski 1996, 130)

Wright regards the worldview as a conception of world, natural events and way of life, of a certain era or a human community (von Wright, G. H. 1997). The medieval Christian worldview secularised gradually and a new viewpoint called the scientific worldview gained power. The previous nature-respecting way of life changed into a new mechanistic one, where man considered himself a ruler utilizing and controlling the nature. The moral law of the Christian worldview, regulating the habits of living, lost its influence on people because of the secularisation. People live in void of values; they are again seeking a new conception of world. But the requirements of past for a harmonious picture are receding. New partial theories are, rather, considered enriching. Wright calls this kind of a 'worldview of accepted pluralism’ or ’post-modern worldview’ a 'diversified successor of the scientific worldview'.

Niiniluoto regards that the birth of the scientific worldview was affected by the natural philosophers of ancient Greece, who explained the world independently of myths and religions. He states further that “the relation of science to everyday experience is complex, because our everyday observations are strongly ‘theory-loaded’, tinged by our beliefs”, and claims, that science is rectifying the information given by the senses also by its own theories. (Niiniluoto 1984, 145)

In Niiniluoto’s opinion contradictions, on their part, are also influencing the development of the worldview. Science is constantly confronted with the traditions, everyday experiences and various beliefs. In the light of these statements Niiniluoto distinguishes four types of worldviews: *magic* or superstition, *religion*, *everyday experience* or knowledge received from everyday observation and experience, and *science* or knowledge acquired by scientific methods, criticised, and accepted for the time being. Changes may happen within the science due to competing theories and approaches. Contradictions can also be caused by external factors like the researchers themselves, groups, institutions and varying popular interests in the society. One dominating theoretical frame or paradigm is in a 'normal situation' free from conflict, but when a contradiction appears the frame must be rectified. It could, thus, be said that there is a constant revolution prevailing in science. Also prevention of dogmatisation of the scientific community, by accepting the freedom of thought among the members, has an influence on the progress of science. Members of the community need not be unanimous about all assumptions of the prevailing theory. A fruitful discussion can also promote the science. This scientific method represents "team-action with communal criteria for rationality." The scientific worldview is shaping all the time. There will always be social conflicts of interests and competition between researchers in science. But substantial conflicts are often useful since the competition between scientific hypotheses is affecting the development of science. (Niiniluoto 1984, 141-152)

4.3.2 Man in the middle of worldviews in the universe

"Astronomy is said to be the oldest of sciences. And we would not wonder, if that were true, for the objects of astronomical research have always shone in the sky above people", writes Kustaanheimo and continues: "The Western man brought in astronomy a technical handiness and technical passion unseen before in history and has with the aid of them made the astronomical observations independent of the limited possibilities of the human organism. He has replaced our small pupil with mirrors of meters in diameter, the retina of the eye incapable of sensing brightness under a certain limit, he has replaced with a photographic plate which 'stores' brightness the more the longer it is exposed to the light, and finally, he has built an electric eye, a photocell discerning more details on the photographic plates than the human eye." (Kustaanheimo 1985, 9)

Kustaanheimo is pondering further: "repulsion for an empty depth may partly explain the fact, so incomprehensible for us, that the geocentric worldview of Ptolemy, despite all of it's complexity, remained the last word of the antiquity on the field of astronomy." Copernicus, as the first western human, changed his conception of world and proclaimed the Sun stationary and the Earth a planet. Invention of the telescope one hundred years later raised the precision of measurement, moved the stars far beyond the planets, and brought forth new stars from ever greater depths. (Kustaanheimo 1985, 10)

Lehti continues, "stimuli from natural sciences have decisively shaped both the material environment and the worldview of the people of our time. In order that we humans could be intellectually and technically able to understand, and partly even control, natural phenomena, must some of our most basic conceptions of the structure of the world and man's position in it be at least approximately correct. " From the viewpoint of the physical worldview, the perception that the Earth is not the immobile centre of the universe, but a heavenly body orbiting round the Sun, was important. This 'Copernican revolution' created a sensation in the scientific world and started a process of change shaping people's conception of the world. Religious contentious issues accelerated the battle of the new worldview. The different ways of thinking caused gaps between people. The heritage of the scientists of the antiquity was influencing in Europe in the 15^{th} century through two traditions. The earlier one is called 'the Latin tradition' and the later one 'the Greek-Arabian tradition'. (Lehti 1989, 7)

Lehti discusses also the position of man in the universe. The branch of astronomy studying the structure and development of the universe is called cosmology. It is one of the most speculative doctrines of science of our time. The question about the position of man in the universe could be, for example, the following: “are biology and history significant branches of astronomy?” or “what kind of limits does astronomy set on the significance of mankind in the universe?” (Lehti 1996, 13)

About the origin and age of the universe Lehti tells, “Most astronomers consider the universe formed of galaxies finite in age. Joining them we can somewhat hesitantly say that the universe ’was born’ in some time period about 10–20 milliards of years ago. About the origin of our solar system we have returned close to the ideas presented already by Kant and Laplace 150 years ago: the solar system was born by condensing from a rotating cloud of gas.” Before the breakthrough of natural sciences, the prevailing cosmology was anthropocentric and coloured by religious attitudes. ”The most significant material object in the universe was, absolutely, the human, and the most significant course of events was the pilgrimage of mankind either to salvation or to damnation. The world itself was an uninteresting coulisse even though it was necessary for the history of mankind, on the one hand as a manifestation of the Creator’s greatness, and on the other hand as a field of seductions.” (Lehti 1996, 14-18)

4.3.3 Turning points in the history of astronomy

4.3.3.1 Time before Christ

"Thousands of years ago life was not so tightly bound by clocks or calendars, it even could not have been, since people in general had neither clocks nor calendars”. However, the agricultural activities of that time required the knowledge of chronology. For that purpose especially astronomers were needed, who deduced the seasons by following the annual path of the Sun. Watching the stars in the sky has probably been an interest of all cultural circles. Few pieces of written or any kind of information about the achievements of the ancient astronomers is left for us. The Stonehenge observatory in England has been in use more than 4000 years ago for observing the Sun and possibly also the Moon. (Valtonen 1981, 25)

Valtonen states observation of the stars reached its highest level probably in Mesopotamia. "There the Babylonians started to follow systematically the motions of planets already in 1600 B.C. and continued that for almost two millenniums.” They had learned to know the most important periods of the motions of the heavenly bodies, and worked up new predictions on this basis. Transition of the observations, collected during centuries, into predictions, required development of new methods of calculation. (Valtonen 1981, 26)

Aristotle's worldview

Aristotle (384-322 B.C.), who came from Stagira, a town near the coast of Macedonia, developed his own picture of world on the basis of what he had learned from Plato. According to that picture, the phenomenal world is the real world, which is changing and moving, is born and will die, but things remain unchanged and eternal. Aristotle presents the structure of the universe as spherically symmetric. It consists of spheres within each other around the centre, where simple motions occur along straight lines following the radii either away from or towards the centre. There are four basic elements, earth, water, air and fire, existing in 'the sublunary world'. The fifth element is the world ether extending down to the Moon. In Aristotle's opinion the universe is finite. (Pannekoek 1989, 113-121)

Valtonen realises that the picture of the Aristotelian world is based on the Pythagorean theories of the universe. ”The motions of the planets observed by the Babylonians became known by the Greek scientists, and they created various pictures of the world to explain them. One of the first was a model presented by Pythagoras about 500 years B.C. where the planets were thought to be located each on the surface of its own sphere between the Earth and the sphere of fixed stars”. The spheres were rotating around their axes, each at its own constant rate.

It was interesting in the theory of Pythagoras that the Earth was not in the midpoint of the universe, but there was a so-called central fire that could not be seen from the Mediterranean. The Earth moved around this central fire. On the contrary, according to Aristotle, the motionless Earth was in the centre of the world. The motionlessness was supported by the observation that an object thrown straight upwards fell back down to the same place. Another observation in favour of the same conclusion was that the stars have no parallax, *i.e.* they seem to be always in the same positions relative to each other. (Valtonen 1981, 27-29)

Babylonian and Greek heritage

When investigating the main trends of the old astronomy, Lehti finds from the early history of astronomy a Babylonian and a Greek 'foot'. The Babylonian astronomy developed arithmetic methods to determine the positions and times of special phenomena of Sun, Moon and the planets. “These special phenomena included, for example, the New and Full Moon, heliacal rises and apparent 'stops' and oppositions of planets. In due course this arithmetic technique changed into calculation of 'schedules', *i.e*. ephemeredes of motions of heavenly bodies, but this was not the original main problem of that astronomy concentrating on prediction of special phenomena.” The methods of calculation did not involve any geographical views about the positions and motions of the heavenly bodies in space. Astronomy was mostly instrumental; “it did not aim at knowledge about the 'nature' of the heavenly bodies, but only at predictions related to their phenomena." (Lehti 1996, 142)

The western or 'Pythagorean' wing of the Greek astronomy followed, the “Babylonian tradition in the sense that it accepted and considered important the regularity of the motions of heavenly bodies.” The general view prevailing before the beginning of the New Age included a spherical cosmos, with the spherical Earth located in the middle, and the planets were orbiting round the Earth in motions composed of regular circular motions. Many astronomers and philosophers associated with this picture an idea of the divinity of the upper stellar world. “This was proven by its solemn stability and regularity, qualities not possessed by the ever changing sublunary world.” The 'Ionic foot' of the Greek cosmology, on its part, explained the phenomena of sky as ”material events of the same kind as those we see also in our surroundings on the ground; for example, the stars were interpreted as glowing stones driven by a material whirl.” (Lehti 1996, 143)

4.3.3.2 The Early Christian age and Middle Ages

End of the classical period

Pannekoek states that the Roman Empire influenced the scientific work of that time in its own special way. The large united and civilised empire aimed at unity also in the field of science. It was wanted to collect together the scientific knowledge accumulated during the earlier centuries. Naturally, part of it had to be translated from foreign languages. The centuries of the Roman power were also centuries of co-operation between sciences. The Alexandrian Claudius Ptolemy (*ca*. 100 – 160 A.D.) and the Greek Hipparchus (*ca*. last century B.C.) were among the most famous scientists of that time. Ptolemy studied the solar and lunar eclipses and published, as the first scientist, a catalogue of stars, with somewhat more than one thousand stars. In the catalogue, the brightness and the coordinates of stars in the ecliptic system (latitudes and longitudes) were registered. Ptolemy grouped the stars into constellations. Geometry had an important position in the Greek culture as the only exact science of the visible world. It was regarded, due to its logic structures, as a manifestation of the abstract truths and the spiritual world outside the material one. The observational objects of astronomy offered a good field of application, for example, for the theories related to spheres and circles. (Pannekoek 1989, 146-159)

Almagest

Valtonen tells Ptolemy developed in about 125 A.D. the Greek planet theory of Hipparchus further, applying it to the planetary motions (Valtonen 1981, 34). These astronomical theories of Ptolemy can be found in a book that is best known by the name *Almagest* of its Arabic translation, (150 A.D.).

Singer tells about the remarkable experimental research of Ptolemy in the field of optics. In addition he praises *Almagest* as one of the most impressive books ever. It contains a mathematical representation of the motions of the physical world, especially those of the planets (Fig. 4.3). In the late Middle Ages and early renaissance it was regarded as the top achievement of science. Therefore, the mathematical astronomy of the Middle Ages rejected all other explanations of the universe. The contemporaries of Ptolemy had difficulties in understanding this mathematical explanation, like we, at present, find it difficult to understand the theory of relativity of Einstein. The book contains also detailed catalogues of stars, partly received from Hipparchus, and the earliest descriptions of astronomical tools of observation. Ptolemy's most important tool of observation was the ‘astrolabe’ consisting of several wheels within each other, coupled together. By this equipment he measured all the angles needed for his theoretical calculations. (Singer 1996, 89-94)

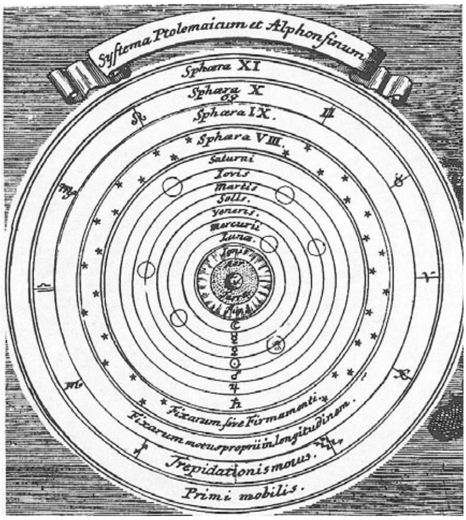


Fig. 4.3 The physical world of Ptolemy

Lehti, on his part, considered it "as a matter of luck, that astronomy did not attempt to rely on the 'Ionic foot' too early, but built a combination of the cosmos dominated by geometric regularities, the motions of which could be controlled numerically". Also these theories were presented for centuries in the *Almagest* of Ptolemy. "Geometry and astronomy were the structured doctrines developed by the scientists of antiquity to the greatest perfection". In general, the erudite people of the classical period treated by mathematical methods only such physical subjects, which were related to astronomy. As exceptions Lehti mentions "the studies of the Pythagoreans of the relation between the length of a vibrating string and the pitch of the resulting tone, the research of geometric optics by Euclid, and others, and the studies of statics by Archimedes, some results of which, especially those related to hydrostatics, are an amazing mathematical and physical 'tour de force'." (Lehti 1996, 144)

"Even though already the ancient Greeks had stated that the Earth positively must be spherical, the medieval world picture presented the Earth still for a long time as a flat disc", says Mustelin and continues, that "not even the magnificent background coulisse formed by the vault of heaven could stop the persistent curiosity of the human mind and its endeavour to reach something beyond it". If one would think, that the vault of heaven was a non-transparent border of the observable universe, there could be other similar systems outside. They could have their own earths as their centres with surrounding systems of sun, moon, planets and fixed stars. As the Christianity gained power in the Western countries "the dream about other inhabited worlds sank into oblivion almost completely". The church, having become all the time more and more powerful, adopted the geocentric world picture as an unquestionable truth. The space outside the shell of fixed stars was regarded as the place of residence of God and all blessed. Finally Mustelin states "also for man, the image of God and a target of His special protection, a unique abode was guaranteed in the unquestionable midpoint of the universe." There was no space for other worlds in the early Christian range of thoughts. (Mustelin 1980, 10-11)

Lehti finds the situation of astronomy in the Middle Ages somewhat obscure. “Although the cosmology of Aristotle and the astronomy of Ptolemy were not completely compatible, the ideas of the mid and late Middle Ages about the world of stars and about the entirety of the world in general, were based on a slightly uncertain compromise of them.” In the Christian cosmology of the Middle Ages man had a central position in the universe. Dante’s *Divina Commedia* is left as a permanent cultural monument of this world picture. “The theories of the erudite men of the antiquity concerning the spherical-shell cosmos form the astronomical basis of the doctrine, but its theological content stems from an age when it was attempted to merge the doctrines of the antiquity and those of the Christianity into one coherent system.” (Lehti 1996, 144-145)

Valtonen draws attention to the Arabs of the mid Middle Ages who were working hard with astronomy (Valtonen 1981, 35). He tells that “while astronomy in Europe was fading in the pressure of the authorities of the Middle Ages, the Arabs continued the astronomical traditions of the Greeks by translating scientific literature from Greek to Arabic, making accurate observations of the celestial motions, and developing methods of calculation.” The climate in Arabia is, from the viewpoint of observation, much better than in the Mediterranean countries. For example, it was the Arabs who found the galaxy of Andromeda around 950 A.D. In the 13th century Alfonso the Great “had composed catalogues for prediction of planetary positions on the basis of the theory of Ptolemy”, and they were the basis of the practical astronomy still in the modern times. Lehti states (Lehti 1996, 144) that neither the natural-philosophical books of Aristotle nor the *Almagest* of Ptolemy become known in the Latin Europe until the twelfth century.

Calendar renewal

From the viewpoint of the development of science, the Middle Ages that lasted about one thousand years have been regarded as a dark era. Pannekoek states that the birth of Christianity at the time of the Roman Empire affected on the need of a calendar renewal (Pannekoek 1989, 217). The question was about definition of the exact time of Easter. There is a mention of it in the Bible, but its exact dating in the calendar requires astronomical knowledge. Karttunen claims that it was just that particular astronomical information needed for specification of the date of Easter, which was relevant from the viewpoint of Christianity. "This task was taken care of by a doctrine, known as *computus i.e.* arithmetic, representing practical mathematics.” (Karttunen 1996, 80)

Lehti tells the renewal of the calendar used by the Christendom turned out to be necessary also for practical reasons especially in the Middle Ages (Lehti 1989, 13). The doctrines about the motions of heavenly bodies, taught in the antiquity, did no more correspond to the arising needs and requirements. For example, the vernal equinox should occur on March 25th, however, already in the beginning of the 11th century it occurred ten days earlier. Also the motion of the Sun was already observed and registered quite exactly at that time.

Karttunen states, the journeys of exploration and increasing navigation were, in addition to the calendar renewal, factors, which influenced the new rise of the astronomy (Karttunen 1996, 94). In these activities, astronomical tables suitable for determination of ones geographical position were needed. Also the chronology had importance on these expeditions. There was an interest in the sciences and nature with the ultimate aim to achieve a control over the nature.

“On the ground of stimuli offered by the ancient Greek literature, there was, in the Europe of the late Middle Ages, a growing interest in the problem of motions of the Sun, Moon and planets” (Valtonen 1981, 37). Although the crystal-sphere ideas of Aristotle were still valued, the epicycle theory of Ptolemy was followed in practical calculations (Fig. 4.4). The idea of Aristarchus (200 B.C), about the Sun as the centre of the planetary system, was confronted both by the arguments of Aristotle about the motionlessness of Earth and by the excellent theory of planets of Ptolemy. Inaccuracies of the predictions derived from the theory of Ptolemy were found occasionally in the astronomical observations carried out in the European universities in the 15th century. Nicolaus Copernicus, among others, learnt this when he was studying astronomy in the universities of Krakow and Bologna. Copernicus did not start devoting himself to pondering of the world system as a churchman until he had reached the age of 50 years. (Valtonen 1981)

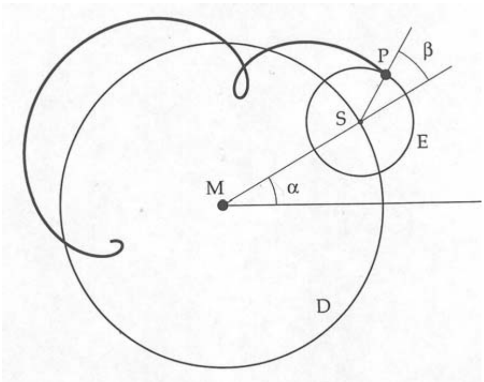


Fig. 4.4 The epicycle theory of Ptolemy

The new rise of science

In the fifteenth century science started a new rise. Pannekoek tells that the scientists of the earlier centuries were rather ‘scholars’ than investigators. They made neither experiments nor observations but studied books and writing. Now observing of phenomena became an important part of the scientific research. In Europe the scientists continued from what the scientists of the antiquity had reached. The new rise of astronomy contributed also to the rise of science then and in the following centuries. The same desire for adventures and the courage, which made people of the past search for new worlds beyond the oceans, was now driving them into search for new discoveries from science. Astronomy had an important position also because of practical needs of every-day life. Chronology and navigation – now even beyond the oceans – required accurate data for determination of time and location. For example, the location of a ship, or its geographical latitude and longitude, were determined with the help of the Sun, Moon and stars. The need to use astronomy in sailing inspired the sailors also to other astronomical observations, for instance, to find new stars and constellations. At the same time, also an interest in astrology was increasing. That is why, weather forecasts, forecasts on catastrophes, and recommendations on certain important activities, even on blood effusion and hair cutting, were recorded in the new almanacs, in addition to the celestial phenomena like eclipses and conjunctions. (Pannekoek 1989, 183- 187)

4.3.3.3 The New World System

Breakage of the world picture

”One of the basic themes of human life is the problem: what kind of relationship is prevailing between myself and the external world.” This problem is different for different persons depending on age, experience and knowledge. Lehti considers this and carries on: “The more specific our knowledge about the amazingly regular structure of the nature is growing, the more confusing our own position in the framework of the external physical world is felt.” During the last centuries there has been a struggle between the human self-esteem and the grandeur of the universe, which arose along with the collapse of the view prevailing in the Middle Ages concerning the structure of the starry sky. After all, the Earth, the residence of man, was not the centre of the universe surrounded by spherical shells carrying the Sun, Moon, planets and fixed stars. As a result of the work of Copernicus, Galileo, Newton and many others, a new, still valid, conception of the universe was developed, where the Earth is just one of the planets orbiting round the Sun. (Lehti 1996, 28)

Copernicus

Fig. 4.5 Nicolaus Copernicus

The series of events associated with the breakage of the world picture is called the Copernican revolution, after its initiator, the Polish astronomer Nicolaus Copernicus (1473-1543, fig. 4.5). The Sun is the centre and the planets are its satellites (Fig. 4.6). The diurnal motion of the vault of heaven arises from the rotation of the Earth around its axis. Copernicus developed a mathematical model for prediction of the positions of the planets with the same precision as by the method of Ptolemy. Valtonen tells that Copernicus observed also that the orbital velocities of the planets were the higher the closer to the Sun they were. This explains the occasional retrograde motion of the planets: when the Earth is passing an outer planet, the planet, being slower, seems at first to stop and then to move backwards *i.e.* clockwise. Similarly, when an inner planet is passing the Earth it seems to move backward on the sky. Encouraged by the representative of Pope and some erudite Protestants, Copernicus was finally encouraged to do the deskwork and present his world picture in the book *De Revolutionibus orbium coelestium libri* (1543), which was written using Ptolemy's *Almagest* as a model. (Valtonen 1981, 38-39)

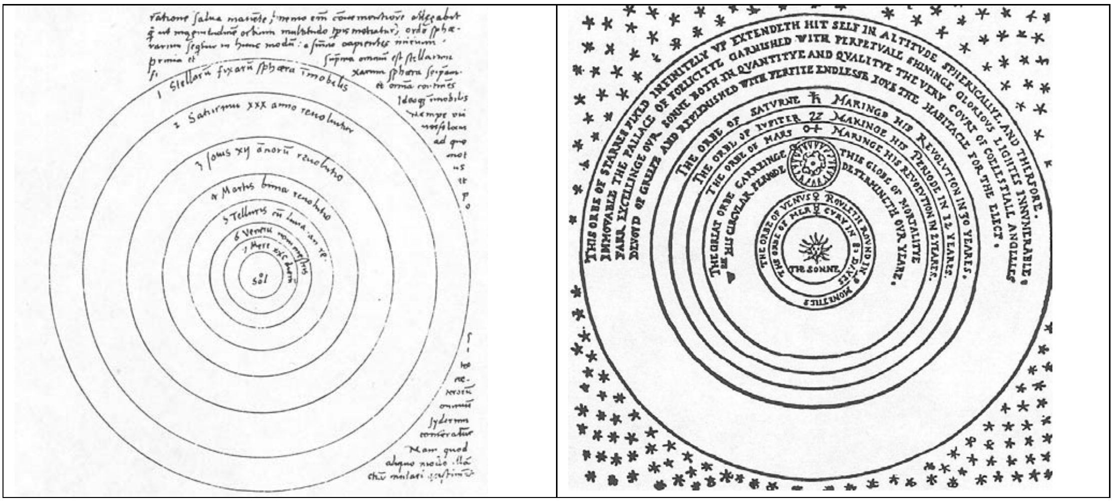


Fig. 4.6 The Copernican world system, on the left the drawing by Copernicus, on the right a graphical drawing on a wooden plate

Mustelin, on his part, writes about the vicissitudes of Copernicus, that he, “on the early 16th century, after a long hesitation and with numerous explanations, revived one of the heretic concepts”, expressed by the Greek astronomer Aristarchus from Samos (310-230 B.C.) already in the ancient Greece: "In the centre of the universe there is the Sun instead of the Earth”. Copernicus thought that it is much easier to explain the planetary motions by the heliocentric than the geocentric model. “And so he happened to degrade the Earth into a quite regular planet orbiting around the Sun like Mercury, Venus, Mars, Jupiter and Saturn.” (Mustelin 1980, 11)

Kustaanheimo writes: “In the case of Copernicus, the planet catalogues of the book *De Revolutionibus*, replaced Ptolemy’s *Almagest* in practical astronomy, not that the transfer from geocentricity to the heliocentricity would have had some practical relevancy, but simply because Copernicus had taken carefully into account, in the details of his mathematical theory of planets, all of the new irregularities of the planetary motions discovered after the time of Ptolemy”. At the genesis of the new physics in the 17th century one started to perceive, in the principal work of Copernicus, certain “prophetical anticipations”: anticipations of Newton’s general law of gravity, Kepler’s first law and the infinity of the space. (Kustaanheimo 1985, 38-39)

Objective evaluation of the principal work of Copernicus must, as Kustaanheimo states, take into account the following documented facts (40-41):

> -" Copernicus opposes strongly the equant motion described by Ptolemy and he wishes to explain the motions of the heavenly bodies in terms of uniform circular motions only.
> - The astronomy of the antiquity had studied the motion of each planet separately. There were no connections between the motions of the different planets. The basic hypothesis of Copernicus, that the main epicycle of each planetary orbit is not real but only an image of the path drawn by the Earth around the Sun, made possible, for the first time, comparison of the orbits of the different planets.
> - Contrary to Ptolemy, Copernicus thought that the same circular-motion mechanism must yield all three coordinates of a planet in the three-dimensional space, *i.e.* its longitude, latitude, and distance from the Earth. From this line the western Physics has not deviated ever since."

Lehti states that "Publication of the principal work of Copernicus in 1543 caused in the astronomy and cosmology a current, which dominated all significant scientific activity in astronomy in the late 16th century." From Copernicus' doctrine of heliocentricity, all planets, except the Earth, were accepted as heavenly bodies orbiting around the Sun. Those details of the mechanisms of planetary motions, approved from the principal work of Copernicus, were still interpreted geocentrically. Therefore it became necessary to write up new catalogues of planetary motions and this increased Copernicus' reputation as a great astronomer. (Lehti 1989, 261)

Brahe

The Danish astronomer Tycho (Tyco) Brahe (1546-1601) is mentioned in the literature most often only by his first name (Gribbin 1996, 68). Gribbin tells that Tycho created, by his measurements of star positions and planetary motions, the basis for Kepler to discover the laws of the planetary motions. He was the best-known observing astronomer before the invention of the telescope.

Tycho took part in the debate evoked by the new theory of Copernicus among the circles of astronomers of the late 16th century, however, he didn't share completely the ideas of the theory. He accepted the theory of Copernicus as for the planets, but he could not consider the Sun as the centre of the world. In his model, the Sun and the Moon are orbiting around the Earth, the planets around the Sun. Tycho observed also other celestial phenomena such as comets. Valtonen continues that Aristotle considered comets as phenomena of the atmosphere of the Earth, but since Tycho "was not able to measure their parallax, he had to conclude that the comets must be sited beyond the path of the Moon." Because of these discrepancies Tycho rejected the crystal-sphere theories of Aristotle. (Valtonen 1981)

Pannekoek tells that Tycho was a passionate researcher with an enthusiastic interest in astronomy. This was evident from his secret nocturnal observations and researches. Tycho supported also, in the habitual manner of the time, the doctrines of astrology. He developed and tested new measuring equipments (Fig. 4.7) in his observatory. (Pannekoek 1989, 204-211)

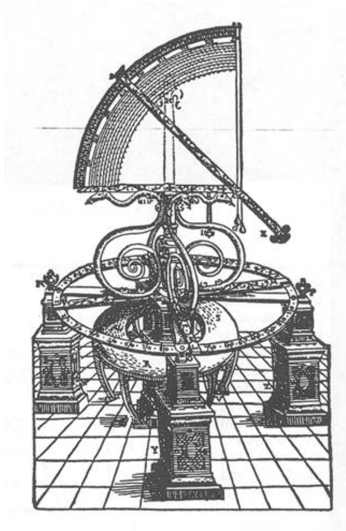


Fig. 4.7 Tycho’s quadrant

Kepler

The German Johannes Kepler (1571-1630), was the first astronomer who accepted Copernicus' doctrines. He also had a strong of influence in the final solution of the dispute on the Copernican theory. Lehti claims “the successors of Kepler found that his version of the Copernican theory differed so essentially from the original of Copernicus, that they characterised it as a ‘Copernican theory in a Keplerian form'. Various later historians consider the work of Kepler to be so fundamentally more than a defence of the ideas of Copernicus, that they place the whole ‘revolution’ rather in Kepler than in Copernicus”. (Lehti 1989, 261)

Singer says, that Kepler was the first to use mathematics as an experimental instrument when he searched for laws of motions of the heavenly bodies. Kepler’s mental image of the universe was, from the very beginning, Platonic and Pythagorean. He adopted the Copernican idea at an early stage and was occupied with problems associated with the measures and proportions of the planetary orbits. He was searching for a natural law, which would combine together the components of the solar system. In spite of failures, Kepler studied the ratios of planetary distances to the periods of revolution round the Sun. After the death of Tycho Brahe in 1601, Kepler had the use of the valuable results of his measurements. (Singer 1996, 236-240)

Kepler studied in Tübingen, in one of the few universities, where the theory of Copernicus was taught. Valtonen tells, that the 'hobby' of pottering around the problems associated with the distances of planets led him to the position of an assistant of Tycho Brahe in Prague, because otherwise Tycho would not have allowed Kepler's access to his findings. After the death of Tycho, the whole of his material, collected during decades, stayed behind in Kepler’s possession.” In his examinations of the orbital planes of planets, Kepler arrived at the best result in the case where the orbital planes of the Earth and other planets go through the Sun. This means that the planets are revolving around the Sun. Valtonen continues that realisation of the higher orbital velocity of an inner planet, it led him “to try heliocentric orbits of different shapes, among others, elliptical orbits with the Sun at one focus, and this finally did work! Over 2000 years the uniform circular motion was considered as the only possibility, but now it was replaced by a simple elliptical orbit, without any epicycle levers or deferent circles”. (Valtonen 1981, 42-43)

This discovery of Kepler was published in the book *Astronomia nova* in 1609. There the planetary motion is expressed in terms of two laws; the third law arose not until nine years later. (Valtonen 1981, 43-44):

- Kepler's first law: The orbit of a planet is an ellipse with the Sun in one of the two focuses.
- Kepler's second law: The segment of line drawn from a planet to the Sun is sweeping out equal areas in equal times.
- Kepler's third law: The square of the period of revolution of the planet equals the cube of its average distance from the Sun, when the period is measured in years and the average distance in astronomical units.

“The exact studies of Kepler of the planetary motions, based on the abundant material from Tycho Brahe's observations, showed that clarity and order could be attained in the whole of the planetary system only by assuming that the planets were really revolving around the Sun.” This is how Mustelin is considering this issue. He continues, “the breakage of the heliocentric world picture turned people’s conceptions of their own position in the universe totally upside down.” According to the geocentric worldview, the stars were revolving once a day round the Earth with their mutual positions unchanged. This led to the idea about a shell of the fixed stars or stars fixed on a solid firmament. “But in the new picture of the world invading the minds of people, the diurnal motion of stars was purely apparent, an illusion caused by the rotation of the Earth. There was, thus, no more need to think the stars to be bound together – they could equally well be floating completely motionless in the space beyond the planets.” (Mustelin 1980, 12)

However, as Mustelin describes, the stellar distances were about to become a real stumbling block. “Already in the antiquity it had been noticed, that the size and shape of the constellations did not change, when one travelled to faraway countries. This had led to the quite correct conclusion: The stars must be located really tremendously far away relative to the dimensions in the Earth.” In spite of this, it was thought: “The annual revolution of the Earth round the Sun would cause, in the course of seasons, some changes of perspective in the night sky”. Such changes or annual parallaxes had, however, not been discovered, but the constellations seemed identical throughout the year. (Mustelin 1980, 12)

Lehti presents an interesting view on the conceptions of Kepler. “An idea of geometrical primary design of the world is a constant pattern of thought by Kepler. A cosmological meaning of the regular polyhedrons is embellishing Kepler’s thoughts from Euclid.” He thought, that the geometry had offered the model for the Creator for shaping the world, so the primary image of the world must be sought from the science of geometry. (Lehti 1998, 322)

Pannekoek pays particular attention to a new scientific research method in the works of Tycho Brahe and Kepler. In this method information is collected by experiments and observations and these establish the laws and rules forming the foundation of science. (Pannekoek 1989, 242)

Bruno

Thus, the fresh view about the dimensions of space, as presented by Mustelin, "brought to the human thinking a completely new kind of conception of distances”. Planets, revolving around the Sun, could be dark objects, which, illuminated by sunrays, are seen in the night sky as spots of light. This includes the insight that the fixed stars, being extremely far away, are not getting their light from the Sun but they must be light-emitting objects and glow brightly to be seen through the space. Thus, they must also be considered as Suns. Mustelin carries on that one of the first persons to perceive this matter of fact was the Italian philosopher Giordano Bruno (1548-1600). He expanded this conception at once further making a presumption, that the stars (*i.e.* the suns) are surrounded by planets like our own Sun. These satellites can, however, not be observed from the Earth because of the enormous distances. “In this way Bruno became a pioneer of our own dreams: he was namely the first person who connected the reverie about inhabited worlds to the astronomical facts. “ (Mustelin 1980, 13)

Galilei

“The theory of Copernicus gained ground very slowly. This was caused not only by the strict opposition of the Catholic and the Protestant churches but also by the contradictions among astronomical facts of that time.” Mustelin says, that the decisive turn was experienced in the beginning of the 16th century, when the Italian scientist Galileo Galilei (1564-1642) pointed his telescope at the sky. He discovered that the planets were bright discs and not only dots of light. (Mustelin 1980, 11)

Valtonen continues about the activity of Galileo, “Galileo was not particularly interested in details of the circulation of planets, and he was not anxious to enforce doctrines of the mechanics of phenomena on the Earth on the heavenly phenomena. Instead, he attained fame by constructing a telescope for himself and by using it as an instrument in his exploration of celestial phenomena. ” It was not Galileo, who invented the telescope, neither was he the only one to use it. Galileo wanted to defend the system of Copernicus on the basis of his observations. He understood better than others the meaning of the celestial secrets revealed by the telescope. He published his findings in the book *Siderius nuncios,* (*Tähtien sanansaattaja*) issued in 1610. Those who believed in the Aristotelian worldview were upset, because of the findings of Galileo; some of them even doubted, that the image in the telescope was only an illusion. Valtonen tells, that Galileo detected mountains and valleys on the Moon, although the Moon looked as a smooth ball from the Earth. Galileo assumed the dark planes on the Moon to be oceans. In addition, he concluded – on the basis of his findings – that in the dark side of the crescent of Moon, some sunlight reflected from the Earth can be seen. (Valtonen 1981, 48-49)

Galileo discovered four new 'planets' (satellites) near Jupiter; he discovered also considerably more fixed stars than seen before by naked eye; further, he discovered dark spots on the surface of the Sun. When he observed the appearance and movements of the sunspots he concluded that the Sun is rotating around its axis once in about 27 days. He saw Venus as a crescent like the Moon and concluded from this, that Venus had the same kind of phases as Moon. The greatest surprise for Galileo was caused by the discovery of the 'ears' Saturn’s; later researches unveiled them as rings. (Valtonen 1981, 49)

The astronomical career of Galileo began in 1604. Singer reports that Galileo’s opinion based on his observations was that no parallax was present whatever the looking direction is. With growing distance the parallax becomes smaller. In the days of Galileo the parallaxes of the planets were observed (Fig.

4.8), but not any of the fixed stars, because of the insufficient accuracy of the equipment. In 1609 Galileo purchased two of the most important observation instruments used in the scientific world, the telescope and the microscope. His early findings made by the telescope are reported in the book *Siderius nuncios.* The most important ones are the Moon with its surface formations, the large numbers of new stars, the satellites of Jupiter, the phases of the inner planets, the rings of Saturn and the sunspots. Galileo could not explain the 'ears' of Saturn, thus it was Christian Huygens, who did the explaining work much later. (Singer 1996, 242)

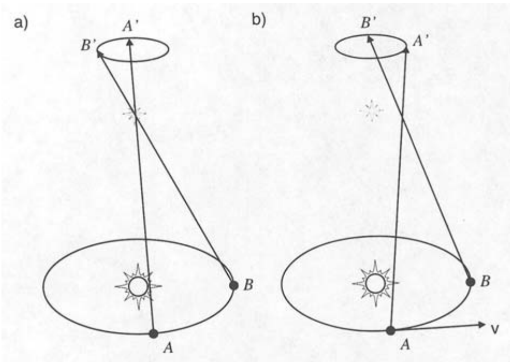


Fig. 4.8 Parallax of a planet

In 1608 the first telescopes become known in Europe. Pannekoek reports, that Galileo offered in 1609 the telescope constructed by him for usage in war and navigation. He developed these observation instruments further and pointed them towards the Moon and stars. His many new findings brought the doctrines of Copernicus into the focus of common interest. The first telescopes were very primitive, and the image transmitted by them was coloured and distorted. The sensational findings aroused also resistance among people – it was hard to believe what one could see with the new instrument. The target of the scientific contest had changed from practical observations towards theoretical argumentation. (Pannekoek 1989, 227- 231)

The most distant objects remained still as mysteries. Kustaanheimo states that "the Andromeda spiral nebula was not known in the Europe before the invention of telescope", but it was not discovered very soon even by the telescope. Although Galileo had discovered those famous near-space objects in 1609 by observing the sky by the telescope, "he had not happened to point his telescope towards the nebula of Andromeda, but the rediscovery of it was left to Simon Marius, the court astronomer of Ansbach in 1612". (Kustaanheimo 1985)

Newton

"Even though causal laws of nature were found to explain phenomena on the Earth, this needed not to indicate that the same laws would had been valid also far away in the space", remarks Mustelin. The planetary motions seemed to be different from the motions on the Earth and "still in the 16th century, it was assumed quite generally, that the planets went around on their paths pulled by angels!" The English mathematician and naturalist, Sir Isaac Newton (1642-1727) demonstrated, that the motions of planets followed the same laws of motion as the objects on the Earth. In addition, the force, which holds planets on the elliptical orbit, is the same as the one, which turns a stone thrown to curve back to the ground. This force was called gravity or gravitation. (Mustelin 1980, 18-19)

Kustaanheimo has the opinion, that gravitation has no prehistory but its history begins suddenly in 1684. Also radioactivity and the quantum theory are lacking a prehistory, but the phenomena associated with them were totally new findings in physics. "Man has obviously been aware of gravity quite long ", so the lack of its prehistory is surprising. (Kustaanheimo (1974) 1985, 78)

Pannekoek claims, that Kepler considered gravity and magnetism equal assuming objects to be 'connected' to the Earth by a magnetic force, which had nothing to do with the circular motion. The attractive force of the Sun was not concentrated on the planets, but the planets were swept into their revolving motion along with the rotation of Sun. Kepler's opinion was that gravity and the circular motion were two different subjects. Galileo regarded the frictionless, uniform horizontal motion as a part of the natural circular motion round the Earth. By later comprehension, the circular motion arises from the influence of a force directed towards a central point. This idea was extended also to the orbital motions of the planets and the Moon. This force was generally known to decrease with the increasing distance from the centre, being inversely proportional to the square of the distance. Many scientists took part in the debate concerning this problem, but it was not until Newton who expressed this idea in an exact form, using mathematical methods developed by him. Newton proved also, that this law represented the orbits of heavenly bodies with mathematically precision. Further, the gravitation acting on an object can be interpreted to act upon its centre of mass. These ideas of Newton were published in the book *Philosophiae Naturalis Principia Mathematica* issued in 1687. Newton wanted to unite Galileo's laws of falling and gravity, governing the motions on the Earth, with Kepler's laws representing the motions of heavenly bodies. He completed the principles presented by Galileo and Huygens into three laws of motion. He determined, by mathematical methods, on the basis of Kepler's laws, the forces controlling planetary motions. Newton succeeded in this task expressly because of his mathematical skills. He was, thus, able to develop astronomy with help of his mathematical discoveries. (Pannekoek 1989, 261-266)

Pannekoek tells that Newton explained also other astronomical phenomena by his theory of gravity. The gravitation of the Sun causes perturbations in the orbital motion of the Moon. The tide is caused by the effect of the gravitation of the Moon and the Sun, on the solid Earth and the seas. Also the planets are perturbing each other's orbital motions. Huygens accepted Newton's calculations and formulas but he wanted also to have explanations. He, as well as his French colleagues, kept occupied with the problem: what is the origin of the gravity. (Pannekoek 1989, 270-273)

Also Valtonen considers that Newton's law of gravity solved the problem of planetary motions. There is, acting between two heavenly bodies, gravity, the strength of which is inversely proportional to the square of the distance of the bodies, and directly proportional to the product of their masses. The laws of Kepler are then valid. Newton was sure, that the law of gravity could be applied also on other heavenly bodies, not only on the planets. He had already stated the comets to travel along very oval elliptical orbits. The English astronomer Edmund Halley (1656-1742), a contemporary of Newton, calculated paths of comets with help of previous observations. (The comet of Halley 1758) (Valtonen 1981, 52-53)

Kustaanheimo, on his part, reports about the meeting of Newton and Halley: “In summer 1684 took place Halley’s famous visit to Newton. Newton answers Halley’s question, which kind of planetary orbit would follow from a force of attraction, decreasing according to the square of the distance from the Sun, without any hesitation, that the orbit would be an ellipse, because he had calculated it.” Within 18 months during years 1685-86, pressed by Halley, Newton then writes his principal work *Philosophiae Naturalis Principia Mathematica* of 510 pages in three volumes. The book contains a presentation of the new theory of gravity with all practical consequences of it, based on the differential and integral calculus developed by Newton. The book went to print in 1686 and was published in 1687. (Kustaanheimo (1974) 1985, 80-81)

Kustaanheimo continues that the third book contains, the “world system” and signifies the start of a new era in the history of astronomy. “During millenniums the sky has meant man a constant challenge for the endeavour to find a rational regularity and harmony in the hopelessly complex motions of the starry sky, which turned out more and more irregular.” The Babylonian number sequences, the epicycles of Ptolemy and Copernicus and the ellipses of Kepler were “the highlights of this struggle, where the human mind seemed to have succeed in unveiling the nature’s conformity to law.” All motions observed on the sky (until about 1850), even the slow motions of the Earth axis (precession and nutation) relative to the starry sky, as well as the motions of the satellites and spaceships, are following Newton's formula. Kustaanheimo continues dramatically “For the first time in the history of science the whole world system is controlled by a formula of just one line”. Also the connection between the rotation period and flattening of a heavenly body, and the dependence of high tide and low tide on the gravitation of the Moon and the Sun, can be found in *Principia.* It was the turning point in the history of astronomy and physics. (Kustaanheimo (1974) 1985, 82-85)

Singer brings up an interesting view concerning Newton's research of the planetary motions. He says that Newton needed description of motions to explain them. Newton regarded the description even as an ordinary method of science. The description of the motions of heavenly bodies by Ptolemy in terms of eccentrics and epicycles, the description by Copernicus of the motions of the Earth and the Sun, and that by Kepler of the planetary motions in terms of ellipses, are mentioned as examples. Newton's own description of motions is based on the gravitational interaction between bodies. Science, the knowledge about nature, was separated from the philosophy, the study of the mystery of the universe. Science is describing the world piece by piece, and every sector of science is choosing its own part. According to Newton's ideas, the research of the structure of the universe consists of three methods: the observational astronomy, *i.e.* observation of heavenly bodies by telescope, the dynamic astronomy, *i.e.* mathematical representation and prediction of the motions of heavenly bodies based on the gravity, and the astrophysics, *i.e.* the research of the physical and chemical structure and composition of the heavenly bodies. (Singer 1996, 296-297)

Virrankoski declares, that in Newton’s physics the natural laws are conducting causally the behaviour of the components and, hence, the entirety. Prediction is possible in such a deterministic theory. So, for example, it is possible to determine the state of the solar system at any moment of time on the basis of the locations and velocities of the Sun and the planets. (Virrankoski 1996)

Interaction as the basis of species-identity

Kurki-Suonio presents a different aspect of Newton's mechanics when considering the birth of the basic Gestalts of modern physics. Interaction appears as an important theme.

"According to the general cultural view, modern physics is thought to start from the birth of the methodological basis of modern science, or, according to the school-like standard interpretation, from Galileo and Newton. Learning means perception, construction of mental images with the support of observations and experimental research. It is essentially creation of empirical meanings and conceptualisation of these meanings. Mental images are the human way of understanding the structure and phenomena of nature." (Kurki-Suonio, K. 2000c)

Kurki-Suonio states that people adopt, via experiences of life, natural mental images, which can be recognised, for example, in preconceptions of the pupils and in the early interpretations of phenomena. The empiry, *i.e.* observations, experiments *etc.*, is testing the mental images, and through this process we are continuously building up our own world picture, perceiving our environment and interpreting the phenomena we observe. Reality consists of entities, and phenomena, on their part, are real events occurring in the time. The identification of entities and phenomena is based on their properties. In classical physics the material objects or particles, more generally, the matter are entities. In the classical period (starting from Galileo and Newton) the interaction became the common basic phenomenon of all phenomena. In the revolution of Newton, the interaction became the supporting theme of the entire development of physics. This revolution linked all of physics with mechanics.

The pre-Newtonian mechanics focused on exploration of the motions of bodies. In its basic mental image a body was the entity, the motion of it was the phenomenon, and properties of the body determined its behaviour during its motion. In Newton's mechanics a body is the entity as well and its motion is the phenomenon, but there is a third factor connected: the interaction. Thus, in the basic mental image, there are two bodies and one interaction between them, the properties of which can be examined independently of the properties of the motion and the bodies. Interaction is the cause phenomenon (*causa*) to be explored. A so-called causal model was created, according to which, both the cause and the effect phenomena (interaction and motion) can be explored empirically independently from each other making possible empirical verification of assumptions concerning the causal law connecting them. This was a revolution and raised Newton's mechanics as a theory into a totally new position in comparison with all earlier theories.

Newton's laws can be examined from the viewpoint of the basic model. Motion of the bodies can change only due the interaction. From the opposite point of view, there are no changes of motion without the interaction. This is the idea of Newton's 1st law, the law of inertia. Without interactions the motion of the bodies stays unchanged, they are moving uniformly. In the case of interaction, the changes in the motions of the two bodies must be equal, because they have a common cause, the interaction. The effects of the interaction on both the translational and the rotational motions are equal for the two bodies. The two new quantities, the momentum and the angular momentum, representing the two kinds of motions, are changing continuously in an interaction, by equal amounts but in opposite directions, so that their total amounts in the system stay unchanged. The rates of change of these quantities define the force and the torque acting on the bodies as two different measures of the strength of the interaction. Here we can see the ideas of Newton's 2nd law, the basic law of dynamics, and of Newton's 3rd law, the law of force and counterforce. The equivalent laws related to rotation can also be formed. Once the concept of force is defined, it becomes possible to examine and determine experimentally the laws of interaction, *i.e*. the dependence of the forces caused by an interaction on the distance, mutual velocity, properties of the bodies etc. This leads, finally, to the possibility of predicting the motions.

The laws of interaction offer the basis for identification and classification of interactions. Further, ability to different kinds of interactions forms a new basis of classification of bodies and particles. In modern physics, interactions have become the basis of identification of the 'species' of particles. On the other hand, according to the basic principles of quantum mechanics, particles of the same 'species' are identical - 'single' particles cannot be identified as individuals, but only according to their species. The individual identity is lost in the world of particles. Only the species-identity is left, to be recognized on the basis of the ability to different interactions.

Kurki-Suonio closes this line of thought with a rhetoric question: What, if there is, fulfilling the dream of particle physicists, just one ultimate great super interaction, as the only kind of interaction? What would then be the meaning of even the species-identity, if there is only one kind of species." (Kurki-Suonio, K. 2000 a and b; Kurki-Suonio et al. 1985, 22-49, 124-137)

Considerations

The gap between thinking before Copernicus and thinking after Newton was deep, Lehti says. The conception of the universe changed completely between 1543 of Copernicus' *De Revolutionibus* and 1687 of Newton's *Principia*. (Lehti 1996, 29)

Lehti keeps pondering (Lehti 1998): "It was typical for the 17th century, the century of scientific amateurs, that the scientific and mathematical interest spread everywhere". Excited amateurs conducted research on everything. Newton's *Principia* opened up possibilities for research in many areas, but now the scientists were already required to possess special technical and theoretical skills. These included astronomy and mechanics as well as differential and integral calculus. Because of the small size of the scientific community, the research was focusing on few fields of science and the other fields had to suffer. (Lehti 1998, 264)

Kuhn regards the cycles of scientific development, leading to the emergence of new theories and conceptions in science, as scientific revolutions. The revolutions of Copernicus and Newton can be taken as good examples. A common feature in such cases is that a theory, which has dominated for a long time, has had to give space for a new one, which in the beginning has often been difficult to accept. Scientific research has had to search for new methods, to accept the changes of problems and new standards in defining them. This all has changed the worldview bringing also new controversial issues to be pondered in the scientific community. According to the conception of science as 'normal science' presented by Kuhn, the old theory is abandoned and replaced by a new one. Kuhn emphasizes that exactly this kind of scientific action reveals the weaknesses of the existing theories. In order that the development of science and the research of future scientists could continue within the new theory, this has to fulfil two conditions. The new theory has to be so significant that it will get its own group of supporters from other fields of scientific activities. On the other hand, it has to be open, so that new scientists will have something to research and problems to solve. Achievements of science, with these two qualities, Kuhn calls changes of 'paradigm'. (Kuhn 1970, 1996)

Lehti draws a parallel between the studies of snowflakes and planetary motions. He asks, "why did the research of snow flakes and speculation about them not become a similar strand promoting the entirety of science as, for example, the theory of planetary motions?" One can ask further, why did the questions, related to the motion of the satellites of Jupiter, the structure of the rings of Saturn and the motions of the Moon, promote the development of science better than the study of snowflakes? Lehti defends his view on the non-significance of snowflakes in the changes of the physical worldview: ”In the changes of the world picture, conceptions adopted for snow flakes were jumping easily from one worldview to another". The conceptions based on the research of planetary motions changed worldviews; because this research was autonomous and independent from the other fields of science. (Lehti 1998, 265-266)

In an earlier book Lehti is considering philosophical questions related to the solar system. He thinks that "the heliocentricity has brought in the mathematical presentation of the planetary system both some beautiful symmetry and admirable exactness of predictions. All people interested in astronomy are happy about that." Ptolemy, Copernicus, Brahe and Kepler tried to find a presentation of the planetary motions as realistic as possible. Lehti then asks philosophically: ”Is the reason for their success to be found in some general guideline of scientific work, be it called Platonic or Pythagorean, that requires science to be directed towards this kind of aesthetically appreciated theories?" The solar system and the symmetries related to it are much more important subjects of wondering than the researchers themselves. The solar system is the only system observable for us whose ”behaviour is determined by few fundamental natural laws – the laws of dynamics and gravity". Comparable symmetry has been found also in other physical systems whose behaviour is governed by some basic natural forces, for example, by the electric force or the microphysical forces. (Lehti 1989, 253)

In the 19th century (Bessel 1838) it was, at last succeeded in the measurement of annual parallaxes of stars. Thereby the motion of the Earth round the Sun was verified. Kustaanheimo suggests that "the observational data of the 16th and 17th centuries could well have led to the result that Brahe had become the Ptolemy of the Western countries, because his system of world combined the experience of the antiquity and the thoughts of Copernicus logically in the most simple way". Newton's mechanics changed the focus of the thinking of this question, and the discussion on the geometric world systems faded gradually away. (Kustaanheimo 1985, 43)

4.3.3.4 Repercussions of astronomical revolution

Kustaanheimo claims 'the star dusts' were not of interest to astronomers for the following 150 years, until in the middle of the 18th century when Charles Messier (1730-1813), a French astronomer interested in comets, decided to list them. The catalogue was published in 1782 and it contains 103 numbered 'dusts' and clusters of stars. Nowadays 'dusts' are called 'galaxies'. For example, the well-known galaxy of Andromeda is Messier 31. After this, galaxies were searched for eagerly during the following century and thereby their number increased rapidly. The Danish astronomer John Dreyer (1852-1926) listed the results of the search in 1888 in the big catalogue called *New General Catalogue of Nebulae and Clusters* (NGC) including more than 13000 nebulae and clusters of stars (1952). (Kustaanheimo 1985, 12, 43)

Crowe tells that Messier was inspired at first to study comets rather than 'star dusts'. Interest in 'star dusts' awakened, because they were easily thought to be comets. Messier discovered 42 of the 103 'star dusts' listed in his star catalogue. As another notable event Crowe mentions a theory presented in the book *An Original Theory or New Hypothesis of the Universe,* published in 1750 by an English astronomer Thomas Wright (1711-1786). According to the theory 'the Milky Way is a flat-shaped cluster of stars with a huge amount of stars'. (Crowe 1994, 42-43)

"The conception of the world admiring the human importance collapsed in the 16th and 17th centuries in the so called revolution of sciences", Lehti describes. The revolution started from a rather restricted problem in the universe: does the Sun orbit the Earth or vice versa. The newest theory of science, Newton's mechanics, ruled the motions of material bodies and the forces between them with help of its fundamental mathematical formulas. At the same time the conception of the stars in the universe changed. Even our own Sun was found to be a star among milliards of others alike. The dimensions of the universe grew unbelievably large. "Man was in this universe a strange and homeless being", states Lehti a little sadly and continues that "the assumed homelessness of man and the humanity in the universe got several forms of manifestation, of which the gap between the so called 'humanistic and scientific ways of thinking' might be one of the most unfortunate ones". For a person oriented towards 'cultural values' the new scientific world picture might have felt even inhuman and cold. (Lehti 1996, 19)

In 1755 the German philosopher Immanuel Kant (1724-1804) presented a new cosmology in accordance with Newton's mechanics. In Kant's opinion, the universe consists of systems similar to the solar system, with a massive central object and a number of smaller objects orbiting it (*cf*. Kants Populäre Schiften, herausgegeben von Paul Menger, Berlin 1911, p. 4). The whole universe consists of a hierarchy of this kind of systems. (Lehti 1996, 33)

Crowe tells that Kant was the first to publish the disk theory of the Milky Way, anonymously in 1755. He was thought to have received this theory from Wright, but Kant knew it only from a review article in a newspaper. Like many great philosophers, Kant was interested in sciences. Also the obituary in his gravestone proves: "Two things fill my mind with ever new and increasing wonder and awe, the more often and persistently I reflect upon them: the starry heaven above me and the moral law within me." (Kant: Critique of Practical Reason, the English translation of *Kritik der reinen Vernunft*) The position of the father of the disk theory became competed for. A German astronomer, physicist, mathematician, scientist and philosopher Johann Lambert (1728-1777), a contemporary of Kant, published his own disk theory in 1761, but claimed having developed it in 1749. Kant and Lambert had different conceptions of the universe: Kant thinks it is infinite whereas Lambert thinks it to be finite. Interesting is that in the books of all three (Wright, Kant and Lambert), there are thoughts about the existence of extraterrestrial life. (Crowe 1994, 45- 46)

4.3.3.5 Classical physics steps aside

In 1781 an English astronomer William Herschel (1738-1822) found, by accident, a new planet, Uranus. Instead, the planet Neptune was found in 1844 as a result of a prediction by Johann Galle of the observatory of Berlin. Valtonen claims the discovery of Neptune gave a boost to the celestial mechanics, which was exploring motions of the solar system by Newton's theory of gravity. (Valtonen 1981, 54)

Mustelin states that the similarity of the celestial mechanics and mechanics on Earth revealed about the nature and its laws a totally new and unpredictable coherence. That was verified also by the observation in the 19th century with help of spectral analysis that the Sun and stars consist of the same chemical elements as the Earth. “The dream of inhabited worlds changed over the centuries because of the development of astronomical information and the worldview based on it, whereas the unawareness related to the life itself, to its laws and internal events was hidden behind divine purposes presented more or less as absolute ones.” (Mustelin 1980, 19)

Lehti says that the medieval human-centric cosmology collapsed after Newton. The period of 150 years from Newton to Darwin forms its own phase in the development of the worldview. A new change was caused by *The Origin of Species*, a book published by an Englishman Charles Darwin in 1859. (Lehti 1996, 30)

Electromagnetic worldview

The great practical success of Newton’s mechanics led, as Kustaanheimo describes, to the other extreme, the ’mechanistic conception of the world’: all the phenomena are reduced into motions of mass points following the laws of dynamics. Since magnetic and electric phenomena had become a central field of research after the discovery of the magnetic effects of electric current (H. C. Ørsted in Copenhagen in 1820), it was natural to try to apply the same theory to these phenomena. For example, the electric and magnetic forces weakened in proportion to the square of distance just like gravity. As a deviation from Newton’s model, the electromagnetic force is depending also on the velocity of the body, so that only a moving charge affects the magnetic needle. (Kustaanheimo ((1974) 1985, 101-102)

Kustaanheimo continues that, in applying the laws of electromagnetic forces to the solar system, the only deviation from the predictions of Newton’s laws was an additional motion of the perihelion of the orbits of the three inner planets. By combining the laws of forces, also this motion of the perihelion could be explained. The Scottish theoretical physicist James Clerk Maxwell (1831-1879) developed the first ordinary field theory, where “the space was filled by electric and magnetic fields obeying certain partial differential equations (the field equations)”. A further theory by the English physicist J. J. Thomson (1856-1940) was regarded, for about three decades, as ’one of the most significant results of modern physics’ (H. A. Lorentz 1909). According to Maxwell’s field equations, a moving or changing electric field always creates a magnetic field, and, vice versa, a changing magnetic field creates an electric field. The waves of these fields are spreading in space at the speed of light carrying energy. To generate the radiant energy emitted by an object, work must be done on the object. As a consequence, ”a charged object resists the force moving it more than an uncharged one”. Kustaanheimo develops the idea further suggesting that ”the inertia of the electron could be only electromagnetic induction by its nature, and it would not have any invariant mechanical mass at all”. This leads him to ’the electromagnetic worldview’: matter does not exist, there are just elementary particles consisting of mere negative and positive electricity”. In the solar system the electromagnetic worldview leads to the same motions as Newton’s theory, apart from the additional motion of the perihelion. (Kustaanheimo (1974) 1985, 103-104)

A German mathematician and astronomer Friedrich Wilhelm Bessel (1784-1846) was the first to use the parallax method for determination of the distance of a star in 1838. In 1858 a German physicist Gustav Robert Kirchhoff (1824-1887) understood the meaning of the dark lines in spectrum of the sunlight. With the help of the new spectral analysis, one can explore the internal structure of distant stars and can determine their velocity in the direction of the line of sight. Kustaanheimo tells, ”the year

1898 can be regarded as the start of the modern star ‘dust’ research. It was then that Keeler begins to photograph systematically star ‘dusts’ at Mount Hamilton in California, by using the 92 cm reflector of Lick observatory as a camera”. Star photography had already begun half a century earlier, though. The nebula of Orion was successfully photographed in 1880, and the galaxy of Andromeda in 1888, with an exposure of three hours. (Kustaanheimo is using the word ‘dust’ also when speaking about galaxies.) Anyway, the researchers were amazed by the rapid growth of the number of the objects discovered, when fainter objects were observed. The number was quadrupled per decrease of the visual magnitude by one unit. (Kustaanheimo 1985, 13)

Kustaanheimo continues, ”Some of the ‘dusts’ have a spectrum typical of glowing gases. These kinds of ‘dusts’ are relatively close to us, between the stars of our Milky Way. These ‘dusts’ are called, based on their appearance, diffuse and planetary ‘dusts’.” He states further, meaning galaxies, that the ”remaining group of ‘dusts’ has instead a typical average star spectrum - obviously the spectrum of the whole Milky Way would look similar from very far outside, when the spectra of the single stars are merging together.” This group he calls ’spiral dusts’ based on their special spiral structure. (Kustaanheimo 1985, 12)

Culmination of the mechanical worldview

After invention of the telescope, astronomy returned from the celestial spheres back to the Sun and planets. Singer sees occurrence of a parallel phenomenon after the invention of the spectroscope: astronomy returned back from star systems to single luminous objects. Even if the spectroscope became the most popular observational tool, the older invention, the telescope, was irreplaceable. Without it a spectroscope was almost useless. In the earlier explorations, little information had been obtained about the stars. In the old star catalogues only the positions of the stars and brightness observed by eye are registered. Singer mentions by name especially the composer of the catalogue of positions of northern stars, a German astronomer Friedrich Wilhelm August Argelander (1799-1875), of Finnish origin. In current observations by modern tools, much more information is available about the stars, for example their spectrum, proper motion, radial velocity, parallax and exact magnitude. (Singer 1996, 452)

Pannekoek ponders the structure of the galactic system. He would like to know, for instance, if all visible stars form a closed system? William Herschel accepted this assumption basing it on his own observations of the Milky Way. The Milky Way, or more specifically its centre, was the main target in the research of star systems. The coordinates the ‘galactic longitude’ and ‘galactic latitude’ were placed in the plane of the Milky Way. The research of the 19th century was focused in two directions: grouping of stars in space and discovery of the laws of their motion. (Pannekoek, 1989, 467)

Also Pannekoek tells about Argelander’s work. Argelander was the first person to realise the importance of the accurate study of stars. During his first years in Bonn, Argelander examined and listed carefully the magnitudes of all stars visible by naked eye. Thereafter he extended his research to telescopic stars (visible by telescope). He developed a better working method. An observer could see all the stars with the same declination by a fixed telescope. Every time a star crossed the north-south line on the scale, he gave a signal, and his assistant checked the time and wrote it down. This gave the right ascension of the star. At the same time, the observer reported its declination and the observed magnitude. The mapping of millions of faint stars was possible only by photography. Then there was no more need for measuring and listing, because the photos were available. Harvard Observatory developed ‘a star atlas', extending down to the twelfth magnitude, in the format of glass plates, which were copies from the originals. In France the equivalent atlas is called *Carte du Ciel*.

Pannekoek continues pondering over a law or regularity of the motions of fixed stars. With that it would be possible to understand the structure of the space and laws governing it. Argelander explored this question as well. In 1830 he demonstrated by a large number (390) of proper motions, determined carefully by himself, that Herschel had been right and the solar system is moving towards a notional apex. (Pannekoek 1989, 468- 471)

4.3.3.6 Wonders of modern physics

'Research of nebulae' changes the worldview

Most astronomers did not approve right away the extension of the spatial image, like in the times of Aristarkhos and Copernicus. In Kustaanheimo's opinion the question was now about "western scientists, who had 'the passion for distances' in their blood, and who had seen the Milky Way expand in front of them". The new world picture was however soon adopted because of new observations. It was now possible to see much deeper in space than in the time of Copernicus. The first 'new' finding was a nova (new star), which Curtis photographed in 1917 in the Andromeda nebula. "A more exact method for determination of distances of 'nebulae' was discovered by the American astronomer Edwin Powell Hubble (1889-1953) in 1924, when he discovered Cepheid type variable stars in the 'nebula' of Andromeda." The distance of these stars can be determined by measuring the period of variation of their brightness, because there is a known relation between the period and the absolute brightness and 'hence' the distance. In these explorations, some nebulae were discovered to be distant galaxies. (Kustaanheimo 1985, 15)

Astronomers soon faced a new discovery. Kustaanheimo tells, that "In 1914 an American astronomer Vesto Melvin Slipher (1875-1969) had succeeded in photographing in Arizona, single spectral lines in the spectra of spiral 'nebulae' ". It was clearly seen that these lines were shifted to the red, compared to the same spectral lines on Earth. This 'Doppler effect' can be explained to be a consequence of the receding motion of a star. Also observations made by the big refractor on Mount Wilson in the 1920s are telling the same story: distant spiral galaxies in the sky are moving away from us and from one another the faster the more distant they are. The velocity of recession, being of the order of 1000 km/s, amazed the observers; the speed is directly proportional to the distance of the galaxy. (Kustaanheimo 1985, 16, 154)

The Austrian philosopher and physicist Ernst Mach (1838-1916) presented detailed studies of Doppler effect. His ideas influenced Einstein when he sketched his general theory of relativity. (Mach explored the behaviour of waves, and published in 1887 photographs of shock waves and their reflections in air. The Mach number, velocity expressed in units of the sound velocity, was named after him in 1929.) (Gribbin 1996, 253-254)

Simultaneously with the research of galaxies, emerged the famous theory of relativity of the German-born American physicist Albert Einstein (1979-1955). High-energy physics confirms Einstein's theory: matter and energy may transform to each other (after modern interpretation, matter is one type of energy, which may transform to other types of energy).

In 1927 the Belgian astrophysicist Georges Henri Lemaître (1894-1966) presented a relativistic world model of the expanding and contracting space. The English astrophysicist Sir Arthur Eddington (1882-1944) made the same conclusion in 1930. Some researchers think that the observed receding speeds of galaxies are apparent. In Kustaanheimo's opinion, "the red shift of the light is not necessarily always a consequence of the speed, even though the red shift of the light of the stars in Milky Way is a consequence of that". (Kustaanheimo 1985, 17)

Einstein's theory of relativity

Valtonen describes Einstein's ideas about the connection between mass and energy: "All mass is connected with energy, the amount of which can be calculated by multiplying the mass with the square of the speed of light, or vice versa, energy has also a certain mass." There are enormous natural energy resources, of which man has utilized only a small part, *e.g.* in nuclear power plants and nuclear explosives. Also interesting is the slowing of time in a fast-moving object when it approaches the speed of light. The special theory of relativity (1905) brought into physics the relativity of time and space. "Time is no more a stream in a similar uniform flow everywhere, as we used to think, but it may flow with different speeds for different observers."

The general theory of relativity (1915) expands the concepts of time and space further. As a new theory of gravity it replaces Newton's law of gravity. Newton saw, as Valtonen describes, "as a problem of his theory that bodies are attracting each other although there is no elastic band, lever mechanism or machinery between them, which could transmit the force". Another problem could be, that in Newton's the bodies have to 'know' the positions of each other exactly at every time. In the general theory of relativity there is not thought to be any ordinary attraction between the bodies. The orbits of the celestial objects are influenced by the positions of their neighbours, because "the neighbours are first changing the geometry of space and the object then is choosing the easiest path, depending on the geometry it 'feels' ".

The changes of the geometry of space cannot proceed faster than the speed of light, so that the general theory of relativity is in accordance with the concept of the light velocity as the general upper limit of speed. As a good example Valtonen illustrates a ball on a curved surface bended by a heavy body (Fig. 4.9). "The curved space creates an apparent gravitation: a ball is revolving around the central body, even though there is no force between them." (Valtonen 1981, 60-63)

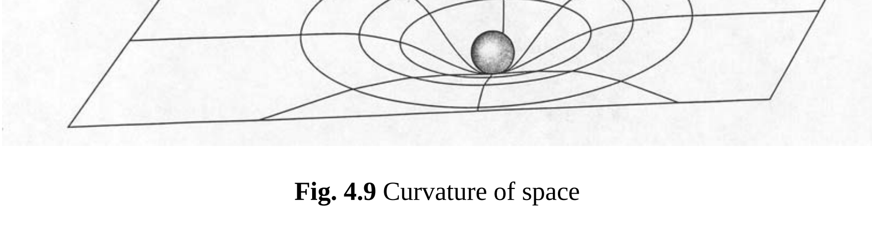


Fig. 4.9 Curvature of space

Einstein's special theory of relativity in 1905 and the nuclear physics refuted the electromagnetic world picture. Kustaanheimo realises, that "one cannot experimentally distinguish the inertias of matter and energy (*e.g.* electromagnetic), because they depend always in the same way on velocity and can change into each other". There are also other types of energy than the electromagnetic and gravitational energies. For example, in the atomic nuclei energy occurs in forms behaving in a completely different way. There is, however, associated with all energies E an inertial mass Ec^{-2}, where c is the speed of light (Kustaanheimo (1974) 1985, 104). Einstein became convinced, that only gravity had to be interpreted as the curvature of space, not until 1915 (p. 153-154). Einstein's formulae or 'the general theory of relativity' predicted several properties of gravity, the three first of which Einstein discovered himself:

1. In Einstein's theory the orbits of planets closest to the Sun are turning a bit faster than they do in Newton's theory because of the disturbance of other planets.
2. According to Einstein's theory, the gravity influences also radiation, *e.g.* light, and *vice versa*. When a light ray comes from a star behind the Sun and passes by the Sun at close range, it bends towards the Sun because of this attraction.
3. The light coming to the Earth from a heavy star is redder than the light emitted by the same atom on Earth, because the light particles are losing energy when they have to conquer the gravity of the star.

The American theoretical physicist Julius Robert Oppenheimer (1904-1967) and his colleague Snyder proved in 1939, that "Einstein's theory includes the possibility of the existence of a so called 'frozen star'". This finding was named later 'a black hole'. In 1916 Schwarzschild found for Einstein's equations a simple spherically symmetric and time invariant solution, with the extraordinary feature of Schwarzschild radius: if the mass of a mass point is M, this radius is $2GMc^{-2}$, where G is Newton's gravitational constant and c is the speed of light. A spherical region of this radius, centred at the mass belongs in some sense to another universe: no matter, no radiation and no information can penetrate the surface of this sphere. "Because of this property, the Schwarzschild radius has got also a more poetic name 'the event horizon'." (Kustaanheimo (1974) 1985, 155-157)

Kustaanheimo philosophises that in these considerations we meet "a singular difficulty typical of cosmological theories only: the physical experiment must be repeated a sufficient number of times and varying the circumstances sufficiently, in order to distinguish the invariant law or 'the differential equation' from the varying circumstances or 'the initial conditions'." Even if the universe is unique for us, it can be, for the physicist, one occasional solution with occasional initial conditions. Our unique universe can nevertheless be the limit and background of our physics. The logical development of mechanics and physics into the general relativity has "refuted the 'mechanical world picture', the great dream of the last century, which still at the end of the last century seemed almost self-evident". (Kustaanheimo (1974) 1985, 164-166)

In Gribbin's opinion, the present conception of the universe is based expressly on Einstein's theory of gravity or the general theory of relativity, and it illustrates the development of the expanding universe since the Big Bang (Gribbin 1996, 131). Gribbin regards the general theory of relativity also as a cosmological theory. This theory is consistent with other modern models of the universe. The special theory of relativity (1905) deals with the dynamical relations of bodies proceeding rectilinearly at a constant speed. Einstein wanted to generalise his theory also into accelerations and gravity, and tried to discover a satisfactory mathematical representation for the dynamics of the universe. Einstein's theory offers a physical picture about the appearance of gravity. Gribbin states that Newton discovered the inverse square law of gravity, but did not give any explanation, why gravity follows it. According to the general relativity, gravity follows this law everywhere, except in extremely strong gravitational fields, but it tells also why it is so. Einstein's theory, thus, includes also Newton's theory, unless the gravitational field is very strong.

Gribbin thinks that there were two significant factors, which led Einstein to discover his general theory. At first, acceleration of falling compensates the gravitational force (or 'the effect of gravity can be eliminated locally in systems falling freely', as the Finnish scientists Maalampi and Perko express it). Secondly, the so-called principle of equivalence (Einstein 1907) should be extended to the influence of gravity in light. Einstein considers the situation in a closed lift, where a person cannot tell whether the lift is falling in an accelerating motion or floating freely in space. When a light ray comes from the wall of the lift and hits the opposite wall on the same height, it must have travelled along a curved path. This leads us to the idea of curved space, where gravity is no more needed, but bodies are moving along geodetic lines in curved space, the world lines of a free body. (Gribbin 1996, 168-171)

General theory of relativity under testing

Karttunen presents phenomena in solar system by which the general theory of relativity can be tested (Karttunen 2000, 582). The relativistic predictions on these phenomena are slightly different from those of Newton's theory. (*cf.* 'Einstein's laws presented before by Kustaanheimo)

> - The first phenomenon deals with elliptical orbits. "According to the theory of relativity, the motion is not, even in the case of two bodies, a closed elliptical motion following Kepler's laws, but differs slightly from an ellipse." This is seen most clearly in the motion of perihelion of the innermost planets. It has been observed, that, in the case of Mercury, the deviation from the classical prediction for the motion of perihelion is about 43 seconds of arc per century.
> - The second phenomenon is the gravitational bending of light. According to the theory, a ray of light should, "bend when passing the Sun". The prediction for a ray passing the edge of sun is about 1.75´´, which is also found when observing positions of stars at the time of solar eclipses, and "in observations of point-like radio sources when the Sun passes in front of them (the solar cross-over).
> - The third phenomenon is the gravitational red shift, which should occur, according to the theory, when "photons are going up in the gravitation field". Photons are losing energy when they have to do work against the field. This red shift of the light caused by gravitation has been observed experimentally.
> - The fourth phenomenon is the retardation of light in a gravitational field. This has been observed to occur close to the Sun in tests with radar.

Thus, in tests made in the solar system, the general theory of relativity has been verified quite successfully. Outside the solar system it has been tested, at least, with help of double pulsars. As one example Karttunen describes an unsymmetrical system in accelerating motion, *e.g.* a double star. It is sending gravitational waves, and losing energy at the same time. As a consequence, the components are approaching each other and the time of revolution is getting shorter. Eventually, they will touch each other and "fuse together into one body". In the case of an extremely dense object, the strong gravitational waves cause observable changes in the orbital periods. This has been observed in one double pulsar, and the shortening of its period coincides with the prediction of general relativity.

Events and researches of our time

The first atomic bomb, exploded in 1945, changed strongly people's worldview, and started a new era in the world. The nuclear energy gave huge resources of energy, but at the same time increased the possibilities of runaway events caused by man.

Since the end of 1960s the microwave background radiation has been measured by radio antenna, and it has been proved to coincide with the 'black body radiation'. Its radiation temperature, about 3 K, is the same as the expected temperature of radiation, originated in the Big Bang about ten milliards of years ago. Also the first quasars were found in the same decade.

Kustaanheimo ponders also over the future of gravity. He says that "gravity is a strangely isolated phenomenon in physics. It controls almost alone the greatest part of the universe. The quantum physics has never needed it". The problem of the motions of three bodies has waited for a solution at least since the year 1684, when gravity got its specific mathematical definition. The future development of astronomy and also the whole of physics depend then on gravity. A new theory of gravity can be developed both empirically and theoretically. An empirical disproving of Einstein's theory would surely increase the interest in finding such a new theory. Therefore experiments for verification of gravitational waves will be continued with more and more sensitive equipment. (Kustaanheimo (1974) 1985, 239)

In physics we have had to give up the dominance of the Newtonian mechanics. The theory of electromagnetic fields, the theories of relativity, quantum mechanics and nuclear physics have proved, as Lehti tells, that "when we try to control natural events, we do not manage with so simple concepts as was thought on the 1700s and 1800s". (Lehti 1996, 20)

Karttunen tells about modern research objects in astronomy. He says that the research area is the whole universe. "Astronomy explores the universal matter from the level of elementary particles and molecules (masses 10^{-30} kg) up to the largest super-groups of galaxies (masses 10^{50} kg)." As for the research of the Earth, *e.g.* the planet researchers are interested especially in the atmosphere, its upper parts and in events in the magnetosphere. The Moon is still to be explored, even if man has visited its surface by spacecraft and brought back samples to the Earth. (In 1957 the first artificial satellite was launched and in 1961 the first manned space flight was made, until in 1969 man was able to step on the surface of the Moon.) All the planets, except Pluto, have already been explored with probes. Spacecrafts have landed, in addition to the Moon, on Mars and Venus (and on Titan). The solar exploration gives information about the properties of other stars, but stars, in general, are anyway the main research objects in astronomy. The latest objects are compact stars or neutron stars and the black holes. "The matter in them is so compacted and the gravitation field becomes so strong, that in the description of matter and space we 'have to use' Einstein's general theory of relativity." Besides stars, interstellar matter, galaxies and clusters of stars are explored. The largest object in astronomical research is the whole universe. Karttunen states yet, "the cosmology, the field possessed formerly by theologians and philosophers, has come, during this decade, within the range of physical theories and, finally, also concrete astronomical observations". (Karttunen 2000, 14-16)

4.3.3.7 Interesting considerations about the universe

This chapter presents a collection of interesting conceptions about the universe. The stories are separate from each other, and do not form any logical set of events. Conceptions of the time period of reference may seem unreal for us, people of the 2000s, since the new ideas have replaced the old ones. It is still interesting to explore the paths of people's mental images about the universe.

* Paradox between finite and infinite
Olbers' paradox is associated with the idea, that the world is infinite with stars evenly spread. When looking in any direction in such a universe, one would always meet the surface of a star. Because the surface brightness does not depend on the distance, the sky would be throughout as bright as the surface of the Sun. However, according to the present knowledge, the stars have existed only for a finite time. Therefore the light from the very distant stars has not yet reached us. Karttunen tells "the status of Olbers' paradox has changed from a proof of the finiteness of universe into the perception, which is explained by the finite age of the universe, let the universe be finite or infinite by size and contents of stars". (Karttunen 2000, 533)

The solution of the paradox came from an unexpected direction. Slipher and Hubble proved that galaxies are moving away from us and also from one another. The red shift of the galaxy is not only 'moving' the spectral lines away from their normal places, but it is also 'dimming' the light of galaxies. The universe has started its expansion from one point, as a consequence of the so-called Big Bang (see also Gribbin 1996, 209-211). The expanding space of finite aged solves Olbers' paradox. The age of the universe is easy to calculate in the theory of Big Bang,. (Valtonen 1981, 294-295 and 1991)

Gribbin states that the original Olbers' paradox was wondering, why the light of stars has not been able to fill the space with energy. The reason is simply that there has not been enough time for that. For example, in the case of a galaxy at a distance of 50 000 light years, it takes 50 000 years for the light to come here, therefore, in the universe of 15 milliard years we can see galaxies only up to the distance of 15 milliard light years. When looking with 'radio eyes' at the interstellar and intergalactic space, we 'see' the weak noise of cosmic background radiation, with 2,7 K temperature. This is strongly red-shifted electromagnetic radiation from the time, when the universe was about 300 000 years old and full of radiation as hot as the surface of the Sun today. Gribbin states finally: "If the universe had not been expanding, all the space would be still as hot as it (the Sun) and radiate as bright as the surface of a star – therefore the red shift illustrating the expansion of the universe is one reason why the sky is dark at night, even if Olbers and his predecessors had no perception about the existence of the fire ball of the Big Bang". (Gribbin 1996, 300-304)

* Friedmann's space models
The Russian scientist Alexander Friedmann discovered as early as 1922, that there is no stationary possibility among the world models allowed by the general theory of relativity: the universe has to be either expanding or contracting, and it cannot stop still except for a moment. His result received little attention, until Eddington remarked in 1930, that the dependence of the receding speed on the distance, discovered by Hubble, followed exactly the prediction of Friedmann's models. Nowadays these models form the basis of our worldview. There are two fundamental types of Friedmann's models, open and closed. Both require a curvature of the three-dimensional space, because they are based on the space conception of general relativity. The surface of a sphere has no boundary, nevertheless its area is finite. Respectively, the three-dimensional closed space is limitless despite of its finite volume. If the universe is closed, its expansion will stop and change into contraction. The open space, instead, will continue its expansion

forever. The density of matter, just sufficient to stop the expansion, is called the critical density. The average density of the luminous matter in space, consisting mainly of stars, is under ten percent of the critical density. If there would be no other than the visible matter in the universe, it would definitely be open. But the latest hints about the presence of dark matter keep the closed space as a noteworthy possibility. Especially non-zero mass of neutrinos could act as a closer of the space. (Valtonen 1981, 295-297)

* Microwave background radiation

The Americans Ralph Alpher and Robert Herman predicted, that there should be radiation in radio waves left from the Big Bang. Quite unexpectedly, the Americans Arno Penzias and Robert Wilson discovered the predicted microwave background radiation in 1965. It does not seem to come from any special direction, but it is everywhere 'in the background' as a universal radio noise. The later explorations have shown, that the characteristics of the observed radiation match perfectly with the predicted residual radiation of the Big Bang. Furthermore, the background radiation contains so much energy, that it could not have born in the connection of the phenomena observed nowadays. Thus, the discovery of the background radiation made the Big Bang theory at once a noteworthy scientific theory, which forms a basis of the modern science of universe, *i.e.* the cosmology. The homogeneity of the universe at the time of Big Bang is understandable. The blow of the strong radiation dispersed all the structures of matter right away, when they began to form. The space became transparent after the formation of atoms, and the radiation spread out, and the gravitation got for the first time a possibility to test its power in forming of celestial bodies. (Valtonen 1981)

* Possibilities of the birth of technical culture

Lehti lists, step-by-step, conditions for the birth of a technical culture parallel to ours. At first, there has to be a planet. Secondly, that planet must have an atmosphere with an adequate amount of carbon, nitrogen, oxygen and hydrogen needed by organisms. In addition, there must be different metals and other heavy elements in the surface layer of the planet. Thirdly, the temperature on the surface of the planet has to be such that chemical and biological development becomes possible. Fourthly, the chemical and biological development must really get started and lead to the development of intelligent creatures. In our own galaxy, the Milky Way, there might exist at this moment about 2 million technical cultures. The average distance between those cultures, which we may call mankind, would be in that case about 300 light years. (Lehti 1996, 21-22)

* Science and elimination of illusions

The presenters of new conceptions emphasise often, how they have refuted illusions of the former 'theories'. According to such an attitude, the new discoveries of science seem mainly to root out errors. They are eliminating illusions, dreams and fantasies, like, for instance, determinism, reductionism and search for Euclidean patterns in nature. Is it, however, not far more important to create illusions, dreams and fantasies, which help us to go ahead? We have all reason to appreciate scientists and their ways of thinking, when the daydreams associated with their ideas created such a marvellous construction as that of classical physics. The elimination of dreams, associated with it or other science, is not a heroic deed; more significant was the completion of these patterns of thought and the partial replacement of them with other images matching better with some aspects of the reality of world. We highly appreciate the theory of relativity, the quantum mechanics and the theory of chaos, and we can, at the same time, calmly look forward to the time when elimination of the illusions, dreams and fantasies included in them gets started.

> If someone is thinking, that the principle of the fractal geometry of self-reproduction in ever-smaller dimensions is valid for the real creatures of world, there we have a true illusion and dream. In some situations it also gives a good clue, just like in some cases we get a good clue by imagining an ice crystal to be built in the shape of perfect hexagon, and the planetary orbits to be regular conic sections of the Greek theories of geometry. The drawers did perhaps think, that an absolute regularity belongs to their 'real essence', so that possible observed irregularities were 'errors', which at random prevented the ideal reality to come true. (Lehti 1998, 326)

4.4 Significance of astronomy teaching and its interpretation

This chapter gives the summarising interpretations of the twelve aims categories introduced in chapter 4.1 representing the final stage of the analysis of the text material. The primary data and its detailed classification have not been translated in English, but is available only in Finnish (web 4.2).

4.4.1 Significance factors based on social aims

Significance factors related to social life and actions (a1)

The needs of everyday life
Astronomy has had an important role in people's lives especially in ancient times. Astronomical knowledge and services has been required in fulfilling the needs of everyday life. These needs are related especially to commerce, sailing and chronology. New discoveries, such as the motion of the satellites of Jupiter or the rings of Saturn, have inspired astronomers to make more specific explorations with more sophisticated equipment. Particularly, after the discovery of telescope, the solar system with its planets became again a research object instead of the search for 'distant worlds'. Confusing thoughts must have been cruising in people's minds when the humanistic and scientific ways of thinking have fought for existence. Who are we, where are we coming from and where are we going to – homelessness in the universe! The expectations of society have, except increasing the significance of astronomy as science, also helped astronomy to develop as a science and through it to benefit the society more and more. This interaction continues still, even if the fields of interactions have changed with the development of society. One does no more compile tables of calculated values as before; the super computers calculate the necessary information in a flash. Astronomers are still observing stars, because they are the most important research objects in astronomy. At the same time they try to develop new theories for clarifying the secrets of the universe. A good example of a modern research subject is the dream to discover experimentally the limits of validity of Einstein's theory. This is, fortunately, only a passion of scientists without any requirements of society.

Conception of the world
In each epoch in the human history the social life has borne the stamp of the conception of the surrounding world. The role of astronomy has varied. Especially, thanks to new discoveries, it has sprung into a higher popularity, but during long 'dark periods' it has sunk 'into a scientific sleep', still without loosing its significance as a satisfier of the needs of everyday life. The history of astronomy can be seen, with very good reason, as the history of the development of people's worldview. At the times of the birth of astronomy, beliefs in mythological stories and astrological predictions were prevailing. The

most important object, according to the medieval Christian conception of world, was man and the ethic law ruling him. As a consequence of the scientific revolution, the scientific world picture became prevalent and the Christian conception of the world became secularised. The modern conception of the world could be characterized as ‘the worldview of accepted pluralism’.

Influential factor in the background

Astronomy has influenced many other sciences and the culture. This influence has been scientific, historical and philosophical by nature. Exploration of celestial phenomena and search for their explanations has given an initial impact for the development of other sciences. During its history, astronomy has often had a leading position among the sciences; in times of the great revolutions it has even been regarded as top science. Astronomy has inspired ordinary people in all the cultural circles to observe celestial phenomena. It is special in astronomy, in comparison with different fields of science, that there are many representatives of other fields among the ancient astronomers.

Significance related to the guidance by society (a2)

Conception of the world

When the conceptions of the world have changed, also the significance of astronomy in social actions has changed. In the time of great discoveries and revolutions, astronomy has always risen to a remarkable position. It has proclaimed itself as ‘the cradle’ of theoretical knowledge producing maxims for mankind. Its effectiveness cannot be understated, after all its research objects are most interesting. Astronomy, when trying to explain the wonders of universe, has been a great influential factor in the society. Particularly, at the time of ‘great revolutions’ astronomy ruled the everyday life more than any other science. Instead, various ideological currents have temporarily shaken the status of astronomy. Particularly, new religious conceptions, as well as new ideas and ideologies with some philosophical viewpoints have acted as this kind of ‘disturbances’.

Astronomical knowledge

Along with the development of astronomy, mankind’s conception of the world changed. These changes reflected also into social life. The needs of everyday life required more specific information of celestial phenomena. Astronomers had to compile new tables for determination of time and location. Especially the sailors needed this information when sailing without modern location-finding equipment, but – oddly enough – even today the sailors must know how to make similar determinations without the equipment produced by new technology.

Individual in society (a3)

Influential factor in society

In ancient times, astronomy has belonged to people’s daily life in a very concrete way. Celestial phenomena have been utilized in everyday activities, like in determination of time and in sailing. Astronomy has been a science of high repute, especially in the times of the great revolutions, when the astronomical world picture changed. In addition to scientists, also monarchs and military commanders have admitted its significance. Their appreciation has been based in the first place on the practical advantage, which they got when using accurate astronomical information in their governmental and military actions. Astronomers have been educated scientists, in modern terms they could be called ‘professional researchers’.

Man in the middle of conceptions
In addition to the pursuit of practical advantage, ancient monarchs have needed astronomers for another reason. Wonders of the universe and phenomena of the surrounding world have always interested people, and they have desired explanations for them. Along with the evolution of social life expeditions in foreign countries multiplied. New ways of life associated with these trips – sailing, trading and travelling – changed people’s conceptions of the world round them and, thus, broadened their world picture. When considering the course of history, one can see that people’s conception of the world has sometimes even been shaken. After the secularisation of the medieval Christian conception of the world, people have lived a little while in a lack of values – searching for a new world picture. As a consequence of the great revolutions the order of world in people’s minds has turned totally, they have had to think anew their position in the universe. Ideas and ideological streams arisen from the social discussions have created a base for philosophical and theological beliefs. The dialog between science and religion has gone on across the years in the history of mankind, and it is still going on. In some cases magic features have been mixed in trends of thoughts; the belief in astrological predictions is one which often is seen as an ‘astronomical’ belief.

Astronomical knowledge
In the middle of the advanced technology of the modern society it is hard to imagine that skills of orientation from stars used in ancient times would still be needed. This is, however, true even today. The sailors must still know how to orientate using stars, how to determine coordinates of location and to make different kinds of navigation tasks with the old methods. This adds to the significance of astronomy as a 'useful science'. Ideas coming up in discussions and publications have often given an initial impact on construction of new theories. People interested in astronomy spread astronomical information round them by their own enthusiasm.

4.4.2 Significance factors based on individual aims of education

Development of personal worldview (b1)

Image of the universe
Man has a natural curiosity about his environment. He wants to get information about it and to understand it. Many celestial phenomena cause emotional experiences. An individual is crisscrossing in the midst of these intellectual and emotional experiences, each one perceiving the situation in his own personal way. An individual constructs, consciously or not, his own conception of the world. Study of astronomical phenomena helps him in this construction of the own worldview. In different time periods of history one can see various kinds of conceptions of the world prevailing in the society. In the Middle Ages the Christian world picture prevailed. After its secularisation the new scientific world picture took its place. When people came to explain spiritual things in terms of material concepts, the world picture became mechanized. Before the grand revolution of science, man was the most significant being in the universe. The world was human-centred and full of religious conceptions.

Playground of mental images
Astronomy has fascinated people throughout the history. It becomes specially inspiring because of the possibility to observe phenomena of the night sky with the whole of ones presence, in immediate contact with the nature, living in the midst of all. Just there, often in complete silence, ones imagination may break loose and one is feeling small in front of the great universe. Everyone faces that moment in ones own way. The smallness of the self and the greatness of the universe will definitely arouse respectful feelings towards the surrounding universe. At the same time an interest may arise, to explore these phenomena and events more closely. In school, the teacher is a key person in this situation. The teacher can guide and encourage pupils to make scientific explorations, but he/she may also stifle the enthusiasm by constraining the flow of imagination. Astronomy has inspired researchers because of man's native inquisitiveness to natural phenomena, but in the stages of history also lack of enthusiasm can be noted. After the breakdown of the medieval Christian world picture, people, in their barrenness, had to look for some new world picture. Inquisitiveness and love of adventure prevailed and forced people to search for new discoveries in science. Sometimes also false interpretations occur: people have pondered astrological problems in the name of astronomy.

Looking for truth
Astronomical problems have aroused in people's minds a desire of search for different kinds of world explanations with the support of other sciences according to the spirit of each time. Explanatory theories have been constructed by virtue of, among others, arithmetic, geometry, philosophy, religion and arts. Stages of the development of people's conceptions of the universe can be followed by acquainting oneself with history. It is interesting to study the changing processes and events shaping the conception of the world. In the strongest of them the entire world picture has turned almost 'upside down'. After discovery of the current system, the pieces of the near space settled themselves into a beautiful symmetry. Thereafter, exploration of the small constituents of matter advanced astronomy in long steps and raised it again into a significant status.

Intellectual development of an individual (b2)

Knowledge about the surrounding world
The inquisitiveness of man has always driven him to explore new areas and subjects. In ancient times people broadened their worldview by sailing over the great oceans. In these trips they were also influenced by foreign cultures and different kinds of conceptions of the world. New thoughts and ways of life have aroused critical attitudes towards their traditional beliefs. Although people have, during their common expeditions, been subject to similar external influences and the same kind of information, they are all developing their own internal picture of the world. People perceive themselves, each in ones own way, as a part of the nature and of its events. In studying science – and also astronomy - it is important to learn about its historical development as well as about the trends of ideas. Particularly the cosmological problems have long exercised people's minds, and the mathematical attempts at explanations of them have had an influence in people's thoughts, shaping their conception of the world.

Astronomical knowledge
The primary aim of astronomical studies is to get the basics of the stellar sky, from the solar system to the most distant objects. The astronomical knowledge contains also information about various theories and interpretations concerning the universe. The world picture varies depending on the prevailing theories - fortunately not much. It is important to try to create a general view about the structure of the

whole world, and about the position of man in it. In addition, one can deepen the knowledge about any structural constituents according to ones interest and enthusiasm. In the history of astronomy many timely subjects can be found. For example, today, in the era of modern technology, it is still necessary to know old measuring and location methods.

Scientific method
Observations, exploration of phenomena and discussions belong to astronomical studies. They will familiarize the pupils with the scientific method almost unnoticed. Astronomy is appropriate in educating pupils as scientists. One can observe and wonder the natural phenomena, discuss them immediately and ponder together over related problems. At the same time pupils may get inspired to continue investigations, maybe even to create own theories to be discussed and criticised by their own classroom community. At its best, such a method can be quite efficient in developing the scientific and social skills aimed at in the education.

Social development of an individual (b3)

Member of society
Man is a social creature. He grows into his own society assuming its culture, ways of life and even the essentials of its trends of thinking. Every society develops its own special conceptions of the surrounding world. Within the society, people have their own ways of thinking, bound, however, strongly in their own culture. It is often very hard for people to accept conceptions or ways of thinking, differing from those of their own. This has caused disagreement among people. On expeditions geared towards foreign countries the travellers had expectations based on the culture of their own society, and their attitudes towards the new countries and peoples were put to a severe test. On the other hand, it must have been very mind-broadening to get to know different kinds of life styles and conceptions. Thanks to this travelling astronomical knowledge was carried from one country to another. This contributed to the development of astronomy and many other sciences. Especially, the spread of changes of the worldview has had an important influence on the lives of entire societies.

Member of the school community
It is fruitful to get familiarised with the stellar world together with the school class. The pupils get the opportunity to observe the same world of phenomena together, to watch the dark starry sky and to discuss their observations. The exploration is holistic, exciting all their senses. Common experiences are a means of education into constructive membership of society, and develop the facility for sharing feelings. Pondering together over questions circling in the minds is a social process. At the same time it adds efficiently to the astronomical knowledge of the pupils.

4.4.3 Significance factors based on aims of subject content knowledge

Significance factors related to the scientific process (c1)

Structure of the universe
The modern astronomical research is concentrating on problems related to the structure of the universe and the laws governing it, instead of observations as before. This branch of science is called cosmology. According to the present theory, the universe is built of systems like our solar system, following

the laws of Newtonian mechanics. But also other models of the universe have been discussed. For instance, in our present view the distant spiral galaxies are moving away from us and from each other the faster, the more distant they are (see chapter 4.3.3). In analysis of astronomical results mathematics has played an important role. The mathematical calculations have yielded more accurate and reliable information than mere ponderings and discussions. Without mathematical methods the exploration of the external physical world would not even have started in its present extent. Regular celestial motions have advanced the development and use of mathematical applications.

The conception of the universe has varied in the past centuries and millennia. Through the increase of physical knowledge, an overall conception has naturally changed with it. In the physical world picture the victory of the heliocentric system over the geocentric one was a decisive change. In its time it was a tremendous revolution in people's conceptions of the world. The current conception of the universe is based on Einstein's theory of gravity describing the development of the universe from the Big Bang to the present. According to the geographical world picture, our world is a part of the universe. The research object is the near space and the spatial relations and motions in its phenomena. Things, which change most slowly, belong in the basis of the geographical world picture.

The life of an astronomer
Natural philosophers contributing to the birth of the scientific world picture in Greece, explained the world independently of myths and religions. Sailors in their turn utilized astronomical knowledge on their expeditions to the distant countries. At the same time, they got inspired in other astronomical explorations, for example in discovery of new stars and constellations. Astronomers elaborated the spherical trigonometry and algebra in their astronomical calculations. The sailors had to determine the longitude and latitude of their position on the open sea. Also ordinary people, other than astronomers, have observed motions and phenomena of celestial bodies. It became desirable to compile together all scientific knowledge obtained about the stellar sky. Of course, some parts of it had to be translated from foreign languages. At the same time, it was necessary to elaborate methods of calculation. The search for galaxies continued eagerly. Also, attempts were made to discover laws, which would represent the planetary motions.

Copernicus, as the first occidental person, changed his world picture and proclaimed the Sun as stationary and the Earth as a planet. Messier, the 'comet hunter', decided to list the comets observed, he also grouped the stars into constellations. Tyco, with his measurements of stellar positions and planetary motions, created the basis for Kepler to discover the laws of planets.

Kant was the first to publish the disc theory of the Milky Way. Argelander explored the characteristic motions of stars, which he had determined by himself, and verified Herschel's proposition about the movement of the solar system towards a virtual apex. An astronomer had to calculate values of astronomical quantities on the basis of the numerical data from his observations. Transforming the observations into accurate predictions required development of new methods of calculation. Astronomers defined the prime periods of the motions of celestial bodies, and on the basis of them they made new predictions.

Astronomy as science
Astronomy is a science, which explores the whole universe. Among the greatest theoretical turning points have been the discoveries of Kepler's first law and Newton's general law of gravity, and the idea of infinity of the space. The near space, particularly the properties of the closest planets, their satellites

and motions, have been targets of great interest, and the resulting new discoveries have inspired researchers to more exact scientific explorations. Particularly in 1800s, the astronomical research focused on two themes, to the grouping of stars in space and to the discovery of laws of their motions.

Later on, astronomy returned from the star systems back to single luminous bodies. Einstein's general theory of relativity replaced Newton's law of attraction as a new theory of gravity. Researchers even concluded that there is no gravity at all, but the space curvature causes an apparent force of attraction on the bodies. Gravity influences also radiation. For example, the light coming from a heavy star to the Earth is redder than the light emitted by the same atom in the Earth, because of the loss of energy needed to overcome the gravity of the star. The future development of astronomy and also of the entire physics depends, thus, largely on understanding of gravity.

Along with the Chinese know-how of paper making the custom of writing down notes on ones scientific explorations became general. In the context of their observations the astronomers developed, at the same time, also arithmetical methods, geometry or land surveying, even metallurgy and anatomy. The astronomical explorations have had an important role on the whole birth of science. As for the development of physics, the significance of astronomy is seen in, for instance, that it has given an initial impact to the set of events, which lead to the birth of electrostatics. Visual astronomical objects offered a proper field of application for theories of physics and also of other sciences.

It is, thus, justified to regard astronomy as a key to sciences. It can be great fun to teach it, but incorrect teaching may kill pupil's interest. By assuming astronomical knowledge a pupil can construct his own world picture. The teacher has an important role in this process, in consideration of both his own conceptions and the development of pupil's worldview. Great revolutions in the conceptions of the world have influenced the daily life of people through the history of mankind, on both the intellectual and emotional level. Teaching astronomy offers the possibility to integrate the pupils' minds with this great historical line of development.

List of astronomical subject matter

Calendar: circulation of the Sun, date of the Easter

Tables: Kepler's tables for the Sun, the Moon and the planets, Tyco's tables for the Northern stars, tables based on Ptolemy's theory for prediction of planetary positions, a great star atlas down to the 12th magnitude.

The world system: the equatorial system, infinity, cosmological problems of the birth and future of the universe, the solar system, planetary motions, theories of gravity, birth and behaviour of star systems, celestial mechanics and mechanics on the Earth, galactic systems, problems in the theory of relativity, background radiation and dark matter, the outer space, the age of the universe and the ratio of the radii of space and atomic nucleus compared with the ratio of the strengths of electrical and gravitational interactions of two elementary particles.

Basics: From the scientific point of view, astronomical studies offer the basics of the stellar sky, including the region of space outside the solar system. Kepler's laws for representation of the elliptic motion, Newton's theory, laws of gravity, laws of dynamics, equivalence of mass and energy. Physical properties of stars and the influences of the space curvature belong to important subject matters, in addition to the physical and observation-based information of near space.

Integration: Among astronomical spin-offs for physics and mathematics are, for instance, the concept of potential originating from celestial mechanics and the series expansions of Keplerian motion, as well as subjects related to the theory of complex power series. Astronomical explorations have had a great influence also in the search for solutions of the famous three-body problem of mechanics.

Significance factors related to the technological process (c2)

Contribution and expectations of society

An interest in natural events and celestial phenomena has been one of the most significant motives in the development of technology since its beginnings. The ancient monarchs co-operated closely with the astronomers, to the benefit of both. In their desire for new discoveries and theoretical explanations, the monarchs equipped the scientists with more and more accurate measuring instruments and helped them to improve their working methods. In discussions with astronomers they got new ideas and inspirations for construction of their world picture. New lines of the economic life – such as sailing and agriculture – required new technology. Among other things, new tools, navigational equipment and practical working methods *etc.* had to be developed. Findings and discoveries promoted the development of many other sciences. For example, astronomy has been a very good field of applications for physics. On the other hand, it has itself utilised new discoveries of physics in its own explorations. Astronomy can be said to have given a initial impacts to many new research projects. The most important of them is most probably 'the great revolution', where the heliocentric conception of the world replaced the geocentric one leading ultimately to the birth of the modern scientific and technological culture.

Tools for exploration

Determination of time and position by the motions of celestial bodies became almost totally omitted in everyday use, when new equipment like sextants, chronometers, clocks and compasses gained ground. The traders have used astrolabes and metallic protractors in the merchant shipping. They have also used guidebooks and maps with meridians and parallels. In Europe astrolabes have caused quite a considerable technological revolution. Foundation of astronomical observatories and acquisition of more and more precise tools for observation and measurement have been significant expressions of appreciation of the astronomical research from the side of society. Discovery of the spectroscope gave astronomy a new valuable research method, the spectral analysis. It was 'a gift of physics' to astronomy. The human eye with its limited observational capability has been substituted by large mirrors, photographic plates and photocells. Discovery of the telescope has been in its own way a great revolution of that time. It has revealed new, more and more distant, objects of deep space, increased the accuracy of measurement and made possible photography of distant and faint objects. Perception of the dimensions and depth of space have influenced the conceptions about the structure of the universe. Beside construction of technological equipment it has been important to develop mathematical tools and new means of communication. Along with these processes, many other branches of science have developed, as for instance geometry, mathematics, metallurgy and anatomy.

Research objects

Determination of time and position has been one of the oldest subjects of research. Sailors, on their long travels, mapped harbours, coasts and islands by astronomical measurements. At see they had to define their location by using values of longitude and latitude. Several terrestrial sciences developed along with the development of mathematical tools for astronomical purposes. The solar system has long been for people the only dynamical system of astronomical objects observable with the naked eye and as such a huge natural laboratory. Discovery of the telescope gave the possibility to explore space at larger and larger distances. New research objects were revealed and the accuracy of measurements improved. Thus, also the way to studies of the dynamics of stars and stellar systems was opened. The spectral analysis made possible study of the composition and internal structure of the Sun and the stars. An interesting and perhaps also comforting result of these explorations was the recognition that these objects are built of the same chemical elements as the Earth. Thus, we are a natural part of the large universe. The gravity waves have been one of the latest research objects. Models produced by mental images and predictions based on modern theories can be tested by measurements and observations, using equipment of modern technology,.

Astronomer under pressure of expectations

In the course of history, astronomers have always been at the centre of attention in society and a target of people's interests, due to the desire for new discoveries and clarification of the ultimate secret of the universe. At times they have even been condemned to death because of their new ideas and theories, which shocked people’s minds. After the scientific and technological revolution the Western people have brought technological know-how, handiness and passion into astronomy. It can be said that astronomy has always been very instrumental, based on measuring and observing by more and more sensitive equipment and better working methods.

Significance factors related to the social process (c3)

Astronomy and other sciences

Astronomy is the oldest science. It has existed as long as any scientific research has been done. Especially, in the beginning of its history, it has had a significant status in social life as a deliverer of knowledge and as a constructor of the worldview. Astronomy can be seen, for good reasons, as a ‘social’ science – it has been in a continuous interaction with other sciences. The centuries of the Roman emperors have been particular centuries of co-operation of sciences. In the Greek culture the co-operation between astronomy and mathematics has been very intense and significant. After the dark Middle Ages, the time of changes with its great revolutions brought a new science, physics, alongside the astronomy. The mutual co-operation of these sciences has brought and is still bringing forward the development of both. For example, common results of Newton’s dynamics and observational astronomy have been regarded as top science, suited to a model for physical sciences. Astronomy is regarded as a universal science because of its continual co-operation with other sciences. The paths of science are full of revolutions. Through them, science is developing and reconstructing itself. Contradicting ideas, which ultimately lead to a scientific revolution, may cause deep social conflicts within the scientific community spreading further into a more general cultural debate in the society. In this way the scientific revolutions can turn out to be useful also in a more general sense, influencing the development of people’s worldview. A revolution may be at the same time both useful and dangerous to mankind. The best-known example is the discovery of the possibility of freeing nuclear energy, which made man encounter the possibility of fatally uncontrolled events.

Foreign cultures

Man has always been a social creature, who has liked to live in communities and in interaction with others. Natural inquisitiveness has forced man to explore areas outside of the familiar environment. His gaze is directed at the sky, to wonder the great space above. The most important research object in astronomy, the universe, has always been close to man, just in front of him. No wonder, that astronomy is the oldest science. Its development has been at the same time development of people’s worldview. When looking for the purpose of life, people have wanted to understand better that world, where they live. Besides exploring celestial phenomena, they have directed their expeditions outside their own country of domicile. In their commercial travels and expeditions they have established relations with peoples in foreign countries, and have became familiarized with their cultures, adopting new influences in their own world picture.

Source of inspiration
Celestial phenomena have greatly interested people in all periods of history, but conceptions of these phenomena have changed in the course of history, being always bound to the cultural era. In ancient times, religious and secular interpretations have fought with each other. As a consequence of long-distance travelling new thoughts and ways of living have shaken off traditional, often magic beliefs from people's minds. When the Christian religion reached a prevalent position, the Christian cosmologists brought theological and ethic content into the explanations of celestial phenomena. Even those who have taken an interest in astrology have thought that they were occupied with astronomical knowledge. Astronomy has inspired authors, poets, composers and artists to interpret their imaginative thoughts about the surrounding world and celestial phenomena by means of their art. In the background of the scientists' interest there has been a desire to find out laws of nature, to interpret natural phenomena in terms of scientific principles and, also, to reach through these explanations a control over the nature. The astronomical subjects have interested pupils and given base for learning science. As a result of the work of an enthusiastic and competent teacher, pupils may get a permanent interest in sciences

Impact of society
The development of the economic life has changed the structure and activities of society. It has even contributed to the birth of culture and science. Interactions between other countries and cultures have shaped people's conceptions of the surrounding world, even of the universe. With the progress of technology the scientists have received more and more sophisticated equipment for their explorations. Entire institutes, like the astronomical observatories have been founded for systematic exploration work. After discovery of the printing art, scientific results and discoveries could be published, at first among the scientists, but later also in the vernacular, so that, at least in principle, all members of the society have been included in the discussion about new theories and findings. This is one of the essential principles in carrying on science and culture. Within the scientific communities there is competition, and conflicts may occur between researchers, but the ideal aim is always to find mutual understanding about subjects, interest, methods and interpretations. Public discussions evoked by the progress of science have had an influence also in arts, in literature, poetry, painting, as well as in music. Especially in the European culture one can note an obvious interest in astronomy *e.g.* in the works of several thinkers, poets, artists and composers.

4.4.4 Subjects for the contents of astronomical studies (s)

This chapter presents the subjects listed in the literature search for significance factors of astronomy teaching. This method was found fruitful and useful as the starting point for planning the astronomy teaching in chapter 10.

Concept system
<u>Planets</u>: orbits, equatorial coordinates --- by calculating ecliptic coordinates, mean densities compared with the density of the Earth, angular velocity of rotation from the spectrum of reflected light, seasons,

periods of day and night, tides, day and night, the Moon, satellites, the Earth, orbital speed, retrograde motion, atmosphere, magnetosphere
Solar system: the Sun, temperature of the Sun, solar eclipse, eclipse of the Moon, comet, symmetries, list of comets, additional motion of perihelion, heliocentric system, geocentric worldview, probe
Star: fixed star, spherical clusters of stars, constellations, annual parallax, atlas, nebulas, 'spiral nebulae', luminous celestial object, parallax, magnitude, telescopic star, nova, Cepheid – variable star, 'frozen star'= black hole, quasar, compact stars or neutron stars, interstellar matter, clusters of stars
Calendar: motion of the Sun, motion of the Moon, day and night, year
Coordinates: longitude and latitude, equatorial system: Right Ascension, Declination, ecliptic system: ecliptic longitude and latitude, axis, celestial globe
Universe: solar system, galactic system, space, groups of galaxies, Milky Way, galaxy, Big Bang, atomic nucleus, radius of the space, elementary particles, molecule, atom, super groups, giant group
Physics: attraction, rotation, revolution, natural laws, law of gravity, laws of dynamics, measuring, spectrum, proper motion, radial velocity, luminosity, length, distance, mass, energy, speed of light, amount of matter, radius of gravitation or the Schwarzschild radius, radius, gravitational constant, background radiation, 'black body' radiation, radiation temperature, temperature, electrical and gravitational interaction, age of the universe, unit, time, light, matter
General abstract concepts: infinity, cosmology, dynamics of star systems, spherical symmetry of Aristotelian world, original elements: earth, air, water and fire and ether, heaven, object to wonder, Einstein's theory, world, theory, observation

Various subject matters
Planets: orbits, seasons, elliptical motions, periods of day and night, tides, rotation, revolution, planet, daily motion of celestial globe, prediction of planetary positions by mathematical model, orbital velocity, retrograde motion, comparison of orbits of planets, longitude, latitude and distance of a planet from the Earth, new-found planets, annual parallax – motion of the Earth, atmosphere of the Earth, phenomena in magnetosphere, the Moon, planet exploration – probes, new irregularities of planetary motions, additional motion of perihelion, size of the Earth – goniometry, planet catalogues, planetarium
Sun: location in space, motion in the horizon, temperature, eclipses, composition – other stars, Sun and the stars are composed of the same chemical elements as the Earth, calendar, clock and compass, solar-centred system, natural laboratory, earth-centred worldview, physical worldview – Earth is not the centre, comet, cyclic motions of celestial objects – predictions, Aristotelian worldview spherically symmetric, the initial four elements, latest theory of science Newton's mechanics – motions of material bodies, forces of interaction
Stars: constellations, catalogue of fixed stars, atlas, research of structure and development of stars, astronomical lists, star atlas, parallax method for determining distance of star, information on stars – spectrum, proper motion, radial velocity, parallax and exact magnitude, distance of stars – period of luminous intensity, 'Doppler effect' – motion of star, looking at sky, understanding the dynamics of galaxies, radius of gravitation or the Schwarzschild radius, nebulas, 'spiral nebulae', telescopic stars, nova, Cepheid-type variable stars, black hole, neutron stars, clusters of stars
Laws: laws of motion governing the universe, fundamental natural laws or laws of general dynamics, law of gravity, electromagnetic laws of forces in solar system
Celestial mechanics: equatorial system – Right Ascension and Declination, ecliptic system – ecliptic longitude and latitude by calculating from equatorial ones, ecliptic coordinates in catalogue, determination of longitude by zero-meridian, motions in solar system according to Newton's theory of gravity

Backgrounds of astronomy: basics of astronomy from the scientific point of view, study of stages of development in historical point of view, historical development and philosophical thoughts in sciences, development of observation tools, books and scientific journals, communication tools
Theories: mathematical presentation of physical world, mathematical analysis of astronomical phenomena, discovery of spectroscopy – physical exploration of fixed stars, spectral analysis, dynamical theory of planets, mathematical theory of planets, pondering over problems related to the first moments and future of the universe and their possible solutions, theory of relativity: the energy of mass – by multiplying mass with the square of light speed, retardation of time in a fast moving body when approaching the light speed, ray of light – curving when passing by the Sun, red shift of light travelling upwards in a gravitational field, retardation of speed of light in field of gravity, cosmology: theory of physics and astronomical observations, astronomical phenomena as examples in physics teaching
Space: spherical clusters of stars outside of our galaxy, enormous size of space; number of galactic systems hundreds of thousands, galaxies in groups or in samples, structure, problem 'infinity', astronomy, physics, mathematics and epistemology, cosmology, real dimensions of nature, cosmos ruled by geometrical regularities, systems similar to solar system, galactic system, Milky Way, background radiation in space, 'black body' radiation, Big Bang, quasars, ratio between the electrical and gravitational interactions of two elementary particle = age of world in units of the time required for the light to pass through an atomic nucleus, matter of universe, interstellar matter
Experimental research: defining time, location and direction, determination of positions of celestial bodies and calculation of coordinates, use of observation tools: astrolabe, metallic protractors, guidebooks, maps with Meridians and parallels of latitude, clock, compass, telescope; determination of longitude by time difference of zero-meridian, calculation of astronomical quantities from observations, development of calculation methods, transformation of co-ordinates, spectral analysis: angular velocity of rotation of a planet, physical exploration of fixed stars; planets: physical properties, determination of size by goniometry, explorations with probe; observation of sky and measurements, explorations of eclipses, astronomical catalogues: fixed stars, comets, clusters, galaxies; parallax method for determining the revolution of the Earth and the distance of star, universe: matter, structure, grouping of stars, laws of motion, deep-sky objects, cosmology, extraordinary findings: nova, Cepheid-type of variable star, pulsar, neutron star, black hole; distance of a star: parallax method, period of variation of intensity, spectrum; theory of relativity in test: phenomena in solar system, double pulsars, search for a theory of gravity, atmospheric phenomena, events in magnetosphere, exploration of the Moon and the Sun.
Mental image: solar system - a little particle in great galactic system, huge space, hundreds of thousands of galactic systems, pondering over problems related to the first moments and future of the universe and their possible solutions, problem of space and time, observations of sky, real dimensions of space, conception of the solar system and the whole universe.

4.4.5 Subjects relevant to selection of methods of teaching astronomy (m)

Teaching situation
Astronomy interests pupils and feeds their imagination. The most important thing is, however, its position in science teaching. It is a key and base for other sciences. A teacher interested in it feels comfortable to teach it and will find ways to realize this desire despite of external limitations. On the other hand, an uninterested teacher may kill pupils' enthusiasm. The best situations for teaching astronomy are created by observing and exploring real phenomena in natural environments. It is very fruitful to make observations together and to discuss them at the same time. This will even teach how to make science.

The teacher has an important role – he knows how to lead the course of discussion in the right direction, giving at the same time space for pupils' own adventures within their worldviews. The teacher can correct misconceptions, give new information, search together with pupils for solutions of the secrets of the universe facing also questions which remain unsolved. It is important to emphasize to the pupils the significance of astronomy in the midst of modern technology. Support can be found in applications of various fields of economic life and science. For example, learning constellations and stars and the use of planetarium belongs necessarily to teaching of stellar navigation. In teaching of physics and mathematics astronomical phenomena and objects are used as targets for application. Different theories, such as the theory of relativity and theory of atmospheric physics, are tested with the aid of phenomena on the Earth and in the solar system. Stars are the most important research objects of astronomy, although its research field covers the whole universe with all its structures.

Teaching tools
The pupils' own eyes are the most important observation tools. The pupils can look at the dark starry sky and sense that world of phenomena around them with all their being. Telescopes and binoculars make it possible to look deeper in space and to see more objects. Photographing the stellar sky, either straight with a camera or through a telescope, is an exciting action with pupils. If stars cannot be observed, for example, because of the strong light pollution so common nowadays, the stellar sky can be studied in the classroom with photographs and slides. Books and scientific journals are a versatile source of information in teaching, the public media of communication as television and Internet likewise. An astronomical observatory is an excellent place to visit with pupils. There they can see how scientific research is done in its natural environment with appropriate equipment.

Philosophy
Familiarisation with the worldviews and ways of thought of different historical eras is essential in scientific studies, besides getting acquainted with scientific achievements and the underlying historical events and evidence. In ancient times the natural philosophers explained the world in the midst of myths and religions and contributed to the birth of the scientific worldview. Also, pondering over the origin and future of the world, debate on mental images evoked by philosophical ideas presented, as well as clarification of problems associated with the reliability of observations, have also always belonged to the subjects of public discussions in the society.

An active learner
Astronomy is an extraordinary science because its most important objects, the stars and the universe, are so concrete, seen by every pupil just in front. Observation in natural surroundings may inspire pupils to make their own explorations. Experimental studies and measurements activate pupils to research. At the same time such actions will familiarize the pupils with the scientific method. Research of astronomical phenomena and events helps pupils in construction of their own world picture. Also, good examples for physics teaching can be found there.

Path of science
All scientific research has to start from observations of phenomena, and to proceed from them towards the theory. Astronomical observation has been, throughout the history, a part of people’s daily life, because the research object, the surrounding space, is always present and visible for everyone. With the development of observation tools, different kinds of measurements and documentation of their results has increased beside observations.

New astronomical discoveries and the measuring data have aroused discussions in different quarters of the society. The discussions may have resulted either in commonly accepted interpretations or in conflicts. Both have been necessary in the development of science.

Scientific research has been strongly dependent on the equipment available. Observation by naked eye has been complemented by a photographic plate, on which any specific areas of stellar sky can be recorded for closer studies. The telescope became an irreplaceable tool for both observation and photography of the sky. Astronomers have always developed and tested new equipment for observation and measurement, although at the end of the Middle Ages they mainly studied books and writings instead of doing experimental research. After discovery of the spectral analysis a more and more careful and accurate compilation and analysis of detailed astronomical data was started.

In the new age, there have been many interesting subjects of research to be noted, in addition to the traditional astronomical observations. For example, by measurement of annual parallaxes of stars the motion of the Earth round the Sun was confirmed. Since then, the parallax method has been used for determination of stellar distances. The search for comets and galaxies has continued eagerly. The discovery of the new planet Neptune aroused interest in celestial mechanics exploring motions of the solar system by Newton's theory of gravity. With the spectral analysis the chemical composition of distant objects could be determined; it has been realized that they constitute of the same elements as the Earth.

Determination of stellar distances could be extended beyond the reach of the parallax method on the basis of the relationship between the absolute luminosity of a variable star (of a certain type) and the period of variation of its luminosity. The general theory of relativity has been tested empirically both in the solar system and outside, *e.g.* by observations of the behaviour of light and double pulsars. The Earth and its atmospheric phenomena, as well as the near space with its planets and the Sun itself are naturally still permanent targets of interest. However, the stars, from the near space up to the outer limits of the known universe, remain as the principal research objects of astronomy.

4.4.6 Events influencing the development of worldview (mk)

Conceptions about the external world

The natural inquisitiveness of man and the needs of the everyday life have forced him to break out from his own familiar circle, to explore the world round him and natural phenomena.

In ancient times the world of phenomena has been seen as the real world. The Earth was situated in the middle of the spherical cosmos and the planets were orbiting it in motions composed of uniform circular motions. In the circles of astronomers and philosophers, the stellar world has been regarded as divine. People have dreamt about other inhabited worlds beyond the stars, but these dreams have been shaken off along with the prevalence of Christianity. In those days the church dictated the 'correct' worldview, where the Earth was the centre of everything. Still in the Middle Ages the Earth has been imagined to be a flat plate. Man had a central position there in the midpoint of the universe.

The ancient doctrines about the motions of the celestial objects were no more sufficient for the needs of the changed society. Astronomers have been faced with new challenges, and got to make more accurate measurements of these motions, and to give the celestial phenomena better explanations. After the col-

lapse of the old medieval human-centred conception of the world, people have felt homeless in front of the huge unknown universe. New ideas have split mankind in two. People embracing the human way of thinking have been anchored in cultural values. They consider the new scientific way of thinking inhumanly cold. Man was no more at the focus of the universe and the Earth was not an immovable centre, but the new heliocentric worldview turned conceptions of the surrounding world completely upside down. The Earth lost its special status changing into a celestial body orbiting the Sun like the other planets. The new conception of the world shook the minds of people of that time, and the event has justifiably been called ‘great revolution’. In the midst of this agitation, astronomy rose again into a significant position as the leading science. The heliocentricity evoked discussions both in public and among the astronomers. All people did not right away approve this new conception of the world. Several astronomers developed their own models of the solar system modifying the old theories, however, the geocentric worldview was soon adopted because of new observations.
Discovery of the telescope increased the number of research objects of astronomy. At the same time the dimensions of the universe grew unimaginable large. It became possible to see deeper and deeper in space. The Milky Way was recognized to be a flat galaxy with an enormous number of stars. New ideas and mental images, inspired by these new findings, have made people to ponder also over the possibility of extraterrestrial life. Scientists have continuously been looking for systems similar to our solar system. People have dreamt about other inhabited worlds around distant stars.

One of the best-known revolutions of the last century happened when the relativistic model of an expanding and contracting space was presented. According to the current conception, the general relativity represents the development of an expanding universe, starting from the Big Bang. The nuclear physics, born in the beginning of the 19^{th} century, together with Einstein’s special theory of relativity, have replaced the until-then-prevailing electromagnetic world picture. In the middle of the last century the nuclear bomb started again a new era in the history of mankind. Despite of the huge resources of energy, people were put in front of a great unknown, under the threat of fatally uncontrolled events.

On paths of science
The history of astronomy can be seen as the development history of worldview. People’s minds were occupied by different kinds of ideas about the universe together with various philosophical and theological beliefs. Man has always pondered over the secrets of the origin and future of the universe and the problem of infinity. Conflicts associated with different worldviews promoted the development of astronomy as the rational way to search for explanations and, thus, to change the world picture. The most important event, which changed conception trends, was perception of the heliocentricity. The improving quality of observational tools opened a totally new research area. People got the possibility to observe by telescope more and more faint and distant objects. Discussions between astronomers and philosophers were dealing with subjects between the scientific worldview and divinity of the stellar world, extending to ponderings over the existence of life outside the solar system. Nowadays, scientists are discussing problems like relativity of space, curvature of space, retardation of time in great speeds, existence of other universes etc.

Teaching situation
Astronomy can be taught in the natural environment. Pupils can themselves observe natural phenomena around them. They can look at the dark stellar sky and get experiences, each in ones own way. Their conceptions of the world will be changed and structured all the time along with new knowledge, ideas and conceptions. The teacher's role is significant – his task is to guide the learning process of the pupils, to inspire them, evoke questions in their minds, correct their misconceptions, to point out essential

features to be perceived in observations, and to draw pupil's attention to the evidence behind the information taught. Discussion and pondering over problems together with the pupils is a way to construct their astronomical world picture.

4.4.7 Summary

The literature for the basis of the text material was selected at first as extensively as possible. According to the criteria of selection, the literature had to concern the school system, reflect general ideas - dominantly Finnish - related to the subject, and to describe the stages of development of astronomy and worldview in a versatile way. In addition, it must be noted that the selected material should deal with real events neutrally as facts, without taking any special stand on controversial issues. As a whole, the collection of extracts gathered from the text material, based on this kind of selection, covers the subject extensively and can be understood to offer a good neutral basis for its classification.

The initial main categories of aims (a = social aims, b = individual aims, c = aims of content knowledge) were based on *the framework curriculum* (see chapter 4.1). They were formulated in co-operation with people who had contributed to the construction of this curriculum. This gives a justifiable authority for the use of this classification. The division into sub-categories (a1-a3, b1-b3, c1-c3) was based on an own interpretation of the detailed contents of aims, supported by classifications derived from current learning theories and ideas about the process structure of the development of astronomical worldview. Additional categories (s = contents, m = methods, mk = worldview), related directly to teaching of astronomy, arose from the text material itself. These bases of the classification are generally accepted and prevailing at present. Therefore only one classifier was regarded as sufficient for analysis of the text material.

Significance factors based on social aims are related to the interaction between an individual and the society.

> Astronomical knowledge and astronomers' services have been required in people's daily life in fulfilling the practical and intellectual needs, associated *e.g.* with chronology and sailing, or with pondering of the origin and end of the universe. Conception of the universe has always ruled the social life in some way. The role of astronomy in the construction of conceptions has varied greatly in the course of history. Astronomy has contributed to the development of other sciences and cultures. (a1)
>
> Astronomy has had an important role in construction of people's worldview, especially when conceptions of the world were changing and more specific astronomical information was therefore needed. The society expected development of methods of calculation and compilation of catalogues for determination of time and location and for more reliable prediction of astronomical events. (a2)
>
> The work of astronomers has been highly appreciated in society – it was them who were expected to give explanations for the phenomena of universe. Ancient astronomical skills are still required, for example, even the present sailors must know how to navigate by the stars. Astronomers have had to live in the midst of various beliefs and trends of ideas, they have taken part in social discussions and have, thus, been greatly influential persons in construction of people's worldviews. (a3)

Significance related to individual aims of education consists of factors influencing the development of personality, both intellectual and social.

Man has a desire for construction of an own picture of his environment and celestial phenomena. They give him emotional experiences and inspire him to observe them more and more closely. Common pondering of people over world explanations has also promoted the development of science and co-operation with other sciences. (b1)

Search for astronomical knowledge has aroused the need to make acquaintance with other cultures and their conceptions of the world. The basics of astronomy are important for understanding the structure of the universe and for perception of ones own position in the universe. On the other hand, observing and exploring celestial phenomena and events in nature, and discussing them together will familiarise the pupils with the principles of science and develop their facilities for social interaction. (b2)

Beside ones own conception of the world, man is bound to his own culture and its conceptions about the universe. He will also meet conflict situations when facing other conceptions. On the other hand, this will widen his views and promote his social growth through the necessary search for mutual understanding. In school, observation together with the class offers common experiences, enhances mutual solidarity and develops their social facilities. (b3)

Significance of content knowledge is based on the ways in which the contents and methods to be learnt can promote the fulfilment of the primary aims of education. As for the principal aim of education, the well-balanced development of personality, it is essential that the content of astronomical studies is structurally correct and can, thus, guide properly the construction of pupil's world picture. For this reason, the aims related to the learning processes have a significant role in this context. They may be grouped into aims associated with the scientific, the technological and the social process.

Exploration of the structure, dynamics and development of the universe, and mathematical analysis of results are main issues of the astronomical research. Astronomers were expected to produce explanations of the world and related calculatory information, as well as necessary reassessment of the conception of the universe. In addition, they have had to make predictions of celestial events, to compile related astronomical data, and to store their results for the benefit of future generations. Astronomy is the basis of science, it is important to teach it for pupils for construction of their world picture. (c1)

Interest in celestial phenomena has also promoted the development of technology, primarily that of observational tools and measuring equipment. New equipment spread to other countries and became more and more refined. Appreciation of astronomical knowledge, and its utilization in practice have opened new possibilities to develop scientific equipment with the support of society, and to employ astronomers. At times, astronomers have been under considerable pressure, but on the other hand, they have gained respect due to great discoveries. More accurate knowledge has been obtained with new sophisticated tools of high quality, and the benefit is thus greater. The influence extends also to other sciences. With the development of technology, man has got the ability to 'see' deeper and deeper in space, to travel in space and to send exploring tools there. Modern technology has made also possible, even in schools, to make acquaintance with the latest astronomical evidence, to follow celestial events in real time, and to make ones own observations. (c2)

Astronomy has been in continual interaction with other sciences – it can therefore be regarded both as a 'social' science and a science of the universe. Because of expeditions and distant travelling, astronomical knowledge spread out from one country to another broadening people's conception of the world, but leading also to conflicts due to different kinds of interpretations. Co-operation with other fields of science and culture has contributed to the development of astronomy. Astronomers have assumed ideas, knowledge and better practical means for their research work. Astronomy has always interested people,

> so also pupils. Under the guidance of a competent teacher, they may get interested in sciences with the inspiration astronomy is giving them. (c3)

The classification according to contents and methods (s, m) is directly useful in planning of astronomy teaching, which would promote the educational aims. Subjects of these categories were presented in form of a list, and no further verbal summary of them is needed. The category of the development of the worldview (mk) consists of factors closely associated with the development of personality. They form the basis for planning of astronomy teaching in chapter 10.

From the point of view of the emotional and intellectual development of personality, the interpretations presented can be summarised as five leading themes: 1. worldview, 2. observation, 3. existence of life, 4. space technology, and 5. culture. The significance factors and aims of astronomy teaching are crystallized in these themes, which will form the basis of the detailed planning of astronomy teaching in chapter 10.

IIB Mapping of conceptual structure

5 The conceptual and processual structure of astronomy

The basis for this chapter is the empirical concept formation as it occurs in physics. It will especially investigate the relation between empiry and theory, the processual structure of concept formation and the origin of the hierarchy of concepts, which are key questions in the teaching of physics. After that the same questions about the conceptual and processual structure of astronomy will be investigated. As in chapter 1, I want to emphasis also in this context that there are a lot of researches of astronomy teaching concerning the details of teaching, but not teaching as a whole. Bailey states (Bailey 2003) the research of understanding concepts, scientific concept formation and conceptual structure as for the science is lacking in astronomy.

Through the comparison mentioned before, the relation of astronomy to physics will be clarified and then a basis for methods in a structural approach to teaching astronomy can be constructed. In this way the same questions of the structure of subject analysis, the relation between empiry, theory, and application, and equal activation of the sub-processes of concept formation are met and dealt with - only the special nature of astronomy must be taken into consideration.

5.1 General aspects about the essence of physics

Laurikainen ponders the essence of physics and its position in society and in human thinking. New theories, having arisen in the beginning of the 20th century, crushed those that dominated the previous centuries thereby creating a new format of physics. At the same time the background philosophy changed. The ideological basis of modern physics is composed of quantum theory and the theory of relativity. (Laurikainen, 1967)

Among physicists there has settled a mechanical picture of the world, which can be traced back to the ancient thoughts of Demokritos. His philosophy is surprisingly close to the prevalent idea of the world from the 19th century, apart from the format of the mathematical description. This mechanical picture of the world was strengthened by advanced observation technology. Based on this a materialistic worldview philosophy sprang up. This ”scientific religion” view heavily influenced social thinkers and has accomplished much good in other areas as well. However this view gradually became an impediment for development in physics circles.

Laurikainen explains (p. 12) the principles of the mechanical description of the world:

- All physical phenomena of material objects and their parts can be reduced to the motion phenomena of their constituent atomic particles.
- Newton’s laws of mechanics control all motion phenomena including atomic motion.

So all phenomena are, according to the mechanical worldview, phenomena of motion. Newton’s equations of motion are considered to be the basic equations of all nature events and they enable an accurate prediction of the future. Thus mechanical laws control all motions in the whole universe. The basic concepts of the mechanical picture of the world in the 19th century are space, time, matter and causality. Motions of an object are controlled by causal laws, a cause-effect-relation, with Newton’s laws as a condensed representation. Physics was not released from the demand of mechanistic explanation of phenomena until the birth of the theory of relativity early in the 20th century. According to that, space and time are relative concepts, constructions of the mind, which each observer creates in a certain subjective way (Laurikainen p. 20). Changes among these concepts influence all of physics and its background philosophy, so one must consider the theory of relativity as a new theoretical basis for physics. The picture of the world in modern physics is mathematical. To emphasise this Laurikainen (p. 100) repeats the words of Galileo: The book of nature is written with mathematical words. In the history of physics one can notice several connections between the development of physics and general cultural development, for example during periods of social crises. (Laurikainen, 1967)

The Kurki-Suonios state physics is a science that carries out research on the basic laws of all natural phenomena (Kurki-Suonio, K. &. R. 1995, 1). Physics research investigates space, time, entities and phenomena, in other words all objects and phenomena and space in which they appear. Astronomy has its own sector of research. It observes celestial bodies that are a subset of all natural entities and phenomena. Physical laws concern both organic and inorganic nature. The Kurki-Suonios continue (p. 2) ”physics is the intellectual, conceptual and methodical foundation common to all science”. The structure of concept formation in physics is at the same time the general way in which the structure of empirical concept formation occurs in all natural sciences.

5.2 Empirical concept formation

5.2.1 Relation between empiry and theory

The Kurki-Suonios state (Kurki-Suonio, K. & R. 1994, p. 141) the relation between empiry and theory is the basic dilemma of modern science. Observations, measurements, experiments and experimental research projects are successive hierarchical stages of empiry. Theory, in the general sense, includes all qualitative and quantitative concepts concerning natural phenomena, especially quantities, laws and theories as well as corresponding mental images and models. Physics is considered an exact science because empirical results and theoretical concepts representing them are intended to be presented in an exact mathematical format.

The Kurki-Suonios consider the relation between empiry and theory as the basic philosophical problem of the worldview. Each scientist or schoolteacher is bound to ponder this problem in his work and to explore his own attitude towards this dichotomy. One can understand the dualism of empiry and theory in both a separating and a unifying sense. It can be considered as antithesis, where one can make a choice either to being a theorist or an experimentalist, or it can be considered as a whole with its parts being inseparable and necessary for each other.

The dualism of particles and waves can be seen as a concrete analogy. In that sense classical physics represents thinking according the separating dualism: Particles and waves are two mutually exclusive classes of natural objects. Particularly, light is wave motion and electrons are particles. In the modern physical thinking they are two interpretative models, which both in their part describe the same natural object. Both light and electrons have to be seen as ’quantum entities’ which are neither particles nor waves but which express their own nature as both particles and waves, or certain observable fundamental characteristics of these natures. Also when exploring the relation between the empiry and theory in the concept formation a ‘traditional’ conception of the separating dualism is going to be replaced with ‘modern’ unifying thinking.

Concept formation in science can be considered as empirical, because the empirical meaning is the core of all concepts. It is a process, which proceeds from observation to theory. Theory is based on observations. The concept formation is nevertheless always an interaction between theory and experiment, progressing at the same time in both directions. Understanding presupposes a perception of empirical meanings based on observations, and after that a presentation of these in a conceptual, theoretical format. But the perception is never independent of theory. It is guided and limited by the "structure of mind" which, as concept formation progresses, contains all that which has previously been understood perceptually and conceptually.

The theoretical presentation has, because of its empirical meaning, the ability to produce predictions, whose validity can be tested empirically. The perceptual concept formation then consists of two processes, presentation proceeding from phenomena to theory (inductive) and explanation from theory to phenomena (deductive), and both processes are always present at the same time.

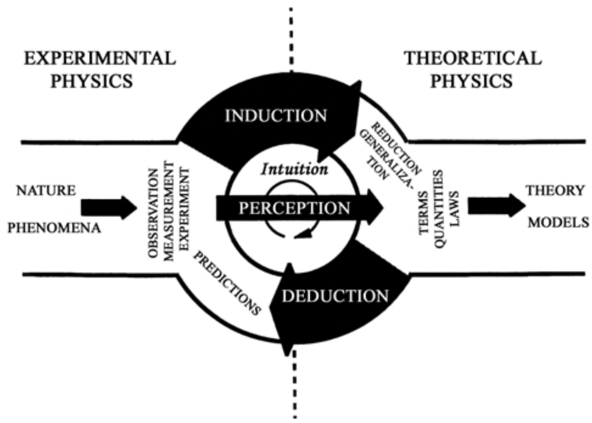


Fig. 5.1 Cycle of perceptual concept formation

The figure 5.1 describes the cycle of perceptual concept formation between the empirical world of observations and the theoretical world of concepts. This chart is convenient for the presentation of concept formation according to either separating or unifying dualism.

5.2.2 Processual structure of empirical science

Understanding and utilizing natural phenomena are the two main aims of physics research. The first one is the aim of 'pure' science, which guides 'basic research', and the second one is the aim of applied research, in practice, technology. The production and progress of science contains some rules and expectations, which are generally approved by society.

Niiniluoto claims the criteria of qualified science and the methods of science are acquired by practicing science and accepting scientific tradition. He defines science as a kind of part of the social system that produces scientific knowledge through research. By research he means the seeking of facts by means of systematic and approved scientific research methods. He links the term 'scientifically significant' to the time period and cultural heritage. Characteristics of science are objectivity, criticalness, autonomy and capability of progress. The results of objective research are independent from the opinions or feelings of the researcher. Furthermore, research must be public and reproducible. Criticalness demands the testing of a hypothesis to follow specific requirements. Science is self-rectifying and is, thus, able to modify or even totally replace the prevalent paradigm. The autonomy of science implies that scientific arguments are tested according to agreed criteria without having to bend to external pressures. Science progresses often in leaps, by great transitions, and even through scientific revolutions. Nevertheless, these periods encourage the development of science, since they demand conceptual and theoretical re-evaluation. (Niiniluoto 1984, p. 20-21)

Singer considers science as a framework for knowledge, which changes along with the periods of life. He thinks that science is an active process throughout the various stages of life. As a good example, he describes the changes with calendar systems in accordance with people's circumstances and needs. In tropical forests there are no different seasons, so the passage of time has been observed with the periods of the Moon. After moving over to agriculture man has needed the knowledge about the seeding and harvesting periods of time. Man has observed changes of seasons by observing and writing down the movements of stars and the Sun. Practicing this new occupation has required a different kind of know-how and procedures than previously. Search for and development of these skills Singer considers as stages of scientific process. (Singer 1996, p. 1-5)

In the progress of science towards its two main targets the Kurki-Suonios see two processes (Kurki-Suonio, K. & R. 1994, p. 145, see also Bressan 2004, chapter 3.2.1). The scientific process means proceeding towards understanding, and the technological process is towards benefit. They can be understood as basic elements of the interaction between nature and the human mind.

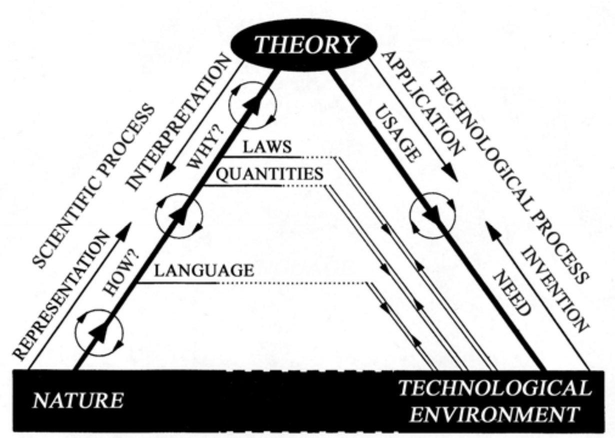


Fig. 5.2 Processes of empirical science

In figure 5.2 these processes are described as interactions between nature and theory or the environment and knowledge.

The scientific process is the core process of empirical concept formation. Its motive force is a creative, intuitive insight, which rests on the unique ability of perception in the human mind. It proceeds basically from nature (empiry) to theory (understanding). It is based on empiry, on observation of nature and on exploring it. It strives for the conceptual analysis of the environment. Its aim is understanding, knowledge about conformance with natural laws, about the causes and effects of phenomena, and about conceptual models of natural phenomena. The process has, however, in all its details, two-way dynamics, which rests on an inductive presentation, ‘how’, and on a deductive explaining, ‘why’. Presentation means “identification and a conceptualisation of empirical Gestalts”, and explaining “interpretation by theoretical models” (Kurki-Suonio, K. & R. 1994, p. 145, and Kurki-Suonio, K. & R. 1991). Understanding in physics means, in the first place, seeing phenomena or classes of phenomena as special cases of a more general class of phenomena. Unifying conceptual insights are therefore the main products of the scientific process. The process is proceeding through new, more and more general ‘how’-questions to ever more general and deeper explanations in a chain, which seems endless. This understanding of nature and environment, developing in the scientific process, is the base of the physical worldview. The scientific process, thus, changes our worldview.

The technological process influences the environment and adjusts man’s actions in it. It is steered by a question ‘what’s the use’. It proceeds from theory to nature, but also it has two-way dynamics, based on application and invention (or problem solving) run by usage and need. When the scientific process creates conceptual understanding, the technological process takes advantage of this understanding to change the environment and to develop useful products. The purpose of this process is to ease human life and generally to solve practical problems by utilizing the conceptual mastery of nature. The technological process includes all actions, which intend to change the environment in accordance with ones aims. Inventions, for example new equipments and methods, are the main products of that process. These are, at the same time, new phenomena and entities to be conceptualised in the scientific process. When the scientific process changes the worldview, the technological process changes the world.

The scientific and the technological process are inseparably intertwined. The technological process is based on conceptual knowledge created by the scientific process, on the laws of natural phenomena and on theoretical models. It works only if there is knowledge, which can be applied. On the other hand, it is necessary for the progression of the scientific process. The technological process is always present in empirical concept formation, because it is involved in all the experiments. All experimental arrangements necessary for realisation of a phenomenon to be explored as pure as possible, requires manipulation of nature, and belong therefore to the technological process.

The progress of science is, however, not a process of an individual. Knowledge is scientific only, if it is commonly understood. Thus, the scientific and the technological process are subordinated to a continual social process. *The social process* is a process of negotiation about meanings. It aims at agreement about all actions and results in the scientific and technological process. There must be a common understanding about, what has been observed in the experiments, how the results will be interpreted and conceptualised, how the experiments should be arranged, how the exploration will go on, what kind of goals are desirable, which problems will be solved and what properties should be emphasized in planning of a product. As for learning, the social process includes all those activities aimed at finding an agreement in school, like teaching discussions and collaborative planning. Language is an instrument of the social process, especially scientific language, including the terminological agreements and standards, as results of the social process.

An inseparable co-operation of the sub-processes is necessary for the progress of science. Correspondingly, fruitful, knowledgeable learning requires all three processes to be activated evenly in pupils’ minds, taking into account their bi-directional nature. (see Lavonen et al. 2004)

5.2.3 Conceptual structure of physics

Physics aspires to understanding of nature by creating concepts presenting environmental phenomena. The formation of concepts is guided by tendencies towards generality and exactness both leading to a hierarchical development of the conceptual structure.

The tendency towards generality follows straight from the aim at understanding. It has led to a unification development, where different phenomena and fields of phenomena become understood gradually as various occurrences of more and more general phenomena (Kurki-Suonio, K. & R. 1995, 3). The consequent *hierarchy of generality* has become the skeleton of the whole existent concept structure of physics. This manifests itself as chains of more and more general integrative concepts, creating an image of understanding getting gradually ever deeper along with the development. Gradual unification of static electricity, magnetism, electric current, and light, into the general class of electromagnetic phenomena, the unification of the different kinds of interactions towards a grand unified interaction, and the unification of the different forms of energy into the general concept of energy are good examples. Thus, the unification development means, in the first place, proceeding in the hierarchy of phenomena towards more general phenomena. The core concept of this development is Newton's grand insight about interaction as a general cause phenomenon in mechanics. As a consequence of this insight, unification of various kinds of interactions can be seen as the central theme of development. It is a penetrating line of physics going through both classical and modern physics, up to the forefront of the modern physics, until the search for a theory of everything. The birth of modern physics combines this line tightly with the research of the object structure of nature in its progress towards ever-deeper levels in the structural hierarchy.

The striving for exactness leads particularly to formulation of the conceptual presentation in mathematical form, or *quantification* of the qualitative concepts. The conceptual presentation of all phenomena and fields of phenomena becomes thus structured by *a quantification hierarchy*. This means particularly a division of concepts to qualitative concepts, lower in hierarchy, and to their quantitative equivalents on the higher level of mathematical representation. *The levels of quantities, laws and theories* can further be distinguished as subsequent sublevels of the level of quantitative concepts. This is evident because quantities are elements of laws and laws are elements of theories.

The quantities are quantitative representations of properties (qualities). The level of quantities can be thus named as the level of the quantitative knowledge. The Kurki-Suonios accentuate the understanding of meanings of quantities as a prerequisite for all comprehension of physics (Kurki-Suonio, K. & R. 1994, 181). All experimental results are presented in terms of quantities, and the quantities are the base elements of any physical theory. The quantities combine the experimental information with the theoretical one, the observations with the mathematical presentation. "All quantities are, at the same time, both experimental and theoretical.

Laws are mathematical models of phenomena. They can be explored and determined by systematic measurement of quantities in controlled experiments. On the basis of a law it is possible to make 'quantity predictions' concerning the phenomenon, and by testing these predictions it is possible to determine the area of validity for the law. The level of the laws is thus one of "exact presentation and systematic quantitative knowledge" (Kurki-Suonio, K. & R. 1995, p. 4).

The level of theories is the highest level of physical knowledge. It can be seen as the level of quantitative understanding and explanation of phenomena. The Kurki-Suonios continue "theory is defined by a general basic model and the basic laws, which are the 'rules of behaviour' of the basic model". Within the theories specific models of phenomena may be constructed for various known situations.

On their basis 'law predictions' concerning the phenomena can be made. “The coherent explanation of natural phenomena offered by the basic theories of physics is the basis of the modern scientific worldview” (p. 4-6).

The quantification hierarchy is presentational by nature. It proceeds from quantities, which represent single properties of entities and phenomena, to representations of their observed interdependencies in phenomena, and further to causal explanations of these interdependencies. Construction of this hierarchy is the methodical core in physical concept formation (Kurki-Suonio, K. & R. 1994, pp. 159-168). The Kurki-Suonios describe it more specifically by the following illustrative scheme (p. 159, Fig. 5.3):

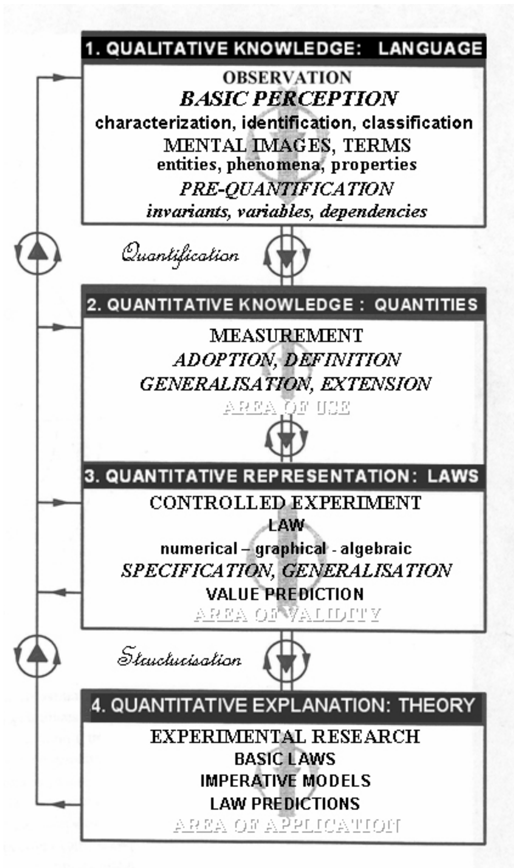


Fig. 5.3 Hierarchy of physical concepts

Concept formation begins at the qualitative level from *basic perception* of the field of phenomena to be considered. Its empiry consists of observations, monitoring and qualitative experiments, and its theory is ‘the structure of mind’ guiding perception and mental models built in the interaction of observation and mind. This is the primary stage where the qualitative basic Gestalts are formed. Entities and phenomena are identified and classified, their properties, variations in the extent or strength of the properties, and interdependencies of them are perceived, and through these a mental model of the causal relations in the field of phenomena is developed (Kurki-Suonio, K & R 1994, p. 160-168).

Conceptualisation of the basic Gestalts creates the language of physics, and makes it possible to speak about the phenomena. Names of entities, phenomena and their properties are agreed. The mental models built in the basic perception are 'the understanding of the phenomena'. On their basis it is possible to describe, how the properties of the entities and their changing in phenomena depend on the properties of the environment. The most essential are the Gestalts of invariance, change and interdependence of the properties, on the grounds of which the justification of the mental image can be tested. It is possible to identify properties changing strongly, weakly or not at all, as well as factors influencing them in different ways. This leads to the quantifying questions: How large or strong are the properties and how much do they change? How strong are the dependences of different kinds? This is why properties must be made measurable.

The measurability of properties is the central issue in the quantitative presentation of physics. How can a property (quality) be transformed into a quantity, or how can it be quantified? How can the measuring method and the unit be defined, so that the 'strength' of the property can be measured in each case it is observed, and be expressed with a numerical value and chosen unit. Each property has to be quantified separately by clarifying, how the strengths of the same property of two entities or phenomena can be compared, so that one can justifiably verify, when *e.g.* the property of one is twice as strong as that property of the other.

The quantification of a quantity is always based on experimental study of such situations, where it may justifiably be considered ‘constant’. There are two types of quantification (p. 186). For instance, length is quantified directly by comparing the lengths of two objects, by measuring the longer with the shorter one, periodic time by comparing the periods of two phenomena perceived as periodic, inertia by comparing the inertias of two bodies in an interaction (collision experiments), and the refractive index by studying refraction of light at the interface between two substances *etc.* On the other hand, velocity gets quantified when, in a motion perceived as uniform, the travelled distance is found proportional to the time elapsed, density, when the mass of an amount of material perceived as homogenous is found proportional to its volume, and respectively, the resistance of a resistor, when the voltage between its poles is found proportional to the current.

In quantifying experiments the defining law of a quantity is verified in certain basic cases. Quantities, which then need be measured, must be known, for the quantification to be possible. So *a (locally) hierarchical net* of quantities is formed. In defining a quantity, measurement of hierarchically lower quantities is required, and similarly “a defined quantity may be needed when defining some quantities higher in hierarchy (p. 182).”

The creation of the quantification hierarchy is a prerequisite for the implementation of the generalisation hierarchy. On the other hand, the generalisation development concerns, at the same time, all the levels of the quantification hierarchy. The interpretation of phenomena as special cases of a more general phenomenon means always at the same time a generalisation of quantities, laws and theories needed in representing the phenomena.

The initial definition of a quantity is always necessarily followed by a generalisation process, in which a quantity is generalised, structured and abstracted. In this process, the meaning of a quantity is gradually expanding to more and more general fields of phenomena, and becomes measurable within ever wider range of values. Each generalisation in new categories of entities, in new fields of phenomena and in larger or smaller values means an expansion of quantification complementary to the definition of quantity, which leads necessarily also to new measuring methods. Through theory all the generalisations are connected to the original basic definition of the quantity in a way, which makes possible and justifies expression of the measuring results in the initial units.

5.3 Empirical concept formation in astronomy

Astronomy as a field of science

Astronomy belongs to the exact sciences. Its objects are not only the stars, but also all celestial bodies and systems constructed from them, up to the whole universe and generally all forms of matter and energy in space. All what is said above in chapter 5.2.1 and 5.2.2 about the empirical concept formation applies to it. Astronomical knowledge has an empirical base. Its research is based on the inseparable interaction between empiry and theory. It aims at understanding its target field of phenomena in terms of conceptual knowledge. It has also practical aims, as we can clearly see from the mapping of the significance factors in chapter 4. Its progress is based on the scientific and technological processes inside the social process all of which have two-directional dynamics.

The progress in the hierarchy of natural structures, from the scale of human beings to ever-bigger structural units, can be regarded as the core of the development of astronomy. In this it relies on the progress in the hierarchy of phenomena, along with the unification development physics, and on the quantitative conceptual structure of physics. The direction of progress in the structural hierarchy can be seen as a separating factor. Physics is proceeding in the opposite direction, from the human level towards ever-smaller basic structures. It is interesting to realise, that the progress of astronomy towards the large and the progress of physics towards the small, are meeting at the extremes of these development lines, when the theories of the origin of the universe are connected with the basic research in particle physics.

Astronomical research is leading to more and more general and deeper explanations of the objects of the universe. It aims at understanding and explaining of astronomical entities, phenomena and their properties. The concept formation of astronomy is guided by the same tendencies towards generality (the generalisation hierarchy of concepts) and exactness (the presentational quantification hierarchy), as that of physics. It requires, however, its own generalisations and extensions for all the central concepts of physics.

The qualitative level

The specific astronomical point of view in concept formation is most evident *on the qualitative level*, whose concepts represent entities, phenomena and their observable properties including their interdependencies. Naturally, all concepts, which represent certain or certain kinds of celestial objects or groups of them, and the terms used to represent their motions, development and changes, belong in them, as well as fields and types of radiation in space, and the terms, which signify their properties and behaviour. *Concept formation on the qualitative level* means primarily identification and classification. We identify and name objects: the Moon, the Sun, Jupiter, the Polar Star, Arcturus, the Big Dipper, Orion, the Milky Way, the Andromeda galaxy etc. We classify them in different classes according to their observable properties, like apparent and real size, mutual positions, motions, colours and brightness. We can distinguish between a star, planet, satellite, comet, constellation, cluster of stars, galaxy etc.

With the advancement of knowledge the basis of classification develops. The position in the structural hierarchy becomes an important basis of classification of such kinds of objects as satellite, planet, double star, star, galaxy and group of galaxies. The quantitative knowledge brings up totally new bases for classification. Classification, originally based on the observable properties of stars, such as brightness and colour, becomes specified into the Hertzsprung-Russell diagram, where the classification of stars is based on the quantitative information about their mass, temperature and spectrum. It evolves further into the development scheme of stars, which divides into separate branches in accordance with the mass of the star, and offers a basis for age estimation of the stars. In this way a clear theoretical basis is gradually formed for such classifying concepts as red giant, white dwarf, brown dwarf, nova, supernova, neutron star, pulsar and black hole. This is a good example of, how concept formation in astronomy proceeds in a spiral by returning over and over again from the levels of quantities, laws and theories back to the qualitative level.

Quantities

Astronomy, like all the quantitative sciences, uses the quantity system of physics. *Concept formation on the quantitative level* follows the same kind of perception process as in physics. Also in astronomy, the concept formation progresses from concrete concepts of the lower level to more abstract concepts of the higher level. Quantitative concepts are formed be quantifying qualitative ones. When the conceptual representation proceeds to the use of quantities, the specific astronomical nature of concepts means that properties of astronomical objects are represented by physical quantities. Astronomical laws representing a phenomenon are expressed as dependencies of quantities, which vary in the phenomenon, on quantities, which affect the phenomenon, and astronomical theories are explanatory models generated from the fundamental theories of physics.

Astronomy has instigated the progression of concept formation towards the quantitative representation, by evoking the need to adopt and define some of the very first quantities of the quantity hierarchy, and by developing the first measuring methods for them.

The first quantification of *time* is based on a comparison of the periods of periodic astronomical phenomena. Especially the definition of the day, month and year as interrelated units of time is a typical primary quantification. At the same time, the need to make exact observations has required development of more accurate measurement of time and definition of smaller units.
Another central measuring problem in the early astronomy was the determination of directional differences. Astronomical measuring methods devised for this purpose have created the basis for the definition of *the angle* as a quantity. These quantifications of time and angle represent at the same time the two fundamental types of quantifications stated before. The quantification of time is based on comparison of periods of periodic phenomena, whereas the quantification of angle is based on the constancy of the proportion of the arc length to the radius of a circle, as fixed by the directional difference, and is, thus, grounded on the concept of length. Correspondingly, the determination of the extent of celestial areas, *e.g.* those covered by constellations, gives an evident starting point for the definition of *the solid angle* as a quantity.

There are not many other quantities, which would have their origin in the need to quantify properties of astronomical entities or phenomena. One example of that is, however, *the magnitude of a star*, which is originally defined by classifying stars on the grounds of their visual brightness. As the quantity system of physics develops, it gets, of course, a definition in terms of energy quantities of radiation.

Another, still continuing role of astronomy in advancing the quantity system is in *the generalisation development* it requires. It forces the extension of the range of applicability for quantities to new scales and magnitudes, generalisation of laws and theories to new entities and phenomena. For example, masses and distances of celestial bodies, the age of the Earth, stars and the universe, the temperature of a star, interstellar matter and background radiation etc. are not measurable according to the primary definitions of these quantities, but generalisations are necessary. Determination of quantities for new phenomena and new scales of magnitudes becomes possible through laws representing the dependencies of some quantities, measurable straight from the phenomenon, on the quantity to be generalized, and which are justifiably thought to be valid in the phenomenon. Often the connection of observations to quantities to been defined, such as pressure inside a star, can be concluded only indirectly, through theory. These laws and theories combine the generalisation into the primary definition, and justify it as a representation of the same property also on a more general level.

Quite generally, determination of quantities in astronomy takes place through 'in a roundabout way', by measuring some other quantities, and by deducing on the grounds of the laws and theories. On the other hand, the modern technology has produced for many purposes measuring electronics, which takes these laws straight into account so, that the reading in a measurement expresses directly the value of the quantity to be determined. The indirect determination described before is, thus, changed, at least apparently, to a direct measurement. Referring to this kind of views, the Kurki-Suonios criticise the traditional division into base quantities and derived quantities, which is, in their opinion, in school physics unnecessarily extended far beyond its ordinary context, the SI system of units (Kurki-Suonio, K. & R. 1994, 195). According to them, quantities have in this sense a different nature in different contexts and stages of conceptual development, *e.g.* in different theories.

Generalisation of *the length* from the measurements of lengths and distances on earth to those of astronomical distances is a representative example about the generalisation of a quantity, even suitable to school. It belongs also in the central basics of the construction of worldview. According to the primary definition, measurement of length is comparison of the length to be measured to *e.g.* a tape measure, whose scale is based on the definition of the metre. The determination of the radius of the Earth and the distances and sizes of the Moon and the Sun is based on measurement of angles and on geometric laws connecting the sides of a triangle with its angles. When the distance of the Sun had been determined, this method could be extended further to the determination of the distances of the near-space stars, on the basis of the annual parallax. More distant objects, with a parallax too small to be observed, require new generalisations and other methods. One can utilize the dependence of the apparent brightness of the star on distance, based on the law of energy conservation, (as simplest the $1/r^2$-law the intensity of radiation). Thus, the distance can be measured photometrically. This requires, however, existence of some type of stars, suitable for use as ‘a standard candle’, all of which have the absolute brightness known with sufficient accuracy. The discovery of such stars, the so-called Cepheids, was therefore a significant step in the construction of our worldview. More generally, when we learnt more about the laws of the development of stars, it became possible to conclude the absolute brightness of a star on the basis of its location in the HR-diagram representing these laws. So, the photometric determination of distance is no more limited to one type of stars. The distances of still more remote objects have been reached through measurements of spectral red shifts of objects, whose dependence on the receding speed of the object is known on the basis of the Doppler effect, whereas the relativistic model of expanding universe brings up a law, which tells the dependence of the receding speed on the distance of the object. Objects, whose distances can be determined with two methods, give an important calibration possibility for the new method.

Astronomical generalisations of all quantities can be considered in a corresponding way, *e.g.* extension of time to the age estimations of planets, stars, galaxies and the whole universe, or extension of mass to the determination of masses of celestial objects or, say, to the so called dark matter. Extensions of the pressure to pressures in the stars and of the interstellar matter, as well as extension of the temperature to cover temperatures of stars or of the background radiation require their own generalisations far beyond the range of the primary definitions of these quantities *etc.* So it is realised, how diversely the physical laws and theories, both those which have been determined empirically and those which have been argued theoretically, are needed as the basis of the determination of quantities in astronomy.

Laws

All regularities of properties of astronomical entities and phenomena, and all the interdependences of them belong in astronomical *laws*. As generally in science, the laws may be empirical, based on observations and measurements, or theoretically justified applications of known physical laws to astronomical objects. Let us discuss shortly three examples of different nature, which all have had a revolutionary significance in the development of our worldview. Together they give an idea about the richness of the spiral progress of the scientific concept formation, about the inseparability of empiry and theory and of astronomy and physics, as well as about the versatility of their interaction.

1. *Kepler's laws* are empirical astronomical laws, based on accurate measurements of planetary motions. On the one hand, they were the empirical starting-point for Newton's law of gravitation, on the other hand a fundamental empirical verification of the basic laws of mechanics in the history of science.

2. The HR-diagram, mentioned before, represents interdependencies between the absolute magnitude, mass, temperature and spectrum of stars. Also its starting points are purely empirical. It originates from classification of observed colours and brightness of stars, which is then replenished and specified with information on spectra, masses and temperatures of stars. When complemented with information about the ages of stars, collected gradually in the versatile interaction of observations and theory, it could be interpreted as a development scheme of stars. Thus, it has become the empirical basis, on which our present conception about the birth and development of stars is based, and therefore also an important starting point for the research of the age of galaxies and the whole universe.

3. The connection of the distance of a star to the red shift of its spectrum is originally theoretic. Its basis is the well-known Doppler effect, presenting the dependence of the observed frequency or the wavelength on the velocity of the source of the wave relative to the observer. The law is both empirically verified and theoretically justified. Especially, the theoretical explanation of Doppler effect of light connects to the theory of special relativity. The idea about the expanding universe of the general relativity, leads to the interpretation of the spectral red shift as a Doppler effect of the light emitted by receding objects, and connects it quantitatively with the determination of distances. Through this interpretation the law gives an empirical justification for our present conception about the size and age of the universe, and offers thereby an important starting point for considerations of the origin and the development of the universe.

Theories

In this context 'theories' are structural concepts of the highest level of the quantification hierarchy. Only the 'finished' great theories of physics can be understood to have this position, which requires internal consistency and a well-mastered applicability on a definite general class of phenomena. The classical mechanics, Maxwell’s electrodynamics, the thermodynamics plus the various types of quantum mechanics and of theories of relativity are theories in this sense. They are also theories of astronomy. All quantitative theoretical law predictions in astronomy are based on models consistent with these theories, adapted to astronomical objects in the way and extent, which is made possible by the necessary generalisations of quantities.

Various, more or less justified hypotheses and even qualitative models are often called theories but do not belong in this level. For example, ‘theories’ on the development of stars and the universe, like the interpretation model of the HR-diagram and 'theory' of the Big Bang, are very advanced conceptual structures. But in the sense of the quantification hierarchy they are qualitative or semi-quantitative models of the qualitative level. The perception of them is a result of a long, spiral development, which has required combination of much empirical and theoretic quantitative information.

If one of fundamental theories should be named specifically astronomical, the best candidate is the classical mechanics, based on "the concept of absolute time and on the fundamental laws of mechanics: Newton’s three laws, the addition law of forces and the laws of interactions” (Kurki-Suonio, K. & R. 1995, p. 10). As stated before in the context of Kepler’s laws, the first exact law of interaction has an astronomical origin, and with this law observations on the dynamics in the solar system became the first great test of classical mechanics and its historically crucial confirmation. Since then, the classical mechanics has been the starting point when considering motions of celestial bodies and their systems. Especially, our knowledge on the masses of planets, satellites and stars is based decisively on that.

Because Newton’s mechanics is the basis of the entire modern development of physics, it is justified to think that the roots of physics are strongly in astronomy. In its time it meant also the first big unifying step in physics, subordinating the 'superlunar' and 'sub lunar' motions under the same fundamental laws, a step, which was revolutionary in the worldview of that time.

Another theory, which bases strongly on astronomy, is *the general theory of relativity*. Although Einstein’s interests in creating it were theoretical, he was well aware of the necessity of empirical justification. And the most important predictions he proposed, like the motion of Mercury’s perihelion and the effect of gravity on light, were astronomical by nature. The historically significant observations of star positions during a solar eclipse, the gravity lenses and the black holes belong to its strong, empirical pillars.

The origins of *classical electrodynamics* and *thermodynamics* are in physics on earth, but they form the basis for the research of electromagnetic fields and properties of matter also in astronomy, and require then their own generalisations.

The origin of *the special theory of relativity* is the absoluteness of the speed of light, and the consequent relativity of the time interval between two events. Its fundamental law is the so called Lorenz-transformation, whose most significant empirically verified predictions are within atomic, nuclear and particle physics. However, the more accurate idea about the nature of time and space provided by this theory is necessary in all considerations of the astronomical worldview, just because of the dimensions of the universe.

The origin of *the quantum mechanics*, the second main theory of modern physics, is mainly in the physics on earth, in radiation physics, spectroscopy and research of the structure of matter. Even there we can find astronomical milestones, such as discovery of helium in the Sun on the basis of its spectral lines. The quantum mechanics is anyway the basis of all interpretations of astronomical spectral observations, as well as for the research of the development and energy production of stars or the origin of elements and different kinds of particles. In cosmological research of the birth of the universe astronomy and modern particle theories meet each other, the extreme small and the extreme big.

Empiry and applications

Astronomy has an own special nature because of *the large distance and big size of its research objects*. The astronomical objects are beyond reach. They cannot be explored with the same kind of methods as objects on earth in the other sciences. They cannot be subordinated on the same way to controlled experiments, by which hypotheses and theoretical predictions concerning them could be actively tested. One must satisfy with the messages carried by light and other radiations from the astronomical objects, and with what one can deduce from them on grounds of the known natural laws. The empiry of astronomy is therefore mainly *observational*. More and more exact and versatile instruments and methods have been developed for astronomical observations and research on the earth's surface. Nowadays, astronomical observations can be made also outside the Earth in the near space, using for instance planet probes or the giant-sized Hubble telescope.

Basing only on observations has even been regarded as a special characteristic of astronomy, in contradistinction to physics, which is based on experiments. However, nowadays *controlled experiments* may occur also in astronomy. The development of space technology has made it possible to explore the circumstances in the very near space and in the nearest celestial objects using physical measuring methods. Experimental research has been and will be done on manned space flights and in laboratories on orbit round the Earth. Already astronauts, on their historical moonwalks, made simple experiments and brought samples from the Moon to be explored experimentally. Probes have been sent to Venus, Mars and lately even to Titan, one of the satellites of Saturn and on paths passing close by several of the more distant planets. Probes are able to take samples of the planet soil and atmosphere, to analyse them on-site and to send the results to the Earth. Samples have been taken even of a comet.

Experiments related to the very beginning of the universe can be done by methods used in research of microcosm. Even circumstances of the birth of the universe, as assumed in the Big Bang theory, can be simulated in collision tests of heavy nuclei in the big particle accelerators (web 5.1), and theoretical predictions can, thus, bee tested experimentally.

In any case, whether merely observational or ordinary experimental research, the physical laws and theories are the basis of both the observations and interpretations of results. Astronomy and physics are in close interaction with each other, by utilizing and applying research methods and evidences of each other. Astronomy, while exploring celestial objects and phenomena, is utilizing concepts of physics, *the physical language*, quantities and their units, and laws. Astronomy with its own concepts is, on the one hand, an excellent target of application for physical theories, on the other hand, an extension field of the meanings of physical concepts. The celestial objects offer the possibility to investigate, for instance, the emission of radiation in different circumstances, the cycle of nuclear energy production in stars (atom and nuclear physics), the effects of gravity and both electrical and magnetic fields on radiation, and the radiation sent by particle beams and its polarization.

The inseparability of the scientific, technological and social process is evident also in astronomy. The needs of the empirical research in astronomy are posing a continual challenge to the technological problem solution. Telescopes, photographing equipments, photocells, devices for spectroscopy and interferometry have been constructed and developed for getting more accurate observation and measuring methods. The range of astronomical observation has been expanded in new areas of electromagnetic radiation, in microwaves, infrared, x-rays and gamma rays, as well as in different types of particle radiation. The technological progress has brought up the radio astronomy. It has made possible observation of neutrinos produced by supernova explosions and the Sun, by enormous supersensitive detectors. Specific gigantic equipment is constructed for observation of gravity waves. Observation of some types of radiation has become possible only by equipments on orbit round the Earth to get rid of the atmospheric absorption *etc*. The development of equipments has revealed new, before unknown phenomena or objects, like cosmic background radiation, pulsars and quasars.

This kind of development and research would not be even possible without large-scale international research cooperation. For such purposes, big research centres and organisations have been founded, requiring international agreements and budget decrees of national economies. Thus, the modern astronomy is no more a matter of the scientists and research communities alone, but it has become, in the full sense of the word, a part of the mankind’s common cultural efforts.

5.4 Considerations about astronomy teaching

Significance of the conceptual and processual structure

The teacher in his work comes again and again to contemplate his own conceptions and structures of knowledge, as well as the pupils' ideas about the subject handled. He has to know the empirical meanings of concepts and conceptual structures. When teaching physics, he wishes to get the pupil to perceive, how “physics understands nature by mathematics” (Kurki-Suonio, K. & R. 1994, p. 246). The aim of physics teaching, as presented by the Kurki-Suonios, to develop a worldview where larger structural entities are perceived, general laws of nature are seen in single phenomena, and the connection between the observed phenomena and their mathematical representations is understood, is perfectly convenient also in astronomy teaching.

The essential significance of astronomy in building the pupil's picture of world (*cf*. chapter 6) means that astronomy teaching must be based on the concept formation and conceptual structure of astronomy. In addition, the exceptional position of astronomy among other disciplines has to be taken into account. The closest connections are those with the other natural sciences, especially with physics.

Teaching based on the principles of empiry-grounded concept formation, as presented in chapter 5.2, the Kurki-Suonios call *perceptional approach* (Kurki-Suonio, K. & R. 1994, p. 265 and 287). Astronomy has always been an emphatically observational and observation-based science. It is, thus, obvious that principles of perceptional approach are well appropriate for astronomy teaching. For example Hubble, whose conceptions about astronomical methodology were of high repute in his time, emphasizes that the original astronomical approach has been by <u>observation and experi-</u>

ment (Crowe 1994, pp. 1-5). However, observation and theory should be, separate fields, because theories are temporary and astronomical observations and laws are permanent.

According to the principles of concept formation in the perceptional approach, two basic directions**,** those of the generalisation-unification development and the progress in the conceptual quantification hierarchy (*cf.* chapter 5.2), should be followed also in astronomy teaching. Astronomy is building mental images about objects of universe. The unification development of these mental images, which would follow the structure of concept formation in physics, becomes possible when proceeding from perception and identification of entities, phenomena and properties through quantities and laws to theories, according to the scheme of hierarchical levels (fig. 5.3). Treatment of astronomical mental images is based on the quantities of the quantity system of physics. On the other hand, astronomy contributes to the generalisation development of quantities, laws and theoretical models.

Occurrence of these principles in astronomy has been discussed in detail in chapter 5.3. A set of principles, to be taken into account in planning astronomy teaching, can be deduced from them.

The twofold hierarchy of the conceptual structure is of central significance. Concepts, higher in hierarchy, become understandable only through the way, how they are built on concepts, lower in hierarchy. The proceeding processes and the stages of concept formation offer therefore an important guide for planning. In order that teaching could lead to conceptual mastery and understanding of phenomena as aimed, it should follow the direction from below upwards in both hierarchies. *Teaching for understanding* cannot begin from theories and formulas, or from black holes and quarks. Learning begins from observations, understanding from conceptualisation of observations. In the generalisation hierarchy it proceeds from the special to the general, and in the quantification hierarchy from a concrete representation to the abstract one. The main line of the hierarchical development of science forms the core of teaching which aims at conceptual mastery. While in physics it is the unification development of phenomena, which in the modern physics leads to the progress towards the more and more elementary levels of the structural hierarchy, in astronomy it means *progress towards the large structures in the structural hierarchy*.

It has also to be realised in teaching that the development of the concept system means always, at the same time, development of language. When teaching concepts *the language of science* is taught. The Kurki-Suonios state understanding and mastery of concepts is revealed by the way, how the concepts are used in verbal presentation (Kurki-Suonio, K. & R. 1987b and 1994, p. 169). *Vice versa*, training of lingual practices in different situations enhances the understanding of meanings of concepts. A pupil describes his observations and mental images formed, at first in his own everyday language, but, along with learning, these descriptions are changing to a conceptually correct exact language (see also Luova 1994). Thus, he gets a tool, which enables him to speak about entities, phenomena, and their properties, and to tell about his conceptions to others without misinterpretations. The language, using correct, jointly agreed and understood concepts, is needed in everyday life as well as in science.

The essence of meaningful learning is in the perception of empirical meanings of concepts, which is a process of the qualitative level. On their basis concepts are understood to represent properties of natural entities and phenomena, correlations or dependences and causal relations between them. The quantification is a threshold process, which leads to the quantitative level of the conceptual structure. While it transforms properties (qualities) into quantities, dependencies become transformed into laws, which can be expressed in a mathematical form as dependencies of quantities. Also causal models will be transformed into theories, the basic laws of which are mathematical presentations of causalities of the phenomenon field (see chapter 5.2.3). In teaching it is important to realise that quantification does not create any new meanings or new understanding. It only specifies what is already understood. If the quantitative representation is introduced straightaway or too quickly, there is no opportunity for the understanding to be born. Similarly, if the attachments of the quantitative concepts to the entities and phenomena, whose properties they represent, are not kept continuously in mind, understanding becomes easily lost under the mathematical formalism. When using a quantity the "connections with the entity and phenomenon, with measurement, law, theory and models" must be kept in mind all the time. (p. 182).

The generalisation process of concepts is a key to understanding the use of physical concepts in astronomy. It is therefore an important link between physics and astronomy teaching.

Figure 5.4 condenses the main principles of concept formation into a scheme, named by the Kurki-Suonios "the ladders of understanding".

THE BASIC ELEMENTS OF UNDERSTANDING OF PHYSICS		
7. SHOULDERS OF GIANT	**1. PHENOMENA** **2. QUANTITIES** **3. LAWS** **4. THEORIES** **5. APPLICATIONS**	**6.** SPECIFICATIONS GENERALISATIONS

Fig. 5.4 The basic elements of understanding of physics

The starting point in the treatment of any subject is the progress in the quantification hierarchy, items 1 to 4, in accordance with the scientific process. Item 5 connects the technological process in the teaching. Items 6 and 7 join the treatment of the subject in the progress of the generalisation hierarchy. The use of this scheme as a basis for planning of physics teaching is described in detail by the Kurki-Suonios (Kurki-Suonio, K. & R. 1994, chapter 4.4). It is convenient also for use as a planning guide of the astronomy teaching.

The roles of experiment and theory in teaching

The experimental and theoretical approaches of teaching represent the two opposite directions of proceeding in the hierarchical scheme of levels of concepts (Fig. 5.5).

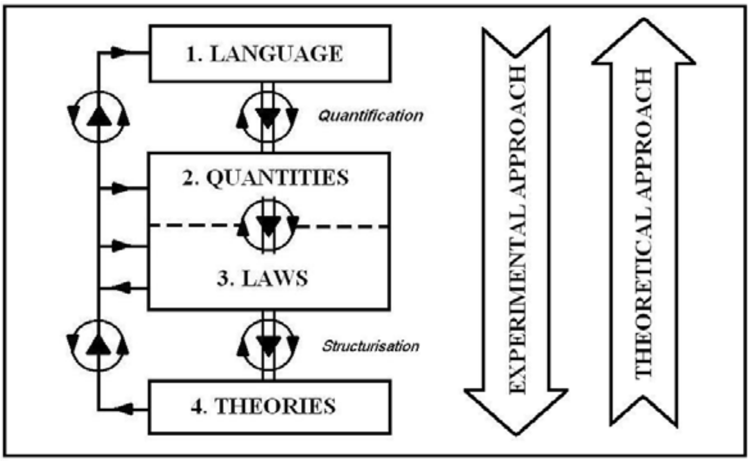


Fig. 5.5 Proceeding of teaching in the conceptual hierarchy

Teaching has to follow, also in astronomy, the natural course of progress from observations to concepts and from experiments to theory. The necessity to base the teaching on empirical meanings makes the experimental approach primary. It does, however, not mean an imperative compulsion for continuous experimental action or denial of the use of theory. It is the *empirical meanings* and use of methods, which would help perceiving them, which are essential.

The perceptional approach has two mottos: "*Meanings come first*" and "*By exploring one will find out*". The former one refers to the nature of learning and understanding as a perception process, the latter one emphasises, in the first place, the significance of empiry in teaching. The approach aims at an organized conceptual mastery of the structures and phenomena of nature, by striving first for creation of the empirical meanings of concepts. The language of speaking about natural phenomena is born and develops when meanings perceived from observations are conceptualised, and the mental images built thereby are tested by new observations and experiments. The empiry is thus the starting point and an unquestionable precondition for understanding of natural phenomena.

The purpose of experiments in teaching is that one would thereby "learn to make observations, to measure, to arrange experiments, to participate in research projects, to discuss ones observations, to analyse, conceptualise, interpret and model them both qualitatively and quantitatively, to make hypotheses, to make predictions from the models and to test them, to improve the models or even abandon them on the basis of observations…" (p. 268). Therefore, the experimental activity ought to be systematic and target-oriented action, not any meaningless 'bustle'.

Also in school, the knowledge must be based on perception of empirical meanings of concepts through observations and experiments or by their support. "Educating to personal empiry is the only way to help the pupil to create meaningful knowledge for himself, to seek this knowledge from the nature and to assess its reliability" (p. 265). The pupil perceives the meanings by himself, that is, no other person can do it for him. The teacher's role is to act as an influential person on the background, to give impulses, inspire and guide.

In school it is, of course, not possible to carry out measurements and experiments of the scientific laboratories, which require great accuracy, expensive equipments and extremely reduced ideal circumstances. The personal empiry must be restricted in selected experiments, well considered in view of the aims. The school empiry means, in the first place, an empirical approach, a uniform and consistently proceeding principle of empiry (Kurki-Suonio, K. & R. 1987a and 1988; see also OPS, Anon. 1994). This signifies that everything is approached through the empirical meanings. Mostly, this is possible only by narrated empiry. Even when the pupils are able to make experiments and observations themselves, the meanings have to be strengthened and specified by considering together, how corresponding observations and experiments have been made and are made in the laboratory circumstances of science.

A theoretical approach becomes possible only when a pupil has reached the level of theory. Once the meaning of a theory has been learnt through the empirical meanings of the quantities used and of the laws belonging in it, it has become, for the pupil, basic material of the proceeding perception, and it can be used when the theory is applied in new contexts. In this way, both the empirical and the theoretical approach have its justified position in the teaching practices, in a subject-specific or lesson-specific sense. The question is just about finding, in view of the aims of teaching, the best way to familiarise the pupils with the empirical meanings of concepts, taking into account the subject treated and the development of pupils.

Setting the highest conceptual level or the level of theory as an aim of learning is, however, a question to be considered very carefully by the teacher, taking into account both the subject area and the stage of development of the pupils. In the lower levels, like in the comprehensive school, it obviously comes seldom into question just in some rare cases, if ever. This, naturally, restricts the possibilities to use the theoretical approach.

In all the teaching, one should try to perceive integrated wholes**,** and to guide the pupils' thinking in the physical direction. "The former one emphasises the significance of the cognitive and conceptual structure of physics, the latter one underlines the method, the picture about the dynamics of knowledge creation conveyed by the teaching" (Kurki-Suonio, K. & R. 1994, 246). Learning is building in the brain a net structure of knowledge, where single pieces of knowledge are building material for perception of the entirety. Their meaning as structural elements of the whole is clarified by theory. The pupil builds his own view of the structural entirety of knowledge by himself, but using different kinds of organizers, like schemes, concept maps or verbal analyses, can enhance his meaningful learning. The Kurki-Suonios continue, "the purpose of them is to create a preliminary general view about the field or the subject to be treated, or about the way of thinking and the problems involved" (p. 248). An organizer can also be used, for clarification of the methodological and conceptual structure. Use of an organizer after a teaching period serves as a revision of the learned subject matter. Use of an internal organizer is based on the repetition effect and connects, at the same time, together different sub-fields in the pupil's worldview.

IIC Overview of pupils' astronomical worldview

6 Development in astronomical viewpoint

In this chapter I will first look at how a worldview and a person's scientific nature develops during the ego development process. Profound theories of developmental psychology are, however, avoided in this consideration. The development of individual's astronomical viewpoint will be viewed both as building one's own inner world and as a part of social interaction and a function of the community. After that I will look at the learning process and the importance of a teacher in building a scientific worldview. Also the challenges that the development of teacher's worldview brings to teacher education will be considered. These argumentations are important when planning astronomy teaching because it has to proceed according to structural hierarchy (see chapter 5) and take in account the stage of the development in pupil's astronomical worldview.

6.1 Worldview in a growing process

6.1.1 Worldview as a cyclical process

Takala has examined young people's perceptions on how their conception of the world has changed during the school years (Takala 1982a). The test group consisted of pupils in the ninth grade in the comprehensive school and in the second grade in the upper secondary school. The examiner was surprised to find out that none of the group included the perception of the ego into his worldview, but only impressions from the outside reality. Takala discovered that young people's perceptions on life consisted of areas one within the other, which were clearly expanding. The direction of the expansion is from the perceptions of the nearby environment to more and more remote environments and abstract concepts.

In a pupil's geographical worldview the basic concept is home and the family members there. Outside there are first the neighbours and the home area with its schools. Finland as a native country, and some foreign countries have their shapes in pupils' mind before the school age; even conceptions of the Earth can be detected in childhood. The concept of the universe, however, is known only in later phases at school. The impression of nature is beautiful and pure in childhood. It is only later that the child becomes aware for example of the pollution and depletion of the natural resources. In the perception of society childhood includes first the shop, the traffic and the police. Then the picture expands to consist of for instance various administrational units of society. This picture includes also the concept of native country, which to a child means various festival days and days when the flags are out. When the child grows he connects also to the concept of pride for a free country and possible threats from outside. In the perception of man the parents are very important in childhood, as well as the teacher at school. The importance of friends is recognized at quite an early age; there is more information available on them than on "the enemies". The changes in the perception of man are usually experienced very individually and the results compared to those of childhood can be just the opposite (Takala 1982a, b and c).

Rauste-von Wright views the ego-concept in the light of interpretation differences appearing in the English language. The traditional "I" in English, as a subject, means an active person, according to the scientific view of man. "I" as an object is "me" in English and it means "comprehension systems of the ego as parts of the worldview" (p. 142). An individual has a possibility to see himself in different situations “in the way the others see him”. He must examine himself and find out, what is the extent to which he can have an influence on his own life and environment. He must recognize himself as a part of an external hierarchic system, which includes the family, the school community, society, the world and even the universe. In this way an individual’s worldview is built as a cyclical process, during which the childhood general view of the world is formed to each individual’s own, harmonious or splintery construction. In aiming at the objectives he continuously tests the perception of his ego and its relation to the external world. In other words he estimates both himself and his relation to the surrounding reality and at the same time builds up a scheme of values for himself. The values formed will change from originally concrete, realistic ones to “abstract” values and they describe an individual’s perception of his ideals and goals. (Rauste-von Wright 1982)

In this study the surrounding world is presented as a set of expanding environments, among which an individual has an adventurous developing process. These environments are, maybe the family not included, very abstract concepts. The name “cyclic process” used by Rauste-von Wright implies a continuous adventure of the “I” between these expanding environments. She speaks also about the changing of the worldview, from a general perception to individual’s own construction. This development can, however, be seen as a specifying of the worldview, rather than as a constructive development.

To cope with life a person needs relevant ideas of the surrounding world and himself as a part of it (Rauste-von Wright, 1997a and b). This entirety of ideas she calls a human individual’s worldview. It includes - in addition to cognitive elements – also elements eliminated from the scientific worldview, such as motives and emotions. An individual’s ego and its relation to the surrounding reality is the emotional basis of the worldview. An interaction between a person and his social environments is reflected in an individual’s worldview. In his everyday surroundings man needs, in addition to information, also the ability to cope with the trivial realities of his culture. This worldview, based on everyday life, shapes itself and expands through the years, but the part of the scientific worldview in it will grow along with the amount of education.

The perceptions concerning the world and the ego are developed along with the activity in the building process of an individual’s worldview. Rauste-von Wright groups the influential factors into four categories. The first group consists of the biological factors which are typical of each species and are connected with the properties of an individual development. They also shape the general frame for human growth and activity. The second group consists of factors of an individual’s genetic biology, which are connected to the interaction between an individual and the environment. The third group consists of the social and the cultural factors, which direct the individual according to the normative terms and expectations of society. How the individual’s activities adjust with the norms of the environment depends on the individual’s way of seeing himself. This can be seen in two ways, which are nearly contrary to each other. The individual can experience himself as a subject who recognizes his functioning and has an influence on his environment. On the other hand he can be a helpless person who seeks guidance from outside. Doing so he seeks approval from his environment. The learning process of his worldview is splintery. The fourth group consists of the interaction between the individual and the environment. It is a learning process, which is “built up hierarchically, proceeds as time passes by and consists of many phases”. The boundaries between these four categories have lowered down during the last decades. The reason for this is the increased information on “man dealing with information”. (Rauste-von Wright, 1997)

Johan von Wright emphasizes the difference between the larger and more concise meaning of the worldview when surveying it from the cognitive psychological point of view. According to the concise theory, the worldview consists only of an individual’s perceptions on different parts of the outside (*cf.* Takala). According to the larger meaning, the worldview means “an inner representation of the world” that is built for an individual along with his development. This representation includes besides the perceptions of the outside also comprehension systems concerning the ego and connected with it (*cf.* Rauste-von Wright). As good examples of these Wright mentions values and aims. The most helpful means in an individual’s socialisation process are the everyday language through which a person categorizes and conceptualises different events and matters. The meaning of language in building a worldview is emphasized especially in philosophy; language is a way to communicate in a community and an interpreter of the social world (*cf.* Rauste-von Wright). By the means of that an individual can transmit his ego perception to the outside world. In building the individual worldview Wright sees three areas connected with each other: the aims of the activity, the cognitive construction and the means to acquire information. The last one includes besides the acquisition of concrete information also the strategies of learning and thinking. (v. Wright, J. 1982)

Aho has in her investigations concerning the impression of nature noticed that ”the nature” is often regarded as a concept not connected with man and his activities. She would rather speak of “an ecological environment”, a part of which humanity absolutely is. The basis for the impression of nature is the world that is seen, starting from the near surroundings within the reach of a child and extending up to observable space. As the child grows older the boundaries of the near environment will move further, to the fields, woods and densely populated areas. During his development process the child learns to identify the familiar things in the near surroundings with other similar things elsewhere. Aho divides these generalisations into three phases: the phase of home, the phase of home area and the phase of orientation to the world (p. 19, *cf.* Rauste-von Wright). She also emphasizes the role of an adult in the development of a child’s worldview. The child learns to do things under the guidance of an adult and adopts his models in his activities. A basis for the child’s conception of nature and thus his worldview is the knowledge of nature and information on his surroundings. Aho tells that an interesting aspect of this is the question how does the child think that nature functions (p. 26). It is important to the child’s development process that he will be given a possibility to have activities with it and learn from it. This is the way he builds in his mind his own worldview. Interaction between older people and other adults provides him with the knowledge and information on his physical and social environment. This process is an important factor in classifying information gained through observations and activity (Aho 1982).

Virrankoski has examined the development of young people’s worldview. She presents the building of the worldview both as concrete expanding circles of environment and as degrees of the growth and the quality of information. She states that the quality of information changes from detailed information to general and even more inaccurate information (general information means in this context information on a higher level in the construction hierarchy) when one moves from the near neighbourhood to far away. An individual has personal experiences and self-produced information on the near surroundings, but the information on even the next environment, some larger area, may be just on the basic level. The most indefinite – unfortunately - is human knowledge of the universe although it is based on scientific research. This may be in accordance with the average research results in a very large population, but not necessarily at an individualistic level. If a person is interested in a special topic concerning the universe his knowledge of it may be very accurate. Virrankoski also speaks of the role that processing information has when the worldview is formed. The environment and its parts are all the time interactive, so called signalling. The worldview is changing all the time due to these processes. The memory system, with the help of which information is processed, is regulating this change in the first place. Another regulative factor is a cognitive construction, which is used to interpret, organize and gain information (p. 13). Virrankoski calls the cognitive constructions schemes, which are part of the inner observation cycle (p. 15). The interaction between an individual and his environment, based on changing information, is like making a personal map of the environment. This process will produce “a cognitive map” in an individual’s mind, the circles of the local environment, a larger geographical area and the universe. In everyday life the background of acquiring information is a perception, either sensed (primary perception) or processed in the mind. There are three phases in processing information with the help of the memory system: receiving, analysing and storing information (Virrankoski 1986).

There are various phases in processing the received information (Virrankoski 1986, 16). The information is said to assimilate when it is similar to an individual’s worldview. In this case the information strengthens his previous scheme. On the other hand in accommodation the worldview is changed in two ways: it either brings a new dimension into the previous scheme or changes the previous scheme totally. If the new information is totally connected in the previous scheme, it is called an expedient learning. What is common to these phases of processing information, is their hierarchy. The significance of the scientific (perception), technological (action) and social (interaction with others) process is seen in them.

According to the research about the cosmological worldview, made by Virrankoski, the children seem their world as a chaotic place. Children think that a sensible behaviour is a sign of a good order. In children’s world there are also fights and inharmonious movements. The celestial objects such as the Sun and the Moon are like living creatures. Virrankoski sees that when children have to give up to believe in the reality of ghosts, it is learning we are talking about, not a natural development. (Brunila 1996)

6.1.2 Worldview as a person’s inner process

Nurmi tells the picture of the world has a central role in regulating action, *i.e.* in how a human being conducts his own development (Nurmi 1997, 58). A human life span means an individual’s development from childhood to old age. Evolutionary psychology emphasizes continuation in human evolution from one age phase to another. The forming of the worldview is based on neuropsychological and psycho-physiological phenomena, which create the basis for memory. Thinking and emotions are important elements in building a picture of the world. The informational side of that picture consists of thinking, concluding, perceiving and learning. The emotional side includes attitudes, conceptions of human beings as well as the ego. Both of these parts include both information on the surrounding world and feelings implying significances of different things. Nurmi states that the picture of the world is produced by culture: “our worldview will be build in the context created by certain culture, group, family, social class, society and historical time” (p. 61). In building a picture of the world a language, other communication ways and different kinds of signals act as transmitters for the information from the external world.

The development of a human means a socialisation aimed to be a member of certain culture and society (Nurmi 1997). According to this evolutionary psychological view, “the child learns various basic skills, information and conceptions either by observing, acting or by guidance of the parents” (p. 62). After childhood the school will start playing this role. According to cognitive psychology, the child himself has always had an active role in his own developing process and in building his worldview. Also the opposite aspect has gained support, in that the development is seen as “passive assumption of the ways of acting and thinking prevailing in the culture” (p. 62). Lately the emphasis is more and more on a person’s active role in guiding his own development.

Thus a person constructs his own picture of the world, according to his own inner interpretations. In this process Nurmi sees at least three principles. The first one is, that interests, desires and motives guide an individual's selections in life. With the help of these a person adds parts to his construction, deletes them and also changes them. In psychological language this means the forming of objectives and aims. The second principle is that an individual creates for himself different ways of carrying out his aims and responding to the challenges of the environment. For example, planning, problem solving and decision-making are means of this kind. If a problem emerges, that can be a sign of a lack of these means or inability to use them. The third principle is that a person has a tendency to evaluate afterwards his way of doing things. Experiences of both success and failure have an effect on the structure of the worldview and the ego (p. 64). Succeeding usually strengthens and builds them up. Failing instead may cause both positive and negative impact. It may strengthen or weaken. Due to many cultural and social factors there are, however, certain limits to how much an individual can guide his own life. An individual's worldview is thus built according to the beliefs and values of his culture, but it is the personal meanings connected with these that make it to his worldview and influence only on his own way of seeing himself. To the activities society offers – *e.g.* to various alternatives of education – every individual reacts in his own way, according to his background. Besides the ego also the self-esteem has an influence on how the chosen activity is carried out. From the evolutional point of view the result can thus be constructive or demolishing. A good self-esteem strengthens the belief in one's own influence, and adds motivation for guiding the life and thus changes the worldview. Nurmi defines three factors that have an effect on human development: an individual's worldview, the ego and one's own choices. These guide life either in a positive or a negative direction. (Nurmi 1997)

Chiodo states that an individual geographical worldview includes both knowledge about the geographical atlas and an individual perception of the Earth as a part of the universe. A person's own picture of world and knowledge about the world around will develop bit by bit along the years. Various experiences and pictures, which belong to the growing process, form a mental image about the world. A person's conception about the physical world describes *e.g.* a drawn mental image map, through which a teacher may find out pupils' understanding of concepts and relations in them, misunderstandings and inadequacies in knowledge. A teacher may use this information in improving his teaching and in understanding pupil's growing process. (Chiodo 1993, 110-117)

Teerikorpi sees a continual change in people's conception about the structure of the universe and their own position as a part of the entire world (Teerikorpi *et al.* 1988). Every person – including a pupil – has to think about a structure of the world around and oneself as a part of it. A life-long process includes also determinations of course. As examples of these Teerikorpi lists some occasions, which shocked the world in their own time: the fight between the geocentric and heliocentric worldviews, the realisation that stars are suns, or the Sun is a star, the discovering of the galaxy systems and the expanse of space.

In co-operation with the social environment, every man faces up to situations when his own perception is contradictory to the views of the environment – of close people or a large group of people. Everybody confronts this kind of conflict in his own way. The essential thing may not be which party is right and which wrong, not even the question whether there is right and wrong in this conflict. What is important is how a person deals with these kinds of things and how they affect his life in the future.

In the education process also the handling of these situations can be taught. A positive self-esteem and a strong ego help to process the problem peacefully and compare one's own perception with those of the environment. It helps if one knows how to use the methods of scientific argumentation. Relying only on emotions can lead to new misconceptions and misinterpretations. Investigation using the right methods and argumentation of results will instead lead to approval and assumption of the right conceptions. Criticism is a part of the social process but the critique must be constructive and not demolishing. It must have a positive effect on the progress of the scientific process. An advantage of a mistake can thus be significant in the educational process. It can build, change or correct an individual's worldview. In addition to that, it can teach social interaction skills, approving of dissimilarity and admitting one's undeveloped state. By doing so it can educate a person in its own, though sometimes painful way.

6.2 Adjusting oneself to scientific thinking

6.2.1 Basis of knowledge and learning

From the scientific point of view the function of learning is to "promote the survival and adjustment of an organism in its own ecology" (Rauste-von Wright, 1997, 35). Compared to other species of animals a human being has few instinctive modes of action. Man is an individual, who seeks information and wants to have feedback on his activity, as well as learns from his experiences. He receives continuously signals from his environment and himself. However, due to a short memory available he can process only a few of them at a time. Rauste-von Wright tells that man, when learning new things, "chooses information and interprets it on the basis of his perceptions, expectations and aims" (p. 36). A person constructs new information by himself when learning, and interprets it on the basis of his previous information. The interpretation of the information always happens in some situation. In addition to that perceptions of the ego, aims and values have an effect on it. These interpretations show the variety of the individual factors. Therefore men experience the world each in their own ways.

Rauste-von Wright sees two characteristics in the constructing process of a human worldview: the routine and the constantly changing view. She says that "all activities which are repeated, also the strategies of thinking and emotional reactions, will be routine in time and become self-evident" (p. 37). The same will happen to the worldview. If the circumstances are the same for a long time, the worldview does not change but is routine. Its components become "silent information" which will be accepted without questions. This routine has both advantages and disadvantages. On the one hand it releases mental resources to be used in solving new problems and to move on in constructive hierarchy. On the other hand it can also be an obstacle to learning and innovation in a constantly changing environment.

Rauste-von Wright unites learning to the action in which the information is learned and used. Both stimuli and restrictions belong to this situation. From these arise aims and also problems. She continues that an efficient learning presumes "understanding, and understanding depends always on the context" (Rauste-von Wright 1997, 38). By understanding a matter it is possible to connect it to a larger context and interpret it there. Concepts can be understood by trying to use them. That gives also an ability to use them sensibly in new situations.

A human being learns the truths and norms of both his physical and social life first in his own everyday environment. Rauste-von Wright states that the learning process is best when a person starts to ask "questions which are personally relevant and challenging" (p. 38). When a person's ego awareness develops also the self-steering skills increase. A person can consider his own understanding as well as survey his motives and endeavours, sometimes even question his own worldview. He can learn to steer his activity consciously. According to the new learning concept every learner constructs his knowledge by himself. Understanding is also the result of his own thinking. The most important task of teaching is to create such a learning environment in which the learner has "a possibility to build his own worldview within the frame of the aims set for the teaching" (p. 40).

The Kurki-Suonios, for their part, regard learning as a personal creation of information (Kurki-Suonio, K. & R. 1994, 143-144). This process starts at birth. The child starts at once to shape his environment by his senses. At the most elementary level it is receiving irritants, forming images based on sensations as well as defining one's behaviour according to them. They regard even these processes as basic elements for the experimental-theoretical natural scientific research (*cf.* p. 268). A child has all the elements of the scientific process (observing, perceiving and concluding), the elements of the technological process (experimental activity) as well as the elements of the social process (interaction with the environment) in him already at birth. Growing to assume scientific thinking means becoming aware of these elements and improving them. It is the teacher's duty to tend to emphasise them all the time, and develop them towards scientific thinking. Sense perception is followed by organized conscious learning, as a continuous evolutionary span, growing phase by phase. It proceeds from observing to learning, from there through studying to research and leads finally to science. Scientific conclusion is developing from natural thinking.

Kurki-Suonios continue that knowledge and learning have a certain biological basis and they form net-like constructions in the brain (p. 246). Therefore the extensively developed, solid and large information construction in physics is useful for learning. However, the development of structuralism needs work and work needs thinking, which for a part is experienced as a difficulty. That is a *pupil*'s own inner process. He will learn only by his own effort. The success of his learning process is thus dependent on the amount of work. Improving the quality of teaching can have an effect on the increase of working motivation. The abundance of details increases difficulties in learning, but not always. Sometimes the final shaping of the entity will happen just by adding a few missing details. The parts create a bigger, homogenous entity, which is easier to remember (p. 247).

The Kurki-Suonios regard "the gradually extending and deepening conceptual mastering of the environment and its phenomena" as genuine learning (p. 266-267). The task of teaching is to help the pupil's processes of observing and perceiving to develop. The pupil can become "possessor of information who creates his own information and uses that as a constructive part of his worldview and can, if needed, evaluate its meaning anew" (p. 267). The start for learning is the perception of sense data. The thinking of a child is built on these images. On the other hand language originates from the need to mediate these images (p. 268). In the basic perceiving on the qualitative level, perceptions are organized to creatures, phenomena and their properties. Quantification is the first process in the physical conceptualisation and it builds the quantitative concept system upon the qualitative perceiving entirety. In building a concept hierarchy a new concept is always built on the older ones. In the same way also learning is built all the time upon things learned before (p. 268).

White defines <u>understanding</u> as an ability to use information and cope with situations. This definition depends on the aims of understanding. The target can be a common topic area, concept, claim, thing, situation or a human. Understanding these and testing it vary by the target. In testing, special attention must be paid on forming the questions. (White 1988/1994, 49-50)

An ability to notice the effects of one's activities in his environment is connected with child's development (*cf.* Ahtee et al. (ed.) 1994, 67). The child learns from his experiences. The result of learning depends on how he interprets his perceptions and handles the new information. These skills of gathering, describing and interpreting are called <u>process skills</u> (Fig. 6.1, *cf.* Harlen 1988, 175-183 and Harlen (ed.) 1988). The information is collected with the help of perceptions and experiments. The gained perceptions are used to explain and the results to interpret on the basis of the previous information construction. The child needs these processing skills to be able to build his own world-view. In figure these skills have been presented as a process according to the scientific proceeding (*cf.* the meanings belonging to the scientific process in Chapter 4.4.3 as well as the scientific process in Chapter 5.2.2).

ordering observations grouping, classifying OBSERVATION interpreting observations, identifying similarities and differences	finding pattern extrapolating, interpolating drawing conclusions INTERPRETATION OF INFORMATION inferring, predicting finding relations
identifying science-related questions RAISING QUESTIONS defining testable	applying concepts HYPOTHESIZING explaining
defining operationally, identifying variables to be changed, controlled, measured DEVISING INVESTIGATIONS planning procedures for fair testing	making records, discussing, reporting COMMUNICATING using graphs, tables & other conventions

Fig. 6.1 Process skills

6.2.2 Natural direction for development

A very essential part of the child's world is the perception of the environment. The models of the environment and assuming of behavioural manners can be regarded as a way the child learns things. At the early age no essential criticism can be seen; it will develop along with age and experience of life. In this context the concept "the child‘s belief" seems to be proper. Successes and failures work up perception and general view of the environment and little by little also ones of a child himself. The guidance of an adult helps the child to examine the surrounding world and seek solutions to his questions. Examining and finding out together with the child teach him at the same time methods of scientific research "like a play". This development process is constructive in the sense that new information is connected to the existing world of concepts either as an increasing, changing or a demolishing factor. A natural direction for development proceeds from perception and curious examining through learning to more exact investigations, criticism and finally toward the way of thinking in scientific research.

Niiniluoto claims that 'scientism' can be learned in educational phases, by rehearsing to do science by oneself or by following the teachers' example (Niiniluoto 1984, 20). The pupil assumes the right scientism by approving the existing traditions. He may face many things around him, closely connected with "science", each of which makes him familiar with scientism. These are among other things the scientific community, the research process, the scientific method or the scientific knowledge.

The Kurki-Suonios speak of “the basic elements of an experimental-theoretical natural scientific research”. They say that “receiving stimuli, construction of sensations and images based on them as well as adjusting of the behaviour to this kind of a picture of the environment are the origins of an experimental, theoretical and applying research (Kurki-Suonio, K. & R. 1994, 143-144). Constructive conscious learning happens seamlessly starting from perception, proceeding through learning, studying and research to the science. As a result of the process natural thinking develops towards scientific concluding.

Ahtee tells that teaching natural science must aim at providing the pupil with such knowledge and skills as help them best to adjust to and cope with the modern information society (Ahtee 1990, p. 19-23). The pupils have to learn to evaluate information critically and even to create new information. To reach these aims the pupil must be taught both natural scientific information and natural scientific way of thinking.

The skills of collecting information, describing and interpreting belong to the procedure of the scientific process (Ahtee *et al*. (ed.) 1994, p. 66-69, *cf*. chapter 6.2.1). In natural sciences information is collected by observing and experiments. The pupils seek information by themselves on nature, examine phenomena and events as well as try to interpret them according to their own understanding. The teacher has an important role when guiding the pupils in handling and interpretation of information. Discussion with the pupils as well as asking questions and answering their questions help them to understand phenomena and research results. By using discussion the teacher can also help them learn criticism necessary in surveying natural phenomena. Trying to pose questions and finding answers to them can encourage the pupils to acquire information independently and make research of their own and so help them to grow to maturity in scientific thinking.

Observing the physical environment as an initiator or inspired with adults or friends around will inevitably cause an interaction between the ego and the surrounding world. The social environment plays an essential role in the development of worldview and learning to make scientific conclusions. It has a decisive meaning to what the result will be. The social interaction is necessary in the development of a common language. Friends’ attitudes and opinions have often a wider effect than the model and guidance a close adult gives. The negative influence of the friends can have fatal consequences. Demolishing criticism stops a proceeding of the scientific process. In this case the guidance of an adult must be interventional so that the arising misunderstandings and the negative learning can be avoided.

Aho states that the versatility and construction of a child’s view of nature depend on his growth environment and the teaching at school (Aho 1982). The child’s information on and the ways of thinking of the nature have been examined to develop the teaching. The adults at home, in kindergarten and at school have here an important role.

Aho sees the role of an adult in the development of the child’s worldview very important. If the child participates with his parents and other adults nearby in various activities, he will due to this interaction get new information and skills that he connects to his own construction. The physical environment has a different kind of an effect on the shaping of the view of nature, for instance in rural areas than in the cities. It is obvious that on the countryside the child has a close contact with the nature and building the view of nature has the basis in perceptions and activities. The view of nature of a child living in a city is more the result of teaching than having own experiences.

Environmental influences should have the same direction. Aho sees therefore important that the information on the nature received from the school and the home "builds up the same conceptual construction" (p. 31). So the teaching at school supports the knowledge about the nature received already in everyday life in spite of the fact that there are differences between the scientific and everyday concepts. The task of the school is to guide the children to notice connections between different concepts and by that help them to build a conceptualised image of the nature and the world. (Aho 1982)

6.2.3 From observing environment to research

Making the occasions towards circumstances favourable to research (*e.g.* the half Moon, the same phenomenon can be reconstructed in a classroom) makes the child grow in a very natural way to investigate things out of curiosity. If the situation is often repeated he will develop a behavioural model, which is investigative and interested in his surroundings. In older ages it will then deepen to scientific research – at least if the development span and the influence of the nature are positive.

An individual's own interests and hobbies direct the choosing of his research topic especially in the older age. Being younger the influence of the close people and the environment is the strongest, but growing older the guiding effect of one's own worldview becomes more effective along with the influence of the friends. Young people's behaviour is guided by isms current at the time, fashion phenomena and trends. In this connection it serves the purpose to emphasize two factors in growing up to scientism: an individual's own worldview and the effect the trends have on the environment. The environment's worldview – even the "ism" system approved by young people – is always a little dissimilar to that of other individuals. This is due to an individual's personal interests, abilities and likings as well as hindrances and restrictions in the opposite case. These personal motivating and preventing factors guide also the choice of research topics and willingness to do research.

The significance of an adult can be deepened also by conscious guiding in addition to being a model. Education is more than just being an idol and a guide. It is also conscious guiding to the understanding of the concepts of and the relations and interaction between the phenomena and creatures of the environment. Both the conscious and the unconscious guiding are the most important means in a child's development. Lemke uses an expression 'talking science', including considerations about language, learning and values with pupils (Lemke 1993).

Hodson sees the rehearsal time important in learning the practicalities of scientific society. The new members can learn to use the social language of the society, assume information and skills from older members as well as behavioural norms (Hodson 1998). The teacher must control pupils' experiments so that they manage to do them and notice that the phenomenon under research will happen. In constructive learning the teacher takes a responsibility for how the pupil learns, he offers his help in a suitable way but gives the pupil the possibility to solve the problem himself. Only in these circumstances is the help of the teacher educative, the critic useful and the feedback efficient. The teacher and the pupil create the learning occasion always according to the progress of the pupil. It changes as time passes as well as along with the increased experience and knowledge. The teacher guides the situation also according to the pupils' interests and ability to understand.

Hodson states that the teacher when giving a pupil lessons must take into consideration his level of development (Hodson 1998). If needed the teacher emphasises to the pupil important and points worth noticing in the material, he checks and corrects its vocabulary and new concepts. He helps pupil in doing his lessons, gives instructions as well as advises him on working methods, gives examples and gives continuous feedback to the pupil. Little by little the pupil grows to self-studying and the aiding part of the teacher decreases. The pupil uses then also other methods in acquiring information than those of the teacher. The pupil becomes initiative and he guides his working by himself. Too little or too much help may both be harmful. Tuition is then at its best when the pupils no longer need the teacher to guide them but know by themselves how to study.

The duty of the teacher is in addition to tuition and controlling the studying also to advise the pupil to investigate the problems and questions arising from the topics of the school material. He can use suitable questions and demonstrations to arouse the pupil's interest. Some provocative argument may give the pupil a spark to deny the argument or prove it right. The teacher can make the pupils acquainted with the scientific conclusion by making additional questions, counter arguments or suggestions. He should also demand that the pupil gives reasons for his opinion. If the conclusion comes to a dead end, they must revert to the earlier phases and go on with the research again. So the pupils get gradually acquainted with the scientific process and they start independently researching the interesting topics on their own.

Niiniluoto regards research as a part of a systematic pursuing of scientific information. Research methods approved by scientific society are used in this acquiring of information. So the results gained by the pupil are scientific information acquired by using scientific methods. The pupil grows through his own, guided research towards the scientism approved by scientific society and society. (Niiniluoto 1984, 25)

In science teaching Leach sees significant that the academies criticize and improve scientific information (Leach 1999). He says that the aim to teach scientific concepts is to make pupils to understand and to use scientific ideas in the same way as scientific societies do. In these societies a social scientific language has come out (see chapter 5) – a scientific way to talk and to think. It is based on the use of specific concepts. It produces development of models, which simplifies a presentation of phenomenon in nature.

Gilbert discusses with his colleagues also about the roles of the academies in explaining natural phenomena (Gilbert et al. 1998). Along with them, it is not self-evident who will ask and who will explain these things. In addition to societies, scientific problems may be explained for instance by science teachers, by curricula designers or even by pupils. Gilbert says that all these four social groups have different kinds of scientific explanations, or the same kinds of explanations, but ones of different levels. Most important is however, that they explain the world – using a commonly approved scientific social language. When bringing up to scientism it has to be highlighted also the reliability and the validity of these explanations.

Scientific research is not a simple activity guided by interest. There are many elements in it worth noting, such as the choosing of the research method, the demand of scientism, the reliability of the results and the critical evaluation. The pupils must be educated to accept the criteria of scientific research, among other things the meaningfulness of the research, the validity and the reliability of the results. Woolnough tells in his review of the science teaching about the significance of doing science when learning, emphasizing both practical and theoretic exercises (Woolnough 1991, 3-9 and 1994). In his opinion pupils should use the same methods as scientists. So they learn best a scientific method and ways of research. This contains a selection problem, caused by several practices and ways of research, but he emphasizes anyway, more important than this, processes of scientism and learning of entities.

To improve science teaching Ahtee sees, as one of the central starting points, the constructive thought, that pupils form their conceptions about things by way of their own knowledge, skills, experiences and thinking (Ahtee 1998). For getting their conceptions, based on everyday knowledge, parallel with scientific knowledge they have to take an active role in their learning. On the other hand, the aim of teaching is to adapt pupils' concepts to recent scientific knowledge and thinking – including a prevention of misconceptions. However, pupils' own incorrect conceptions are extraordinarily unchangeable and resistant to teaching.

Poole wants to start science teaching, based on the constructivism in thinking, from the level of understanding, using methods which activate pupils – like for example discussion – and to build in this way social learning environment (Poole 1995, 34-45). Wheatley writes about the same subject and realises among other things, that knowledge in the constructive view will build up, on the basis of the learner's activity, about the creatures, which are the structures of mind (Wheatley 1991). He says that the amount of knowledge depends on the learner's action and experience; to know is the same as to act and to understand in a certain way. Jones thinks that an informational growing happens when pupils try to integrate and to rationalise an everyday and 'formal' knowledge (Jones 1998). If these two knowledge areas are opposite, an informational conflict will occur. Jones claims that new ideas will not be added to the former knowledge. On the contrary, they interact with each other and change old conceptions.

Abrams says that doing science and talking about science are conditions for the teaching whose goal is an understanding (Abrams 1998). He also says that science teaching should happen in the scientific environment, where pupils study sciences through experiments in the real world. Marton, in his side, combines the world of phenomena and constructive thinking by using description for presenting the concepts (Marton 1981). The world has to be seen as a group of constructive ideas, i.e. as concepts and beliefs highlighting explanations of reality. These new concepts will be added in the existing structure. Meichtry, for his part, accentuates the significance of experimental research, when a pupil constructs his knowledge of science, and when he reflects new information in his own structure (Meichtry 1998, 231-241). The pupil may learn scientism for instance by following the working of scientists, by participating in scientific discussions, or by practicing scientific research if only through trial and error.

6.3 Teacher's role in the development of pupil's astronomical worldview

6.3.1 Expectations toward the teacher

Teacher's own knowledge

In addition to his know-how, the teacher needs in his work also pedagogical skills as well as the ability to unite these into a separated teaching strategy. Shulman (1987) calls this entity "Pedagogical content knowledge" (PCK, *cf.* Ausubel's theory of meaningful learning, see chapter 1). He states that content knowledge, methods of collecting data and historical background information belong to content knowledge. The knowledge of school system, teaching scheme, pupils, teaching methods and mastering the teaching belong to the pedagogical knowledge.

Johan von Wright ponders the teacher's role in delivering and handling information (v. Wright, J. 1996). The teacher's ability to direct both his own and the pupils' attention to relevant subjects is put to hard trial. Also the teacher constructs his own knowledge and world. He observes, interprets and criticizes them according to a scientific process. The better he has assumed the phases of this process, the better qualifications he also has to transfer them into the activities of his pupils. Wright regards teaching also as learning. During the teaching process the teacher learns both from his pupils and the processes of the class, and also for himself. Wright states that the most important task for the teacher education is to develop the teacher's preparedness for teaching.

Teachers' own knowledge in his discipline has an influence in his choices concerning the subject matter, also within the curriculum. Davis and his colleagues discuss the aims of science teaching and about the selection of the contents (Davis et al. 1993) by inquiring among other things, which contents will belong in the basic teaching in science, and who will determine them. They propose representatives of different qualifications in this work, such as a professional scientist, a science educator, a textbook author, a researcher or a curriculum coordinator. They feel that a teacher is more like a researcher when trying to follow the construction of knowledge and the understanding of concepts with pupils. In this sense, it means that, according to the constructive paradigm, the teacher is a learner by himself, as also von Wright has realized before. Mintzes agrees with a process of building constructive knowledge (Mintzes 1998a, 31-57), but in addition to that he emphasizes the quality of knowledge instead of the quantity. He thinks that a learner should, in place of remembering, look for significances of the subjects to be learned. Mintzes sees understanding as an aim of teaching, besides the pure knowledge. For achieving this, when planning the teaching, a position of both a teacher and a pupil in the classroom and a purpose of experimental work for gaining an understanding, has to be considered carefully.

Aebli ponders also problems in the formation of the contents (Aebli 1991). He asks, besides the big curricular problems, questions arising from the physical reality in the individual's environment, such as the most common concepts. He wants to know for instance, which are the concepts people have to know to understand this reality. At the same time he sees that finding a solution is a part of the teacher's work. In the selection of contents the teacher has to consider along with his own knowledge, if the things he brings up in the teaching will help a pupil to see and to observe in his environment the 'right things', which are valid for development and social action.

In addition to the content knowledge Osborne emphasizes also the know-how of the methods (Osborne 1997, p. 61-66). An effective teaching includes many different kinds of methods. Finding a proper strategy to each teaching entity and using it in a proper way requires that the teacher knows how to cope with both the content knowledge and methods. For example, a big group of pupils may observe the starry sky at the same time, but the phases of the Moon can be explored in a darkened room with "a lamp sun", as individual work or as teamwork.

Parker emphasizes yet, how important it is, especially for teachers in the primary school, to understand basic phenomena in astronomy (Parker 1998). He says that the teacher should recognize in the first place <u>the learning strategy</u>, the information about how a child is going to learn, in addition to the subject knowledge taught by him and to the understanding of astronomical events. As an example he mentions a concept the Earth and the details in it, like the birth, the position at least in the near space, and properties. The learning strategy includes a construction of these details into a part of the great structure in the universe, and in pupil's own worldview.

Keeves has the same opinion about the know-how of the content knowledge and methods (Keeves 1992). He claims that the teacher's qualification is very important when learning science – as well as all other disciplines- in schools. It is worrying that the number of especially physics teachers is diminishing; in future they assume to be even a shortage of these teachers.

Teachers' awareness of pupils' conceptions and level

The pupil and the learning environment are central in all education work. Kurki-Suonios see the teacher should improve and guide the realisation of the learning process in all his pupils (Kurki-Suonio, K. & R. 1998). They say that pedagogics highlight structures of the pupil's mind, and research how the structure of knowledge is born and develops, and how the teaching could influence it (see chapter 5.2). Fortunately, in modern teacher training this point of view has been taken in account. The pre-service teachers get in their studies not only the know-how of content knowledge, but also an ability to understand and to improve the learning process.

Rauste- von Wright reminds us about the utilisation of the teacher's alertness in the learning situation. This method presumes that a teacher has the capacity for to observe the class and then change the learning environment if needed. For getting this, the teacher should be aware of the stages in the learning process and recognise them in the pupils. (Rauste- von Wright 1997a)

Nussbaum subscribes, as also Piaget, to an interview in evaluating pupils' understanding. He sees this method as appropriate both in the teaching itself and also in the research of it. Without this, it is hard to find out for example what kind of conceptions pupils have for instance about the Earth as a celestial object and about the ego-central world. (Nussbaum 1979)

White sees understanding as a capability to use information. The teacher may test his pupils' conceptions and understanding also by problem solving exercises. At the same time he may test for use of the right concepts and remembering. White feels this testing to be so difficult, because the criteria have such varied significances. With the tests he investigates more like quality of knowledge than quantity of it. (White 1988)

Mintzes tells us that he has used a concept map, analogies and graphical organizers when testing understanding (Mintzes 1998b). He emphasizes a meaningful learning in sciences, where also the exploitation of knowledge is taught besides the scientific knowledge (see the technological process, chapter 5.2.2).

Neal and colleagues prefer the most important aim in environmental education to be that pupils acquire responsibility to the planet Earth, appreciate its beauty and look forward to improve their environment. They underline ethical values to the environment, in which they include physical processes, an ecological interaction and the behaviour of people. (Neal et al. 1990)

Lightman compares teachers' predictions and pupils' conceptions before and after his astronomy teaching. The aim of teaching is a meaningful learning of science, which produces a sample of concepts of a higher grade for pupils to assimilate. The pure reassurance by the teacher is not strong enough to remove the misconceptions. (Lightman 1993)

As well as misconceptions, also various beliefs and mental images have to be remarked when the teacher makes observations about pupils' conceptions and about the level of understanding. The teacher himself may also have beliefs, which can improve or disprove teaching. Hashweh tells about the epistemological beliefs of science teachers. In his opinion the teachers, following the constructive paradigm, use several teaching strategies and accommodate at once in pupils' conceptual changes. Yet they see the development of knowledge in the personal level and in science as a process of conceptual change. (Hashweh 1996)

Also Pajares ponders teachers' beliefs, especially in teacher training (Pajares 1992). He thinks that a study of the pre-service teachers' beliefs may help teacher trainers to establish a curriculum and a training program considering these things. He sees it as very important to investigate beliefs, so that it could be possible to find out the changes in beliefs, including processes in them, and also a structure of mental image. If concepts and their exact significances are understood and internalised, beliefs can be predicted on the grounds of the determinations of the known belief structures. This knowledge can be utilized in exploring the structure of mental image and in forming a clear concept structure.

Ogborn with his colleagues discusses pupils' mental images, thinking that a mental image and an analogy are significant both in scientific and in everyday sense (Ogborn *et al.* 1996). By the last one they mean the popularisation of science. Mental images will carry out naturally in the right environment, so they behove to explore phenomena just there as much as possible, and not purely in the classroom. Also Solomon talks about pupils' mental images in an epistemological sense, he sees epistemology as a method to make science (Solomon 1994). In addition to this, it could be mentioned that the most talented pupils will be recognized in science by becoming familiar with scientists and their work personally. If this is not possible, also telling about the working of scientists is memorable enough to create a valuable 'subject content of epistemological thoughts in young people's minds.

Johan von Wright tells the problem of "the inner representation" of knowledge has been discussed in investigations of cognitive psychology. Along with this one could ask for "How is our knowledge of the world and ourselves organized in our memory?" (p. 8). Wright sees this question also as a pedagogical problem. In his opinion tuition cannot be effective if the teacher does not know how his pupils deal with the information they receive. The teacher should also be aware of how scientific concepts and perceptions taught correspond with the everyday life's "spontaneous" concepts and perceptions. A seemingly simple learning occasion thus includes many other components in addition to traditional ones, i.e. components concerning knowledge and skills. In Wright's opinion the teacher faces a "complex" problem: "What would be the way to 'conceptualise' construction and content of the perception of the world?" (p. 11) When evaluating the pupil's conception of himself and especially of his "conception of man" the teacher is compelled to evaluate the correspondence of his own and the pupil's conceptions of the world. Teaching can sharpen pupil's conception of man and provide his every day knowledge with "scientific basis" when the new information is integrated with it. The changes in an individual's worldview often presuppose that automated knowledge and skills are "broken down" or substituted for new knowledge and skills (v. Wright, J. 1982).

Osborne emphasizes also the importance of the teacher mastering the situation (Osborne et al, 1989, p. 82-91). The teacher should first find out what the pupils know of the matter in question and then start from this level. In addition, he should be aware of the way the pupils understand the conceptions and what is their understanding of the world around. This is when he can also correct possible misunderstandings and thus help the pupil to shape his worldview. The teacher should know his pupils in order to make plans for his teaching that are consistent with the pupils' capacities. Postlethwaite has done the research about differences between pupils' knowledge and their understanding and skills (Postlethwaite 1993, 24-27). Differences can be found on some sections of the skills, like absorbing of information, communication, interpretation of knowledge and using tools. The teacher should take these in account in his teaching. Erätuuli mentions, concerning this subject, an awareness of the likes of the pupils to physics. It is often regarded as a difficult discipline (Erätuuli 1988). The situation may become better by renewing curricula and by teacher training courses, where the importance of the discipline, the understanding of the significances of learning contents and the use of various teaching methods are highlighted.

Pupils' views

Ahtee states that the examination of the pupils' views in developing the teaching of natural sciences produces information on what kind of difficulties the pupils have in understanding the natural scientific conceptions and explanatory models (Ahtee 1992, p. 3-4). In previous researches in the 1970's the emphases were put on finding the pupils' misconceptions and changing them by teaching. A current research is based on two trends in the natural sciences, Piaget's genetic epistemology and information theoretical surveys. In Piaget's opinion the pupils' understanding of the natural scientific conceptions is developed along with the age (time) (for more details see below). According to the information theoretical survey the pupils' conceptions are based on beliefs and assumptions. Changing these prejudices and misconceptions presupposes changing of the way of thinking, which can be considered equal to changing the Kuhn paradigms (*cf.* chapters 4.2.3. and 4.3.3.3). Part of these misconceptions has arisen from the pupils combining their knowledge without bringing the matter to a logical result (Ahtee 1991, p. 65).

Why do pupils have misconceptions? Additional questions can be asked: Why is it so difficult for pupils to understand simple astronomical concepts even if they are explained to them year after year? Why are some people better able to understand these things than the others?

Baxter says children have already, when starting school, their own presumptions and everyday observations of the spatial matters that are in conflict with scientific explanations (Baxter 1989). Also Driver (1985 and 1994) and Sutton (1992, 98-99) have similar thoughts. As an example Driver refers to a white paper sheet in noonday sunshine. Its dazzling light originates from the light of the Sun reflecting on it. Trumper, in his concern, wonders pupils' conceptions in the upper secondary school about basic concepts of astronomy (Trumper 2000). According to the questionnaire about this subject, they have great misconceptions about astronomical things. Trumper suggests discussion as one of the means, through which the pupils begin to form logical scientific conception and structure of knowledge.

Vosniadou remarks the pupils' presumptions, every day thinking and the scientific knowledge previously assumed must be taken into consideration in every stage of teaching, starting from planning of contents and methods for curriculum, and ending in acquiring of tools needed and in establishment of proper learning environment (Vosniadou 1991, 1994 and Vosniadou, Ioannides 1998). Ignoring advance information when teaching new topics, will lead, in their opinion, to a series of misconceptions. Several kinds of beliefs will occur to pupils about the surrounding world, on the grounds of their own observations and culture. Vosniadou thus ponders ways how these entrenched beliefs could be replaced by the right explanations. As one solution she suggests that pupils should be brought in such a situation and circumstances, where they have to estimate their own beliefs in the light of experimental evidences. As a second solution she would give them a clear explanation about scientific concepts, preferably by abstract models or analogies. As a third she would show them how new abstract models better describe observations they made than the former beliefs. In teaching it is important to get pupils to recognize that their beliefs about the world are not necessarily facts, but just theoretical structures, which may 'be subject to falsification'. These explanations give them a cause big enough to change their beliefs got in experiences of everyday life, and replace them with the right scientific explanation model.

Recognition of misconceptions is a challenging task for the teacher. Schmidt mentions several examples about different kinds of testing methods (Schmidt 1996). The most used of them are interview, multiple-choice questions, concept maps, writings and word-association tests. He thinks that misconceptions rise from an individual interpretation of the existing knowledge. Gunstone has used concept maps and various diagrams for investigating pupils' conceptions (Gunstone 1998). An identification process, concerning the change of opinion about the concepts, proceeds to observations made on the grounds of predictions, and finally to explanations of them. Klaassen with his colleagues has used discussion with terms of misconception in the identification process (Klaassen 1996). In this method it is obvious, that pupils have misconceptions, and in discussions a conflict with the correct physical ideas is meant to prove. In recognition of misconceptions the teacher has to take in account ordinary things to be considered in evaluation, like for instance readiness, too difficult, pupils' attitudes and schoolfellows' attitudes. Klaassen tells an illustrative example about astronomy for preventing misconceptions. In that teacher should continuously bring out the difference between the Aristotelian system and the Newtonian paradigm, compare and reflect these two paradigms, and thus create a basis for assuming the correct conception. In this example the repeated revision is therefore one of the best teaching methods. Thereupon the real know-how is a consequence of the combined processes concerning the correct learning ideas and the in-educational misconceptions.

Brown considers the using of examples as a preventing factor against misconceptions (Brown 1992). He sees that they help pupils to assume and to connect analogically physical intuitions in building a new conceptual model about the situation to be explored. Brown sets however one condition for that examples have to be understandable and believable for pupils. Especially he considers a visual model of a phenomenon to be very illustrative.

There is no simple way to prevent misconceptions. In the opinions presented above a pupil has to see an aim of research. Gil-Perez turns a sight to the teacher: what could be done in teacher training in this matter of fact (Gil-Perez 1990). One of the most important evidence about misconceptions is the better understanding of the scientific learning difficulties and the necessity of the changes in the teaching/learning processes, so that meaningful learning could happen. Also Percy is concerned about the same subject, in reference to researches made in the 1980s, along whose children and adults have strong misconceptions about basic scientific concepts, and traditional teaching has not been competent to correct them (Percy 1996). He claims further to teacher training that "those who can, teach!" Also he is afraid that good reputation of astronomy will suffer because of the wrong and distorted mental images, and pupils fall in some kind of 'fantasy world'.

Swiss psychologist Jean Piaget has especially emphasised that pupils' ability to understand is developed along with their physical growth (Piaget 1929:1988). Also human intelligence develops gradually. The pupils in the lower grades are at a concrete level and it is difficult for them to understand abstract matters. Most students in universities are at the level of "formal operations" and they are even able to think abstractly. Differences in learning are partly explained by different grades of maturity. Even the grown-ups learn more easily with the help of concrete teaching methods than with abstract ones.

Piaget states that for example understanding the phases of the Moon is difficult at least from two-dimensional diagrams. It is difficult for the pupil to imagine when seeing merely a diagram, what the Moon looks like seen from the Earth in the middle. So he reverts in his mind to the illusion that the shadow on the Moon is caused by the Earth. Piaget suggests this misconception to be corrected by starting from the pupil's aspects and using concrete models in addition to observations to illustrate the phenomenon. Using simple equipment a concrete situation of the event is arranged for the pupils in the class. A lamp in the middle of the classroom is the Sun. The head of the pupil is the Earth and a small ball in their hand is the Moon (*cf.* Hickman 1993, chapter 9.2). The pupils turn around and around in a darkened classroom just in the light of the lamp and hold the Moon at their arms' distance from themselves. They see the phases of the Moon just the way we really see them on the Earth. It is easy to show to the pupils the difference between the shadowy side of the Moon and the shadow caused by the Earth as well as the formation of the eclipses. (Piaget 1929:1988)

Piaget tells about the very common misconception for university students that concerns the understanding and explaining of the H-R Diagram (Hertzsprung-Russell). It presents the absolute luminosity of a star (brightness at a standard distance) as a function of colour. Colours represent the temperature of a star. With the help of observations and experimentations the astronomers have discovered the evolutionary paths of the stars. When evolving the brightness and the temperature of the star can change and it changes also the position of a star in the diagram. Many students think that the star is physically moving on the diagram just as if it was a spatial map. It is difficult for them to understand that the diagram presents the relation between two quantities and moving along within the diagram means changes in these quantities, i.e. the state of the star. (Piaget 1929:1988)

Examining the phenomena with the help of models helps the pupils to a better perceiving of the phenomenon. Mäkinen tells about an astronomical seminar in Tampere where they pondered on the difficulties and faults aroused in teaching astronomy. A good example of a misconception is when the pupil thinks that air is necessary for gravity to exist. This conception is strengthened when he sees the astronauts floating without gravity in the airless circumstances of a spacecraft. These kinds of misconceptions can be corrected by practical experiments, discussing with other pupils and with the help of a skilled teacher. (Mäkinen 1986)

As teacher in the classroom

Hodson refers to three different phases of a teacher's role (Hodson 1998). In the first phase the teacher acts as a model. Learning happens by observing the teacher's presentation of the theme at hand. The model can be presented both in laboratory or field circumstances and with the help of literature or media. The teacher has to act as an expert. But at the same time he can transmit to the pupils a scheme of how the scientists plan, produce, test and report scientific information. Thus the teacher shows them a model of scientific research and behaviour, i.e. teaches them processing skills (see Chapter 6.2.1). In the second phase the teacher guides in actual practice the work of the pupils and in the third phase pupils work independently. Also Sahlberg and Ahtee talk about the changed role of a teacher (Sahlberg, Ahtee 1990). According to constructivism, teacher's role has changed from the delivery of information to the guide and the consultant. The scientific information does not always transfer directly from teacher or textbook to pupil, for an active, meaningful knowledge. It is fundamental in the teaching work, to clarify pupils' preconceptions as the basis of teaching. Besides the experimental work, team learning has been emphasized and the significance of logical thinking has grown up.

Sneider presents some <u>basic ideas</u> in an astronomical learning process (Fraknoi 1995). He regards learning by asking as a very important one of these ideas. The pupils' phase of development and their ability to understand should be taken into account when explaining phenomena and events to them. Using 3-dimensional models instead of 2-dimensional ones is a more efficient way of helping the pupils to understand some phenomena. The pupils must be let to build their worldview by observing and using models as well as on the basis of their own theoretical constructions. Sneider does not want to teach his pupils just astronomy but he wants to teach them to be astronomers. They are allowed to observe the Sun, the Moon and the stars, gather observation material and manipulate it, use observation and measuring equipment as well as build models of phenomena they have noticed. He considers these experimental methods to be much more reasonable than just theoretical studies.

In physics and chemistry, pupils should be made to explain and argue their findings. Ahtee and Rikkinen give this opinion when they investigated pre-service class teachers' mental images about sciences (Ahtee, Rikkinen 1995). They say that teacher should avoid 'to teach' everything known, but he should guide pupils to discover themselves. Pupils like to make experiments, but it is hard to put them to think, to ponder possible reasons and to consider useful methods. Ahtee lists several things containing in teaching work, which should be taken in action in teaching (Ahtee 2003). At first she brings up an expertise of pupils' concepts and their development. Secondly, the teacher has to pay attention to central and significant ideas about the subject to be taught. Next, the teacher should take notice of a correct expression. Fourthly, discussions should be used in teaching. It would be important to transform the physical subject knowledge to the pedagogical content knowledge in class teacher training.

Solomon would teach, in addition to science and technology, also social skills. He subscribes also to discussion for clarifying mental images (Solomon 1993). He underlines two important things in teaching, which are a convenient learning environment and competent teachers. The former one creates in school a good atmosphere – positive impact, the latter one includes expert teaching, use of the appropriate materials and strategies, in other words a high-grade teaching in addition to forging an atmosphere. Spector with his colleagues describes an STS-course (science, technology and society) they have given. Especially scientific processes in creation of individual knowledge are taught to pupils, *e.g.* the nature of science when modelling processes used in creation of new information (Spector 1998). Pupils' learning possibilities were grown up; they learn by practical doing. It was a new experience for them, to learn 'doing science' instead of the former 'learning science'. They imitated scientists, when processing data, and presenting facts to the audience in conferences or in articles.

Sneider mentions in addition that in his school the projects have produced teaching material available to everyone. The teachers can select material for their teaching from the research reports produced by these three main projects. According to the reports the natural sciences are aimed at everyone, not just at those interested in natural sciences and mathematics. The teachers are encouraged to use in their teaching new teaching methods instead of theoretical teaching, *e.g.* surveying a phenomenon, using creativity, experimental methods and problem solving. The best methods to teach astronomy are both efficient in bringing up and entertaining. Sneider tells that teachers using new teaching methods allow their pupils to spend extra time in a laboratory examining and asking instead of learning from the books. (Fraknoi 1995)

Hodson emphasises the meaning of a teacher in teaching correct conceptions and scientific expressions. Linguistic activities improve, enlarge, enrich and work up the pupil's personal information net and give him a better understanding of it. A skilled teacher emphasizes the key points of the theme he teaches, clears up their meaning and helps the pupil to organize their ideas and bring them into relation to other aspects of the same theme. Discussion with the ss also clears up the analysing and understanding of the themes. Working in groups has also the same kind of an effect. A successful teaching presumes that teachers have a thorough expertise in their own occupation. They also have to know the historical background and development of their profession and be able to describe its meaning to the whole society. (Hodson 1998)

Kurki-Suonios state that the basic aims of teaching are procedural, not informational (Kurki-Suonio, K. & R. 1994, p. 267-269). They state that the basic elements of scientific process and thinking have their roots in natural human observation, thinking and learning. According to a perceptual approach learning process is built on the information, experiment and vision of a pupil. Every subject that is taught is based on subjects taught before and aims at subjects that will be taught later. Thus the teacher must have a clear picture of the contents of the course. The question in a perceptual approach is primarily applying the processes of the empirical science to the teaching (*cf.* chapter 5.2.). This means emphases between theory and experiments as well as science and technology. A presumption for scientific explanation and technological application is that the theory on which it is based is understood. Technological innovations can be found only if the pupils have a valid conceptual background.

The teaching starting from nature or the environment produces a basic practical problem, solving of which presumes an innovative process. Kurki-Suonios continue that teaching and problem solving in groups motivate pupils to work independently (p. 270). The meaning of all the processes used in teaching is to support the proceeding of conception formation. “The quantities are hierarchically connected with each other in an order defined by empiricism – a perceptual approach in teaching”, the Kurki-Suonios state and continue that “the problem of hierarchy is confronted at all levels of planning the teaching, in planning schemes for the courses and aims for them or in writing textbooks” (p. 274).

Teacher will not be the only one who evaluates his own teaching and learning results of his pupils. Lavonen and Meisalo realize that also policymakers and representatives of the economic life are interested in the states of both teaching and learning results in physics and in chemistry (Lavonen, Meisalo 1997 and 1998). They say that development of evaluation of teaching and learning has risen as one of the central theme in elaborating a comprehensive school. One should like to improve teaching yet to more experimental practice, in hope of the better learning results (see Anon. 1989b. Committee 1989:45). So in evaluation, there has to be taken in account an emphasis in the new area, it means there has to be evaluate also the handling of the skills in application of facts, in interpretation of research results and in experimental working (see chapter 6.2.1, the process skills). One of the central aims in evaluation is that a pupil self would learn to evaluate his own working and to develop it from the ground of self-evaluation. Teacher should then teach to his pupils, skills for self-evaluation in which belong, among other things, giving and receiving both positive and negative criticism and also a constructive discussion.

6.3.2 Challenges for teacher education

The most important aim in teacher education is to give information on pedagogy and subject know-how (*cf.* PCK, chapter 6.3.1). In present Finnish teacher education, the subject knowledge is given out in specific departments, and pedagogical knowledge in the department of teacher education. Astronomical courses are given out in the department of astronomy. Teachers study physics didactics in the department of teacher education. They are taught the methods of teaching and the confronting of pupils from the point of view of their own beliefs concerning the worldview. As a new course in the department of physics at the university of Helsinki, there has been already for some years a course of didactic astronomy. This course consists of practical teaching in workshops where the phenomena are examined either in nature or with the help of models. An educational objective for this course is to provide the students with abilities to teach the constructional worldview to the pupils, to master producing suitable subject combinations as well as teaching methods with perceptual approach and modern concept of learning.

Rauste-von Wright regards education as a condition to broaden and deepen the worldview connected with everyday activities (Rauste-von Wright 1997, 39). In her opinion, the task of education is "to broaden, deepen and question within the frame of objectives set by the society the worldview its members have learned in the interaction of everyday life". Education changes learning situations although the principle of learning itself keeps the same. Education systems in various occupations are dissimilar. For example, in natural sciences a new framework for understanding the phenomena is continuously being created, everyday conceptions are "reconstructed or substituted for scientific concepts and conceptions" (p. 39). In human sciences everyday facts have had time to grow deep roots; to give them "scientific meanings" can be a problem to the pupils, teachers and also to the researchers. Valtaoja considers also as important to expand the worldview by education. He realises that "if anything, the school teaching should be all-round educational and worldview constructive/broadening" (Valtaoja 2004, private discussion). Also Arons tells about the same things in the chapter with teacher training problems. There he emphasises three significances in school, such as comprehension of contents, methods and social interaction. He states that when pupils' knowledge and understanding grow up, they may discuss philosophical, ethical and social questions fruitfully and meaningfully. Arons tells also about difficulties in physics teaching by shifting responsibility to teacher training (Arons 1990). The future teachers should be taught to explore and to reflect on things more deeply than in textbooks, to observe pupils for getting feedback, to discuss and plan their teaching according to the stage of the constructive picture of world.

Rapid changing of the world, increasing scientific information and development of new paradigms had their effects on the education process. In times of rapid changes an individual's worldview needs more time to develop, i.e. there is not always time to process the fusion of the new information and the current information system. In this case the information can become splintered. The new information should be fused into such a wide frame as can be understood and used in a proper manner. Rauste-von Wright tells that new information technology offers efficient methods for teaching and even learning (p. 41). In her opinion, however, all the possibilities it gives do not support the reasonable construction of the individual's worldview. The objectives of learning and teaching along with the learning processes should be the starting point for information technological education.

Kipnis should like to integrate history in the physics courses in teacher training (Kipnis 1998, 177-196). He also should like to help teachers to change their teaching practices from science with facts and equations to the more human things. For achieving this, practical and inspiring exercises should be included in teacher training courses, such as investigative experiments, enlivening constructs of historical events, modelling of everyday life phenomena, team discussions and common discussions about problems. With the historical considerations, teachers will get an impression of an origin and a development of various theories, and they learn at the same time scientism and research strategies for teaching them further for their pupils. Also Saarikko recommends withdrawing from science-central learning, and emphasises, instead of it, human dimensions in physical science (Saarikko 1998, 98-105). All this requires change in students' attitudes and in the learning environment. He also says that "Physics is, as a science and as a discipline, a common for all and human activity and not any mysterious science of strange customers" (p. 102). Human dimensions are factors which influence in the development of personal worldview, and which give examples to "ideal and ethical ways of life". They are also factors which contribute to motivation in physics studies, and through which one can "adopt cultural values of mankind". When planning the teaching, the history of physics may give ideas for empiricism and for other practical activities.

In research, made on pupils in primary school and upper comprehensive school, concerning the construction of the universe, pupils' *poor knowledge* aroused astonishment (Pietilä 1996). The results are far behind those of a normal school exam. Pietilä argues that some teachers even refuse to teach astronomy because it is a science with no interest! This gives rise to a question as to where is the problem: in textbooks, teaching methods or inadequate quantity of teaching. According to the research, the problem is in teacher education. The reasons can often be found in misconceptions. The children are taught to be interested only in manual training and physical exercise. The teachers think their knowledge of astronomy is too thin so they skip to teach astronomy. The research notes that teaching astronomy should be started even in the first grade, the child is at that age curious and eager to learn from his environment. He can understand the concept of rotation, the shifting of night and day in general. Teaching the construction of the universe helps to understand that we are a part of an entity and united with nature.

There are many kinds of opinions about teacher training. Sarjala is concerned about the level of qualification in mathematics and science teaching (Sarjala 1996). He sees teacher training to be in a central point in this case. Especially he is concerned about the know-how of physics with the pre-service class teachers. A reason for that is, that their education program has not contained any specialized studies in physics or in chemistry. Seinelä, on his side, put his concern to the subject didactic applications (Seinelä 1988). If the teacher-training program produces teachers with didactic thinking, it becomes an interaction between theory and practice. This might help to teach physics with dreaded problems in attitude and in motivation. Haapasalo brings challenges to develop teacher training (Haapasalo 1993). Both Haapasalo and Seinelä state that in class teacher and subject teacher training both the knowledge and the didactical structures should be combined as a united entity with educational knowledge. The teacher should, in Haapasalo's opinion, learn to internalise the significance of different subjects from the point of view of culture and the development of the pupil. The aim is to help the pupil to form a harmonious picture of the world. In addition to that, a teacher has to learn, even in his education period, to internalise a persistent, co-operational planning of teaching.

Teachers and representatives of other social branches ponder the development of scientific education. Meisalo reflects the need of development in the education of physicists for the needs of both the industry and research (Meisalo 1991). He sees as the main aim in the Finnish schools to develop the personality of each pupil, and that aim has a direct influence on teacher training. Pomeroy emphasizes in the scientific education program, that teachers should concentrate on the structuring processes of knowledge, relative to children and their own practices (Pomeroy 1993). He compares beliefs of scientists and comprehensive schoolteachers about science. According to the evidence, the different kinds of views about science will occur because of their view of how a child will learn. After another explanation, teachers' perceptions about the nature of science may arise from their own structuring processes of teaching knowledge, about their experiences and observations.

Hodson presents practical ideas for the development of teaching, by requiring more empiricism even in the teacher-training program (Hodson & Hodson *et al.* 1998). According to his story, teachers were put in the practical course, where few reviewers were present. It was meant to create more authentic science, to pay the pre-service teachers' attention in the planning of practical activities and in the use of them in science teaching. Also Gott with his colleagues suggests that practical experiments and planning of them for teaching be taught in teacher training education (Gott et al. 1996). They see those roles as fundamental for understanding the scientific realities. At the other side, they see also some additional activities, through which the realities can be taught. They leave the final choice of the method anyway to a teacher, who makes it considering his pupils, the tools to be used and information technological equipments. Neittaanmäki emphasizes the importance of club activities in school, when learning science (Neittaanmäki 1991). He thinks that societies and schools would have to support mathematics, physics (also means astronomy, in the writer's opinion) and chemistry clubs in their actions, like they do with sports and art clubs. As one reason for the unpopularity of subject teachers' scientific education he sees the combinations of too many disciplines. He thanks anyway the modern teaching practices for the fact that it brings guiding and developmental discussion to the natural part of the action in school.

6.3.3 Reflections

In my own astronomical workshop course I have noticed that the students are eager to observe astronomical phenomena in nature and also with models in the classroom. Arranging the teaching event to be as natural as possible has proven to be good. For instance exploring the phases of the Moon in a darkened classroom, with the help of a lamp as the Sun and a Styrofoam-ball as the Moon, has been a very practical and instructive method. Only one phase of the Moon can be seen at one time in nature. All the phases, any moment of the day and night as well as all kinds of positions can be explored in school class circumstances at the same learning situation. The most important benefits of the workshops are the perceiving of subject entities, the flexible formation of current themes according to the students' level of understanding as well as continuous use of such learning environment (*cf.* Bennett 1999), which emphasises activity and learning by doing.

Part III Planning of astronomy teaching

III A Preconditions

7 Mapping of present situation in astronomy teaching in the comprehensive school

In this qualitative assessment of the present situation within the sample group, abilities and qualifications of teachers and schools for astronomy teaching are examined, as well as the role of astronomy in curricula and in some textbooks that are in use (*cf.* Fullan 1991). The situation of the teachers and schools is studied by making a questionnaire and a set of interviews. The sampling of the schools was carried out so that in the register of the National Board of Education, the first school was selected by random and after that, the rest of the schools were selected by regular intervals. The sample covers, in regional, linguistic and educational aspect, equally the whole guild. The idea was to get 100 schools from both school levels into the inquiry. As a result, approximately every sixth school was taken into the inquiry (there were about 1300 comprehensive schools at that time). The number of the schools (200) is appropriate (*cf.* OECD PISA programme, 156 Finnish schools (but thousands of pupils as respondents) were involved in the programme in 2000, web 7.1; see also IEA, web 7.2)

Part I of the questionnaire (App.7.1, part II is in Appendix 7.2) includes 40 questions related both to teachers and schools. The questions are grouped to five subject entities: background information, teaching, learning materials, tools and education. The themes arose in the authentic school practices every school has to face in its daily activities (*cf.* chapter 2). The groups include open and multiple-choice questions. For some questions it is possible to have more than one choice as an answer. For instance for choices of teaching methods, I have included such common methods, which are used in the teacher training (INSET) courses (*cf.* FINISTE, Sahlberg 1990; see also Joyce et al. 1996; Monk et al. 2000 and Woolnough 1994) and in articles *e.g.* in the Finnish teacher journal of Dimensio. I did not define these concepts, on purpose; the respondents have their own perception on them. It is the same case with questions concerning of teaching tools, materials and classroom activities. In these multiple-choice questions I have included a choice “other” for the special cases. This kind of question formation does not influence in the collection of results, because the idea is not to make deeper statistical analyses, rather the results will be mostly searched for frequencies of the different choices. For the sake of readability and clarity the most interesting results from the point of view of this study are presented in tables or figures. All percentages (except the one of the first question) have been calculated from the total number of valid answers (94). The total percentages less than one hundred are the result of questions incompletely filled.

7.1 What is the situation of astronomy teaching in schools?

7.1.1 Background information of the respondents

A good representation of the structure of the group of respondents can be seen in the answers related to age, gender and school level. In the other background of the respondents, what is most noteworthy are the issues related to the teacher’s qualification and astronomical studies. This information is not only interesting but also beneficial in estimating the reliability of the inquiry. The name of the school is asked only for the sake of registering incoming answers and sending the possible reminder letter. The respondents were asked to give their name and contact information if they were willing to be interviewed.

Altogether 102 answers were received (52%), of which 94 were valid. In the ‘invalid answers’ were different kinds of reasons for not answering, such as: the language (questions were supposed to be in Swedish), wrong school degree (questions were regarded incompatible for the lower degree), the attitude of the commune towards the inquiries in recently founded schools (no teaching experience in the school as yet), or because the school does not exist anymore.

Fortunately, ‘the obstacles’ mentioned before were only single cases. Generally the respondents were very flexible in regards to the inquiry, even if at some point the questions were not exactly applicable to them. The teachers of Swedish speaking schools answered either in Finnish or Swedish. In creating the contents and answer options, the expressions applicable for both school levels were taken into account. Each teacher was able to answer the inquiries privately, even if the commune denied the official licences for research. The real time data of schools had not always been updated to the registers of the administrative officials; therefore one of the sampled schools had been closed. Additionally there were a couple of respondents appealing purely to feelings.

Personal image (questions 1-3)

Out of 97 schools in total, there were 32 valid answers from the lower level of the comprehensive schools, and much more from the upper level, with 62 out of a total of 100. Thus, answering percentages are by school degrees of 33 and 62. From both school degrees there were four invalid answers. Two-thirds of the comprehensive schoolteachers in the upper level answered to the inquiry, compared to only one-third in the lower level. Reasons for this can be both in the teachers’ education and in the learning contents of the natural sciences. Astronomy is associated as belonging mostly to the teaching of physics and also geography in the upper level of the comprehensive school than in the teaching of environmental and natural sciences in the lower level. Fortunately, a teacher’s personal interest and activity compensate these understandings.

Respondents were asked to give their contact information in case they would like to be interviewed later. This contact information was found from seven answers. In five answers the name of the school was missing. This caused some difficulty, as the reminder letter may have been sent to the schools that already had responded. A very positive sign in the prejudiced researcher’s opinion was that there were almost as many male as female respondents. In my experience, the male respondents would be much less active to answer to inquiries, but in this case the situation was quite different. There were 51% female and 48% male respondents, altogether 99%. The missing one per cent is because all respondents did not answer at all to the question about gender.

In asking the age of the respondents, the aim was to map the attitude and capabilities of the teachers of different age groups for teaching astronomy. The respondents’ ages could be applied in many ways, but their importance for this study is marginal. The subjectivity of the applications reduces their reliability. Instead, it is interesting to compare the age distribution of this study to the official distribution in the statistics made by The Finnish Association of Teachers of Mathematics, Physics, Chemistry and Informatics MAOL ry (web 4.4). Age groups have been created with ten-year intervals, except the last group, to which all belong to more than 50-year-old respondents. In table 7.1 all respondents have been grouped to the age groups and also by school degrees.

Table 7.1. Respondents' age distribution in numbers

	20-29 years No.	**30-39 years No.**	**40-49 years No.**	**> 50 years No.**
Lower level (32)	2	5	16	9
Upper level (62)	3	12	29	18
TOTAL (94)	5	17	45	27

In the table, it can be seen that most of the answers are from older teachers. Most active in this group are the respondents in their early Middle age. This phenomenon might not be generalised. MAOL's statistics show that the majority of the teachers in the mathematical-scientific disciplines are between 43 and 58 of age. Instead, three-quarters of the respondents are over 40 years old, which can be found as a significant trend. Possible reasons can be numerous. Older teachers have more experience on different teaching methods, courses and curricula, so they have more to say in their answers to the questions of the inquiry. From this perspective, they may be more willing to respond than the 'inexperienced' young teachers. Also, the teachers' social relationships may contribute to who has to or may respond.

Job description (4-7)

With the help of the questions, the idea was to map the teachers' employment situation, educational background as well as main or special subject choice. The aim was to ensure the reliability of the given answers with comments based on practical experience. Also seen in the answers can be aspects related to teacher education.

A majority, *i.e.* 83% of the respondents are full-time teachers with permanent office, and 9% are part-time teachers. Nearly all respondents of the lower level of the comprehensive schoolteachers are permanent (94%). In the lower level there were no substitutes or part-time teachers. On the other hand, these kinds of positions are quite rare in the lower level. In the upper level of the comprehensive school a clear majority of teachers (77%) are permanent, whereas 13% are part-time. These percentages tell a bit of the teachers' placement into different offices (4); there is no need for a more specific definition here. Choosing of respondents can also have an impact in this distribution.

Teaching experience (5) increases with age, so the distribution describing experience goes quite well, hand in hand, with a form of the age distribution. Two-thirds of the respondents have been teachers for more than 16 years. Only 9% of the respondents have been teachers for less than six years. This distribution is good from the point of view of this research, because the more experienced teachers 'have had time' to try many kinds of teaching, and they also have formed their own practices in their every day job. This also increases the reliability of the results. However, many young and starting teachers have new ideas and desires to experiment. They want to test their ideas immediately into practice. Yet at the time of the inquiry being sent, MAOL's statistics show that in many schools there truly do not exist young teachers of mathematical subjects.

With the question related to the teachers' competence (6), the idea was to test the teachers' placement into offices. The question also includes an educational aspect, meaning graduation and placement into a job matching the education. Results should be equivalent with the results to the question number four. 95% of the respondents inform they are qualified for their office. 3% convey being unqualified. The percentages related to qualification are just about on the same level inside the two school levels. Approximately 97% of respondents of the lower level of the comprehensive school are qualified and around 94% in the upper level. All unqualified teachers are in the upper level. According to question number four, 83% of the respondents have a permanent office. Thus, only a small part of the qualified teachers that responded at the time of the inquiry have a temporary office or work part-time or as substitute. This is a good issue from the point of view of the schools. Of course, the best situation would be if all qualified teachers had a permanent office, matching their education.

The main subject (7) of studies was asked mostly from the teachers of the upper level of the comprehensive school. The teachers of the lower level told their specialization subject in this question. Answering options include as separate mathematics, physics, chemistry, biology and geography. 52% (62) of the upper level teachers told that mathematics is their main subject, 23% physics, 13% chemistry and 2% biology and geography. There are many interesting points in this distribution. At first, the number of 'mathematicians' compared to 'physicians' is more than double. Secondly, a majority (88%) of the respondents represent 'mathematical' subjects, whereas only 4% biology-geography. This is quite surprising because according to the preliminary estimates the geography teachers were expected to answer to the inquiry more actively. Astronomy is taught currently in the geography courses, but luckily it is still taught more in the learning contents of physics. The option "Other" 5% included the answers where more than one main subject had been mentioned as equal.

Astronomy studies (8-11)

With these questions the idea was to know the extent of studies, studying practices and possible further education. The aim of the questions is to get references to the recommendations of teacher training as well as the contents and methods of the further education. Some of the questions are optional, in which the respondent could select multiple choices. In these cases new variables are needed in order to handle the results statistically.

In the results of the question related to astronomy studies (8), it is interesting to see the different answering options presented as independent in the answers. Thus, in addition to the distribution of the new variables, frequencies of each form of study have also been presented in a table. The frequencies describe how different forms of study are represented in the sample group. The astronomy studies have been broken down into university studies (basic-, subject- and specialisation studies), separate courses and self-studies/interests. The last option was for a situation where the respondent had not taken astronomy courses at all. What is meant here by university studies is taking grades in the university. Other grades are mentioned in "separate courses". Many that have taken grades in the university have also taken additional or self-study courses.

In table 7.2, the astronomy studies have been presented grouped into three: university studies, courses/self-studies and no studies at all. Respondents have been divided into different answer groups according to the highest level of their studies.

Table 7.2. Respondents' astronomy studies

	University studies %	Courses, self-studies %	No studies %
Lower level (32)	1	17	16
Upper level (62)	14	31	20
TOTAL (94)	11	27	18

Less than half of the respondents had taken courses or self-studied astronomy. The upper level of the comprehensive schoolteachers had taken significantly more university studies than the lower level of the comprehensive schoolteachers. In addition to the different contents of studies, a reason for this can also be the different structure of education. The majority of respondents are more than 40 years old. Therefore, they have not participated in the current teacher education, whereby class teacher education is a part of the university education. Earlier class teacher education was arranged in its own educational establishments separate from the universities. While 18% of the respondents of the lower level of the comprehensive school have studied some astronomy, the same percentage in the upper level is 45%. It was positive to notice, at least to some extent, that so many of the respondents have studied astronomy. This clearly shows an interest towards the subject.

The upper level schoolteachers had also taken more self-study and separate courses. This is probably due to the fact that in the upper level, the astronomy has had its own position in teaching physics and later also geography, whereas in the lower level subject, astronomy is handled quite briefly within environmental and natural sciences studies. In addition, astronomy has been available as an optional course in the upper level for many years, which has promoted teachers' independent astronomy studies.

In the next table 7.3, the frequencies of each form of studies have been calculated.

Table 7.3. Forms of respondents' astronomy studies

Astronomy studies	Frequency %
Advanced studies in university	0
Subject studies in university	2
Basic studies in university	13
Separate courses	17
Self-studies, interests	44
No studies	41

There are more answers in "No studies" than in the preceding table. The reason for this is because in addition to "no studies" being selected, some also answered separate courses or self-studies. The respondents felt they would still be considered a person that has no astronomy studies at all. Modesty or a different understanding what is meant here by studies could be the reason for this.

By asking the timing of studies (9), the idea was to point out if the astronomy studies were taken as a part of the actual studies or later when working as teacher. This was in hope of giving references for the planning and recommendations of the teacher education. Also in these answers were some multiple selections when the respondent has been located to an “upper” category. For example, as an upper category, it has been regarded as a part of the actual studies compared to studying later when working as teacher. Approximately 21% of the respondents have studied astronomy as a part of their actual studies and 32% merely when working as a teacher or at some other time. 12% of the respondents inform that they have studied astronomy outside their actual studies or teaching work. This kind of time was, for instance, a period of holiday and alternation.

As a conclusion and a positive observation, it can be said that so many of the respondents have studied astronomy. In this, the information of three respondents is missing. Studies have been focused strongly on independent information seeking, which is also good. However, in the background there was a wish to have astronomy education when studying or further education while working.

Taking benefit of separate courses (10) was asked independently in order to find out which kinds of courses are desired and where the courses are provided. Results are direct, but they absolutely did not cover taking into account the low answering percentage. About courses, it was asked the name of the course, organizer, length, venue, year and aim group.

The answers list many different kinds of courses. Based on these answers, the courses are grouped into new categories. Six new categories are created: course of Heinola, course of National Board of Education (other than Heinola), university course, open college or workers’ institute course, course of astronomical association and EAAE course (European Association for Astronomy Education). (In European countries, the EAAE has already arranged many summer schools about astronomy school teaching for the teachers of different school levels. See chapters 9.2 and 9.3). The frequencies of different categories are presented in table 7.4.

Table 7.4. Participation of respondents in separate courses of astronomy

Course	Frequency %
Course of Heinola	4
Course of National Board of Education	2
University course	5
Open college and workers’ institute course	1
Course of astronomical association	5
EAAE course	1

Courses are mainly short courses. However, not all respondents tell the length of the course. One course of the National Board of Education and one university course are 5 credit courses. The sum of frequencies is a bit larger than the frequency presented in question 8 for the separate courses. There are at least two reasons for this. In some answers more than one course was listed. On the other hand, the border between university studies and separate courses could have been a bit unclear. A university course is not always obvious if the course is a degree course or some further course. In this type of case, the course has been categorised as a separate course. The EAAE course is the only international course on the list. The timing of courses is between 1996 and 1998. The aspired group was generally the group of teachers, however everybody has a possibility to participate in the Open College and workers' institute courses as well as courses of the astronomical association.

In self-studies (11), the respondents used all suggested source materials. Slides, exceptionally, were rarely used. In this question, the respondent can again choose multiple options. Thus for the statistical analysis, the frequency of using sources as categorization criteria create new variables. Described in the next table 7.5, are the results of the occurrence of different options of answers.

Table 7.5. The source material used by respondents in their self-studies

Source material used in self-studies	Frequency %
Learning books	62
Science books	56
Videos	40
Slides	7
Magazines	68
TV-programs	57
Observation	32
Observation tool	18
Other	7

The meaning of "Observation" is an observation by telescope, binoculars or the naked eye. Listed under "Observation tool" were much different kind of tools such as a camera, telescope, binoculars, tellurian and star-map. Mentioned in the option of "Other", was using computer programs, Internet and listening to the lectures. More than half of the respondents use the most easily available tools such as learning books, science books, magazines and TV-programs. Self-study methods requiring more activity such as observing and using observation tools are more rarely carried out. To many, the lack of an observation tool – especially a telescope – can be an obstacle for observing. Only 12% of the respondents reported they use a telescope. The usage of observation tools is told in more detail in chapter 7.1.4 Teaching tools.

7.1.2 Teaching (questions 12-24)

Asked in this chapter were some practices related to teaching astronomy. The questions concerned included the learning contents of astronomy into the school curriculum, time spent in and timing of teaching, goals, teaching methods, pupils' attitude and evaluation. The goal is to get a big picture of realized teaching practices as a background for planning teaching astronomy and implementing the further education for the teachers.

<u>Context</u> (12) in teaching astronomy was asked in order to find out the subject or teaching situation that the astronomy course was associated to. Provided as answer options, the main course of physics, environmental and natural science, geography, short course or a club were mentioned. If none of these options were applicable, then the respondent could write his answer under the option "Other, specify where?" Actually the very last option was "I have not taught astronomy at all". For the major extent, the answers were unambiguous. Multiple options were chosen in few answers. Astronomy is mostly taught within the main course of physics (39%) and in the environmental and natural science course (28%). This distribution is parallel with the distribution of school degrees. Astronomy seems to be taught very rarely within a geography course (3%). However, the result is in line with the number of geography teachers that responded to the inquiry. 9% of respondents tell of having given short courses and only 1% has kept a club.

The answers included some that were difficult to interpret. For example, issues of this kind were defining a short course and an optional subject, and the difference between "teaching some astronomy" and "not teaching astronomy at all". The respondent could select the option "I have not taught astronomy at all" (13%), but mention, for example, teaching astronomy every time it fits the context, teaching every sixth year, integrating with history, teaching occasionally in context of themes, giving an advanced course or their own compulsory course. It is quite typical that a teacher has many situations when astronomy can be taught. For example, these kinds of combinations are physics/geography, geography/club, geography/environmental and natural sciences, and mathematics/physics/chemistry. The last is interesting, and at the same time it is also very creditable. For instance, the respondent handles astronomy in the following contexts: in 7th grade with mathematics and physics when big numbers are concerned, in 8th grade with chemistry in subjects related to the birth of elements, in 9th grade with mathematics when geometry is concerned and physics when spectrum is concerned, and in all grades of the upper level of the comprehensive school when sphere geometry is concerned.

Many respondents do not regard the short 2-4 hour period in the spring of the 9th grade as teaching astronomy. Astronomy is in many physics textbooks the last chapter, so when proceeding according to the book there is no time for astronomy or it is useless from the learning point of view. The last weeks of the last grade in comprehensive school are busy and often obscure. In addition, planning and realizing excursions takes much time from the actual studies.

<u>Number of lessons</u> (13) given in teaching astronomy per group in a year describes on its behalf the teachers interested in and acknowledging the importance of astronomy. The answer options were grouped by four hours (in Finnish school system we speak about 'hours' when meaning lessons) except for the last option, which belonged to all respondents teaching more than 12 hours of astronomy. As much as 42% of respondents report teaching astronomy less than 4 hours, 25% teach 4 to 8 hours, whereas 13% teach 9 to 12 hours. It was good to point out that even 13% of respondents reported teaching astronomy more than 12 hours, which is a considerable amount of hours. But 9% of respondents did not answer this question. Almost half of the respondents belong to the group that only briefly touched on the subject of astronomy during a school year. As pointed out in the last question, obviously that group is the same as the one that briefly touched on the subject at the end of May. There were many different interpretations in the answers on what is a considerable amount of lessons.

In <u>timing of astronomy teaching</u> (14), the idea was to find out at which time of the school year the teacher has taught astronomy. The answers were thought to tell a bit on how important the teacher sees teaching astronomy. The answer options included some suggestions a bit challenging, like the order of the textbook, individual teaching period in the beginning of the school year and always when it fits the context. In the answers, there were multiple options selected. Thus, the frequencies of the options only describe each representation of the options in the teaching practices of the respondents. Comparing the frequencies of options does not add any value. According to results in the upper level of the comprehensive school, the teaching dependant on textbooks is quite typical (27%) at the end of the ninth grade. Only 6% of respondents report teaching astronomy in the beginning of the school year. As a positive observation, it can be seen that almost one third (27%) of the respondents in the upper level always teach astronomy when it fits the context. Those kinds of opportunities are numerous in mathematical natural science subjects. In the lower level, the timing of teaching varied a lot. However, the total teaching percentage was good, approximately 29%. The most typical timing of teaching is in the 5th and 6th grades. Listed in the “Other time” option were the following single moments of teaching astronomy: theme work, internet connection, integration to other subjects like mathematics and art, separate course in 8th and 9th grades, compulsory course in 7th grade and 1st grade of high school, combined group in 8th and 9th grades for one term period, project work, teaching geography and the visit of external lecturer. Most popular, as expected, was the separate astronomy course.

As main aims of astronomy teaching (15), one part of the respondents mention the learning contents they have used, so the answer of this question would belong to the next question. The answers can be interpreted so that the intention of the respondent is to teach his pupils to know the subjects and concepts of the astronomy he mentions.

There were altogether 24 different aims in the answers. According to the respondents, it is most important that a pupil:

* would understand the extent and diversity of the universe, the structure of the system
* would figure for himself an astronomic picture of the universe
* would learn to know the structure and components of the Solar System
* would motivate himself to take an interest in astronomy.

In addition to these general subject matters there were multiple special subjects that will be grouped again into three concept categories: individualised subjects, subjects based on a man’s position in the universe and philosophical subjects. There are subjects that would belong to at least two categories. The border between the categories is not unambiguous.

> Individualized subjects include distances and laws, the Milky Way, formation and size of galaxies, planets and satellites, stars and constellations, basic concepts, seasons and times of day, time and space travels. Most popular of these subjects are planets, stars and constellations as well as distances and laws. Into the relationship between a man and the universe are connected understanding the position of one’s own planet in the universe, man’s position in the cosmos, knowing the natural phenomena, observing the space as well as the birth of elements. Subjects related to philosophy include the history of research, space travels, food for thought, questions from children and understanding the essence of life.

In the results, there are similar subject matters as in themes presented in chapter 4.4.7 and 10.1, guiding the planning of teaching astronomy.

The learning contents (16), used by respondents in their teaching, were expected to bring many kinds of subjects and subject matter. There were even 53 different learning contents in the answers. However, few of them can be combined into bigger subject matter due to the similarity of contents. Most popular is definitely the Earth-Moon-Solar System – subject (59%). The second most popular is knowledge of stars in the sky, lifecycle of stars and the universe with its Big Bang (28%). Only third most popular are planets, including their structure and the galaxies (18%). Fourth are the Milky Way, space research and the conquest of space (12%). Distribution is consistent with the aims in question 15.

The rest of the subjects are grouped into three concept categories: individualized subjects, observation tools and general subjects. It is also difficult in this grouping to draw a border between different categories.

> As individualised subjects are mentioned, *e.g.* gravitation, orbits of planets, chronology, seasons and times of day, halo effect, eclipses, influence of the Sun, comets, shadows, aurora borealis, Kepler's laws, epicycles, satellites, black hole, tide, phases of the Moon and quasars. Subjects related to observations and observation tools include telescopes, astrophotography, mini observatory, observation, star map, astrophotography, optical tools and scale models. Mentioned as general subjects are electro-magnetic radiation, contents of environmental studies, uniqueness of the position of Earth, science fiction, phenomena observed on Earth, the theory of relativity, calculative tasks, man and life in the universe, history of astronomy and research, origin theory of elements, the problem of understanding, development of the picture of the world, natural scientific working methods, astrophysics, magazine articles and subjects composed by pupils .

The list is comprehensive, even if the dispersion of the learning contents between the teachers is considerable. Altogether, the learning contents cover a very big proportion of the subjects related to the basic knowledge of astronomy. The idea is to take them into account in chapter 10.2 when planning on teaching astronomy according to the principles of structural hierarchy of the universe (Chapters 4.4 and 10.1) and concept formation in astronomy (Chapter 5). Many respondents wished to receive teaching material or whole course packets for their astronomy lessons.

By asking the principle of <u>formation of learning contents</u> (17), the idea was to find out on which basis each teacher chooses the contents of their astronomy lessons. The aim was to know from which sources the teachers take their subjects of astronomy. Almost half of the teachers (43%) report they teach according to the textbook. Approximately every fourth report they teach according to the official curriculum. About 24% of respondents use their own curriculum and 27% of them use separate subjects in their teaching. This is related to the point in question 14 "always when fits the context". In the "Other, specify" option, 11% of respondents mention as principal information of learning contents, examples such as current events like eclipses and space flights, videos and observation tools such as the sundial, current magazine articles and astronomy subjects in other text books. The current astronomy news inspire to handle the topic right away with the pupils. Media is of great importance in addition to the teacher being enthusiastic about astronomy in terms of staying up-to-date.

<u>Teaching methods</u> (18) used in teaching astronomy is an important and interesting subject. With the question, the idea was to get to know the popularity of each method in teaching. The aim is to create a big picture of the readiness of teachers for different teaching situations in order to plan the teaching and teacher education. Teachers were supposed to choose all the methods they have used. Altogether 14 options were given. However, in addition there was an option "Other, specify" in order to also record surprising methods. Due to large frequency, the results are presented graphically with a bar chart (Fig. 7.1).

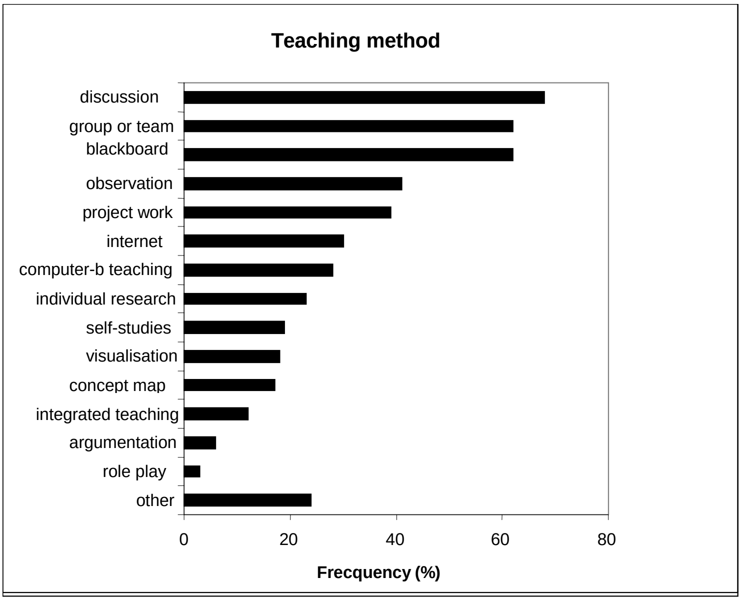


Figure 7.1. Distribution of teaching methods used by the respondents

The most popular teaching method is discussion (68%). Nearly as popular are ‘normal’ classroom teaching (blackboard) and group work (62%). The third most popular are observation (41%) and project work (39%), and the fourth are Internet (30%) and computer-based teaching (28%).

In the option ”Other”, video is the most popular. Next are the visits to planetariums and using a quest lecturer. Altogether at this point the next options were listed:

- experimentalism	- slide shows	- technical work
- presentations	- videos	- decision making exercise
- movies	- cd-rom	- quest
- theme day	- science day	- essay
- visit observatory	- visit Heureka	- visit planetarium

Many of these are surprising choices. With some of them, however, you cannot help thinking if the question is about an actual educational method or a separate recreational event separated from conventional school activity. These kinds of events include visits outside the school, science days, guest presentations, movies or usage of audio-visual tools. The step from these to the teaching method known as actual educational method is a bit indefinite.

In the next question, the idea was to specify the respondent's opinion on the popularity of teaching methods (19) he has used. The intent is to get references for recommendations of methods. The respondents were supposed to give numbers 1 to 3 on a line before the option of question 18 so that number 1 means the 'most used method', number 2 'often used method' and number 3 'sometimes used method'. Combined results are in table 7.6.

Table 7.6. Frequencies of the three most popular teaching methods used by respondents

Teaching method	Most (no)	Often (no)	Sometimes (no)
Classroom	**20**	11	9
Project work	7	7	5
Individual research	3	2	5
Argumentation			
Visualization		3	3
Discussion	**20**	**22**	9
Computer-based teaching		3	5
Self study	3	2	2
Concept map		2	2
Internet	1	2	5
Group work/teamwork	**16**	**13**	**17**
Observation	5	3	9
Role-play			
Integrative teaching	3	2	2

In the table, the most popular methods in each column have been given in boldface in order to figure out the result easier. Of the 'most used' teaching methods (1st position), the most popular are classroom teaching and discussion followed by the group work/team work. So the teachers are using very traditional methods! Of the 'often used' methods (2nd position), the most popular was discussion and the second most popular was group work/pair work. Of the 'sometimes used' educational methods (3rd position), the most popular was group work/pair work. Based on this question it seems that this group of respondents would not use argumentation or role-play at all. However, in the 18th question 6% had chosen argumentation and 3% role-play. On the other hand, in many papers the question of the popularity of the methods had been left unanswered, even if multiple choices for methods had been made in the previous question. This skews the results a bit, but apparently the error is distributed evenly between all answer options, so the shape of the distribution is approximately correct.

By asking the pupils' attitude towards astronomy (20), the motive was to find out what kind of attitude the teachers have faced when starting astronomy teaching. In addition to that, the questions concerning increasing motivation for exploring the nature were asked. The aim is to examine which kind of impact, according to teachers, the astronomy has had in pupils' motivation. The question is open, and for that reason the following answer categories were created: positive attitude, negative attitude, clear motivation impact and no answer. The border between first and third categories is a bit open to interpretations, at least when it comes to motivation. It is positive to note that even 55% of respondents tell that astronomy is clearly increasing motivation in their studies for exploring the nature. Positive experience has been noted by 22% of respondents, and fortunately, only 9% with negative experience. 14 % of respondents left this question unanswered.

When asking the pupils' attitude towards current astronomical issues (21), the answer was looked for in questioning whether the TV programs or magazine articles inspire the pupils to discuss and ask questions about current astronomical and space research related issues. The aim is to study the usage of different methods in teaching. The categories of this open question are similar to the ones of the previous question. Even so, 67% of respondents have noted their pupils' interest towards current issues of astronomy, but few respondents felt it difficult to answer to the questions related to those issues. 13% of respondents had not noted any significant interest towards the current issues of astronomy in their pupils. In particular, only 3% of respondents had active and interested pupils. The high motivation percentage of the last question (55%) does not necessarily mean that pupils would be socially active and loud, but they can be motivated silently, personally or in their circle of acquaintances. A teacher sees this activeness in the pupil's activity, yet it does not necessarily come out when the pupil talks.

Next the teachers were asked about evaluating the starting level (22) of the pupils' knowledge in astronomy. The aim is to study the educational methods that are used. The question is open and in the answers there are ten different kinds of evaluation. Due to the low number of options, categorisation is not done this time but all options are given directly. Definitely the most popular evaluation method is discussion (28%). The second most popular is inquiry (17%), written or spoken. The margin between these is a bit unclear, as in the school world the inquiry often includes quite a lot of discussion, and during a discussion there can also be a lot of questions brought up. The rest of the evaluation methods are single cases. In the answers, it is not mentioned how they have been realised in practice:

- drawing pictures of the phenomena
- drawing a mind map
- clarifying basic information
- teacher observes pupils' knowledge
- motions of the objects in space
- usage of textbook
- argumentation situation
- quiz

In addition to evaluating, the starting level – which is also how the teachers test the verification of the aims (23) – was to be clarified. 22 different answers were received to this open question. The most popular testing method, as expected, is a test (40%). Second most popular is a spot check either spoken or written (18%), and third most popular is project work and their presentation (11%). Fourth could be mentioned discussion (7%). The rest of the answers are grouped into three categories as follows: giving a spoken or written output, observation and other testing. Here, giving an output means another kind of output than project work; for example, a poster or scale model. Making a presentation, as well as drawing a mind map and pictures, is also a calculable output in testing the aims. According to the answers in observation, this goes along with the pupil's independent work, development of interest, studying (for example of constellations with the help of computer programs), and continuous follow-up of the pupil's progress. As an example of the last mentioned follow-up, there have been mentioned a set of follow-up periods that include notebook work, tests, interests and essays. Other testing of the aims happens by using the following criteria: understanding the causal connection, final criticism, self-evaluation, giving the test questions in beforehand

and excursions. The subject matter of this category is quite wide, but it only tells about teachers' great variety of ideas and their enthusiasm on their work.

Running evaluation (24) was asked by an open question because the respondents should not have been given any guiding information. There were 7 different answers to the question. Again, grouping the answers into categories is a bit difficult, as for one thing; the respondents use many kinds of expressions. For that reason, it has chosen a separating solution rather than one too combining. For example, the common evaluations of group work and discussion have been marked as separate evaluation methods. Of course common evaluation contains discussion, but not all discussion is evaluation of some output. Clearly standing out from the others, the evaluation method is carrying out a test and numerical evaluation (26%). The second most typical, even if very close to the idea of the first evaluation method, is a combination of test and classroom work (13%). Therefore, 39% of respondents evaluate their pupils' knowledge of astronomy with the help of a test. The third evaluation method is verbal feedback and common evaluation of group and project work (11%). As other evaluation methods, there has been mentioned observation, discussion, essay and test of the sky map. Mentioned separately has been following the evaluation, the upgrading impact to the main subject (physics, geography) due to the pupil's successful performance. Astronomy is not a separately evaluated discipline apart from the optional course. Therefore, the pupil's learning or performance evaluation, managed by all evaluation methods, surely impacts (in most cases upward) the grade of the actual main subject.

7.1.3. Teaching material (questions 25-28)

The following four questions relate to the textbooks and supplementary materials used at school. Unfortunately the meaning of the words "supplementary material" and "teaching tools" are a little unclear to some of those answering the questionnaire. Their answers to these questions can include elements from two to even three questions. These are mentioned in the explanation of the results of each question.

The textbook used (25) was asked for the main reason that the catalogue be compared to the list of textbooks under analysis introduced in chapter 7.3. There is no desire to evaluate the publishers. The formulating of the question was not the best possible because the inquiry was mainly concerned with the textbooks of physics, geography, as well as environmental and natural sciences. Nevertheless, the answers mention also astronomical books. In appendix 7.4 there a list of textbooks the respondents used when teaching different subjects and the amounts of users. The mark "x" after the name of the book means that the book is included also into that part of the research, which examines the contents of teaching astronomy. More accurate references of the x-marked books are presented in Appendix 7.5. Distribution agrees with the distribution of the respondents among the teachers of lower and upper levels. 17% did not answer at all. In all other subjects, except geography, the book under analysis is also found on this list of textbooks used by the respondents.

To get a picture of the standard of equipment at schools, the question about supplementary materials was asked (26). The aim was to examine the facilities of the schools for teaching astronomy. The question is open but it also gives alternatives. There were alternatives for different kinds of supplementary materials such as series of slides, videos, TV-programs, literature, computer programs, newspapers, and movies, as well as materials found on the Internet. Possible details of these were asked in an open part. In addition to that, the respondents were asked to indicate whether they had used the marked supplementary material or not (Y/N). The results are presented in Table 7.7 and in Figure 7.2.

Table 7.7. Utilisation of supplementary materials in the schools of the respondents

Supplementary Materials	Frequency %	Utilization Rate %
Sample of slides	45	69
Video	61	89
TV-program	38	92
Literature	64	82
Computer program	33	87
Newspaper	45	83
Movie	4	75
Internet	73	59
Other	15	

In the table, frequency indicates the rate of acquisitions of astronomical supplementary materials in the schools of the respondents. Utilisation rate, on the other hand, indicates how much the respondents used materials in question in their teaching. Even 42 schools have a series of slides and 29 report the use of it in their teaching. Thus the frequency of occurrence is 42/49, i.e. 45%. The utilisation rate, however, is 29/42, meaning 69%. The respondents indicate that in teaching they mainly use TV-programs, videos and computer programs.

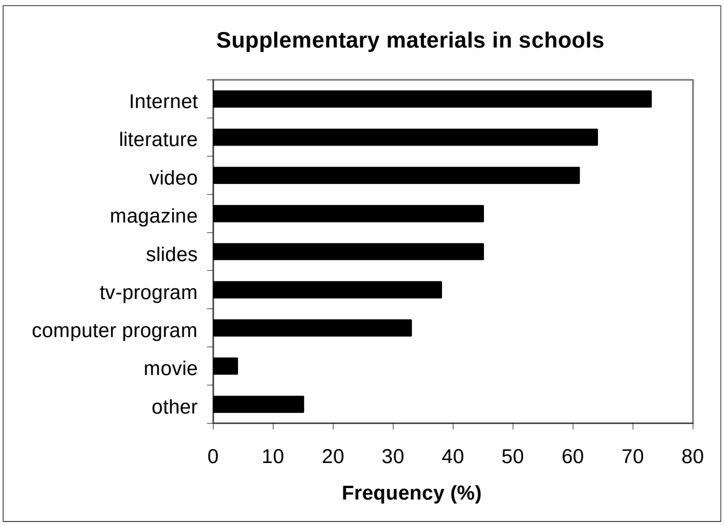


Fig. 7.2 Supplementary materials in the schools of respondents

In addition to scientific books and series of books, the respondents mention the following books: Maailmankaikkeus suurimmasta pienimpään (The universe from the biggest to the smallest), Tuula Koukku 1983), Jännittävä avaruus, löytöretkisarja (Exciting space, series of informational books) as well as Nuorten tähtitieto (Astronomical knowledge for the youth). The following videos were mentioned: Avaruusarkki (Space arch), Robotti v. Rosenbergin tutkimukset (Explorations of Robot von Rosenberg) as well as Kotitallilla (In the home stable). Of the newspapers only Tähdet ja avaruus (The stars and the universe) is mentioned in three answers. As to the computer programs cd-roms Avaruus (Space) and Tiede (Science) are mentioned. In the item "Other" a very versatile assortment of different kinds of supplementary materials is mentioned including even in this connection not so good alternatives like visits to planetariums, Heureka and Tietomaa, which belong to the question 32. The answers include experiments, posters, clips from newspapers, pictures of the starry sky and halos, series of films, models of the starry sky, self made copies and a movable planetarium, which actually should be among the answers to the question 29.

The question on the acquisition of temporary supplementary material was posed to more closely define the use of supplementary material. The aim was to find out how the teachers act if their supplementary material is insufficient. If the school has not had a possibility to acquire materials of its own, the teacher has been able to borrow them for the time of teaching astronomy. In many especially larger municipalities there is a centre for teaching materials, where the schools in the city can borrow teaching materials. The teachers can also borrow materials from their colleagues at other schools or from their friends. The borrowed materials are mostly videos (19%), then books (14%) and slides (5%).

In addition a few sporadic votes are given to the following: scrap, binocular, telescope, cd-roms, visitors, pictorial material, star maps, transparencies, models of the Solar system, movable planetarium with guides, newspapers, TV-programs, equipment for solar and lunar eclipse and movies. There were also a few mentions of using one's own materials like computer programs, newspapers, TV-programs, movies, videos as well as books. A part of these belong clearly to the question 29, a visitor on the other hand to the question 32.

In order to find good ideas for teaching, there is a question that inquires for supplementary materials created by the teacher himself (28). According to the answers to an open question, the teachers have been quite creative and productive when developing their own materials for teaching astronomy. Clearly, distinguishable kinds of developed materials are transparencies, teaching materials forming a whole and teamwork materials. The rest of the answers can be grouped into literary products and observational tools.

Scraps, slides, books, astronomical games, question series, web pages on the school's homepage, questionnaires for videos, teamwork manuals, observational material, a short course Solar system–Galaxies, star map, reasoning exercises, introduction of the Solar system and map of concepts on the wall are literary products. On the other hand, equipment mentioned in the book "Kuu taivaalta", a set of balls as planets and the Moon, the Earth, mini observatory, tool for calculating the number of stars, magnitude diagram, model of the phases of the Moon, wall map of the night sky, equipment for solar and lunar eclipse and model for alternation of the seasons are all observational tools.

7.1.4 Teaching tools (questions 29-35)

The emphasis in this chapter is on concrete tools, but among other things, supplementary materials are again mentioned especially in the answers to open questions. The question 32 (activities) has been taken within this part because it also includes a teaching tool, i.e. planetarium. It is the aim to find out the standard level of the teaching tools to evaluate the possibilities for teaching. This leads to examination of possibilities to teach astronomy and it also helps to choose the methods.

The first question in this item was asked to evaluate the level of astronomical teaching tools (29). The most usual equipment in the schools, such as binoculars, mini model of the Earth, the Moon and the Sun as well as a rotating globe were given alternatives. Sundial, sextant and telescope were suggested in addition to that. In the alternative “Other”, the respondent may write about the specialities in his own school. The results are in Table 7.8.

Table 7.8. Tools for astronomy teaching in the schools of the respondents

Teaching tool	Frequency %	Utilisation rate %
Telescope	23	50
Binocular	62	59
Rotating globe	74	69
Sundial	5	20
Sextant	2	50
Earth-Moon-Sun - model	45	83
Other	7	

The schools had mostly globes, binoculars as well as Earth-Moon-Sun models. In quite a few schools there is also a telescope although only half of those who have it and 12% of all respondents use it.

> In the item ”Other” some mention plani-spheres, scale models, Moon globe, model of the starry sky, Solar system model and a dismountable planetarium. Cd-rom belongs more to the question 26 and an excursion to the observatory to the question 32.

Generally speaking, it is surprising how small the amount of tools, used for teaching astronomy, are at schools. Only 10% did not answer this question, thus the estimation corresponds to the reality among this group of respondents.

As a sequel to the previous question, using of tools in teaching was asked (30). In Table 7.8 the last column, “Utilisation rate per cent” indicates in percent the amount of users in relation to the amount of tools in question. For example, there is a rotating globe in 70 schools (the amount of schools is 94) and 48 respondents report that they use it. The frequency of occurrence is thus 70/94, i.e. 74%. On the other hand, the utilisation rate is 48/70, i.e. 69%. However, the most used teaching tool is the Earth-Moon-Sun mini model.

The question of using other tools than those at school (31) was asked because there was a need as the first of all to find out the possibilities teachers have to acquire equipment they temporarily need, and secondly how active the teachers are to act upon this. The question is connected to the previous questions 27 and 28, which handled acquiring, borrowing and self-preparing supplementary material. In some answers the contents of these questions are partly mixed up. A part of the equipment mentioned, like telescope and binoculars, is apparently borrowed to the school for the time of teaching. Self-made Solar system models and videos are used most of all. The second biggest group mentions the use of telescope and Internet. Videos and Internet can be regarded also as supplementary materials. The rest of sporadic answers have been grouped into three categories: teaching tools, supplementary materials and actions.

> Binoculars, computer, observational models, torch, device for defining distances, mini lamps, picture, self-made sundial, cardboard planet models, welding glasses for observing the Sun, compasses, ruler and calculator are mentioned as teaching tools. Cd-rom, pictures, non-fiction books, transparencies, star map, storybook as well as computer programs are supplementary materials. Using guests, inviting the movable planetarium to the school, various kinds of organising tests, observational happenings as well as excursions to observatories are categorized as actions. These are apparently mentioned also in the answers to the question 32.

The total amount of teaching tools mentioned is 32, of supplementary materials 18, and actions 5. These results are interesting mainly in relation to the versatility of the equipment used. Only 36% gave an answer to this question, thus the variety of equipment, even in such a small group, is amazing. One begins to wonder what other kinds of equipment could actually be reported in the forms of those not answering this question.

A separate question on <u>the actions completed at schools</u> (32) was established since the subject is very interesting and also to find out various action models. This question belongs to the group of questions on teaching tools mainly because of the planetarium. Also, since dismountable planetariums are available at schools, they too can be regarded as teaching tools. Alternative answers are mentioned as planetarium demonstration, an excursion to planetarium or observatory, a guest lecturer, as well as a work project for the pupil. The question was answered by a little more than a half of the respondents, 53%. The action preferences are illustrated in figure 7.3.

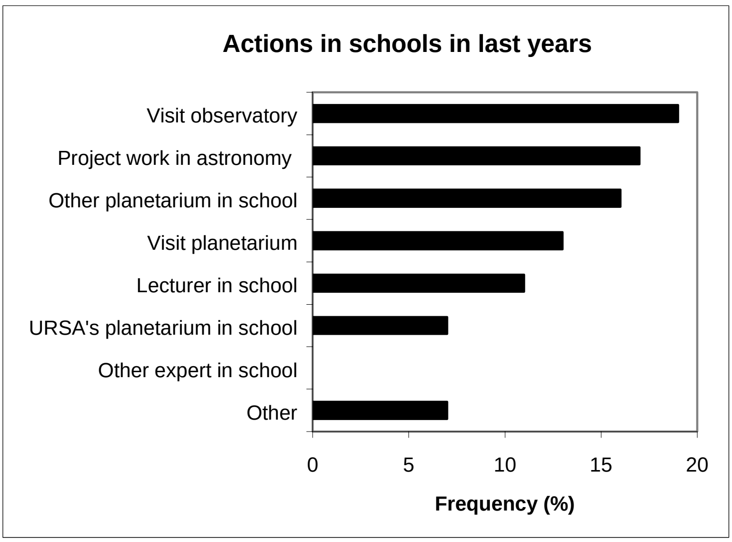


Figure 7.3 Actions realised in recent years in the schools of the respondents

Excursions to observatory, work projects for the pupils, as well as the acquiring of a planetarium to the school are the most preferred actions. Nearly as popular are excursions to the planetarium, as well as inviting a guest lecturer.

> Lector Arvo Kuusela's planetarium and a special tent for planetarium are mentioned as other planetariums. Excursions have been made to planetariums at Tampere and Heureka among others. In Ursa planetarium there have been performances for the public during various happenings. Eleven excursions to observatories in other cities have been reported. The most popular of them are the observatory of URSA in Helsinki and URSA's observatories in Turku and Lahti. In addition to these the following places, in different parts of Finland, are mentioned as visiting resorts: Jyväskylä, Mikkeli, Töysä, Rautalampi, Kontiolahti, Ulvila, Karjaa and Iso-Syöte. The guest lecturer's subjects have been universe, space, distances, eclipses, meteor showers as well as observation. As lecturers are mentioned by name only Heikki Oja from Helsinki University as well as Arvo Kuusela. A guest lecturer arranged an astronomical course at one school. Projects have been made, such as solar system on the table, universe, constructions of the planets, "Stars and universe" –course (12 h), multimedia performance, constellation picture and fictional interview. An exhibition has been gathered up from the products of the pupils' own subjects. In addition to that there are a couple of mentions of projects but their motives have not been reported. Reporting of the star course does not indicate whether pupils or the teacher plan the course. In item "Other" a visit to the office of Ursa has been mentioned as well as a lecture of an employee at ESA, preparing of treatise, excursion to Tietomaa in Oulu and excursion to URSA's planetarium at the neighbouring school. In addition to these, many actions due to eagerness of the pupils are also mentioned without any detailed notice.

By asking a question of <u>self-made observation tools</u> (33), it was the desire to find out how active and innovative the teachers are when making plans for teaching. It was the aim to get an idea for making recommendations to the contents and methods of astronomy teaching. This question produced 13 dissimilar answers. Answering percentage was indeed very low, only 19%. All "demonstrational tools" like things, supplementary materials as well as literary products have been accepted in this context as observational tools. Most models produced are Sun-Earth-Moon models and solar models. The second biggest groups are models for planets' distances and sizes. The rest answered with stray votes are grouped to things and literary materials.

> In some answers the grouping is difficult because the mere name of an observational tool does not indicate the quality of the tool. *E.g.* "a night sky in a mini form" can be a thing or a picture. Sundial, peaked cap Moon, black hole model, a spherical model illustrating shadow's course as well as a mini model of the starry sky are things. There are also notes of self-made observational tools without any further specification. Transparencies, a wall map, a model of eclipse for an overhead projector as well as materials presenting galaxies and constellations are all literary materials.

As a sequel to the previous question, there was a question about <u>tools under construction</u> (34). They can also give good hints to the planning of teaching subjects and methods. This was an open question and the amount of answers was quite small, only 4%. The contribution of this result is very insignificant. The respondents themselves have planned cd-rom, eclipse models, slides, videos and other observational tools, which they don't specify in details.

<u>The origin of an observational tool</u> (35) was asked in order to explore connections that teachers use when acquiring teaching materials and to get an idea of the useful "net" around the school. The respondents were inquired about the origin of the model/idea to their self-made observational tools. There were five alternatives given: the respondent has developed the model by himself or he has got the idea from the media, literature, other schools or Internet. The answer percentage was 22. Literature gave an idea to 16% of the respondents and 9% used their own idea to develop the model. Two or three respondents reported that they got the idea from other schools or media. The Internet did

not seem at all to be the source for ideas. The group of answers to this question is so small that no generalizations can be made.

> Other sources than the given ones have produced single ideas. As these kinds of sources are mentioned Heureka, fellow teachers, trainees as well as various astronomical courses, both domestic and international, like the EAAE astronomical summer school in Italy and a course in England. Material packages and the book "Kuu taivaalta" by Ursa have been mentioned as literary sources.

7.1.5 Education (Questions 36-40)

In the questions of the last topic, the readiness of teaching, willingness for further education, habits of education and the need of material support are asked from the teachers. The aim is to map the need of astronomical courses, ways of realization and the school material offered in teacher training and further education for teachers.

With the open question concerning the readiness of astronomy teaching (36), the respondents were hoped to evaluate their own attitude to the teaching of astronomy. Because of the nature of the question, the ways of answering are varying. Based on the answers, 17% of teachers announced to have good and 27% satisfying opportunities in teaching astronomy, while 39% of the respondents considered themselves to have poor opportunities. The rest (17%) found their possibilities nonexistent or left the question open. In total almost a half of the teachers (44%) considered to have some kind of opportunities in teaching astronomy. On the other hand, teachers have certainly different opinions of what are the sufficient knowledge and preconditions. Almost the same amount of teachers felt to be in a weak position to teach astronomy. Of them, 57% would like to get further education.

Astronomical studies being planned (37) were asked to find out the eagerness to study. The purpose is to investigate the possible response of astronomical courses among teachers. From the answers of this open question, nine different kinds of types were found. The percentage of answering was very low, 18%. The most common option was to plan self-studying by reading books and magazines. The second most popular choice was to follow current events, take part in courses and look for information on the Internet. Additionally mentioned were taking a university degree or a working course of physics at the university. Participating in the activities of the astronomical society Ursa was also considered as studying astronomy.

With the question about the education supply in astronomy (38), the teachers were hoped to take a stand on the realization of education. As expected, this open question was understood in many ways. Among the answers, 25 different options were found even though some of them meant almost the same thing. The question was answered by 46% of the teachers. The answers can be grouped into three clusters: types of education, contents of education and methods of education.

> Types of education contained the following hopes: a summer course, the EAAE summer school, a visit in a planetarium, a basic course on how to keep an optional course, an observation course, a course in the university, weekend courses, a visiting lecturer, an elementary course, a special subject evening, a series of lectures and introductions of teaching entities. Selection of courses is versatile: there are both one evening courses and longer courses aiming at taking a certain degree.
>
> The following wishes were gathered under the contents of education: information on the solar system and the energy balance of the Sun, demonstrations, a textbook of astronomy, making simple demonstration tools, making a curriculum of their own, teaching material, the newest astronomical

information, the universe, space laboratories and ready packages for self-studying the basic information.

Methods of education were hoped to give ideas for diversifying and enlivening the teaching, and information on the appropriate methods of teaching and planning the lessons of astronomy.

The purpose of the question about the most suitable way of education (39) was to clear what kind of education would be suitable to plan for teachers and what would be the chances to realise it. Five answering options were given. The answering happened by writing numbers 1, 2 or 3 on a line in front of the answering option so that number 1 means the best option of way of education, number 2 indicates the second best and number 3 sometimes suitable option. Of the answers, 12% had no numbered order of suitability. All the choices concerning each way of education has been counted as percentages. The combined results are in Table 7.9.

Table 7.9. The most suitable types of astronomy education for the respondents

Type of astronomy education	Most Suitable %	Suits well %	Suits some-times %	Selections in total %
A course in Heinola	15	6	11	35
A course in own locality	24	12	12	54
Distance teaching + close periods	3	14	10	29
Self-studying freely	9	10	10	32
Self-studying with ready packages	23	18	10	55

Of the most suitable options, the most popular were courses in own locality and self-studying with ready packages. The latter is mainly a wish of the respondents, because ready packages meant for self-studying the astronomy are mostly not available yet. A plan should be made to produce these packages. Guided self-studying is more popular than free self-studying. The percentage of answering for this variable was 77%, which indicates clearly a need and hope for further education. No answer was left by 12% of the respondents.

Courses in Heinola reached the third place, but almost as popular were the self-studying freely. Delightedly many hoped also for distance education with close teaching periods. This is a fairly new field in further education of astronomy. In option "Something else" was mentioned VESO -summer course (VESO = collective bargaining contract), a course in Swedish, a magazine containing ideas for lessons and a ready package for teaching young pupils. In June 1999, a summer course of astronomy was organized in the Department of Physics in the university of Helsinki. Apparently the course was accepted as VESO-education. Other hopes were development ideas worth of consideration.

Finally, the hopes concerning the support and material for own teaching of astronomy were asked (40). This open question gathered a variety of answers, which can be artificially grouped into teaching equipment and supplementary material, actions and general hopes. The question was answered by 48% of teachers.

Of the teaching equipment and supplementary material, videos were the most hoped for (12%), followed by movies, slides, transparencies, books, magazines, computer programs, cd-rom, posters, picture material, instructions for observation tools, an information package on planets and constellations, file of astronomy, a telescope, information package for an optional course, a textbook of astronomy, a guide to teaching, instructions for pupil work and a book type of "Polaris" (including subjects for two lesson studies in astronomy). Functions included a school-television series with activating materials for the lower level of the comprehensive school, teaching material in web pages of Ursa (astronomical association) or Heureka (science centre), different kinds of courses, visits of an expert and visits in planetarium. General hopes were material in Swedish, internet-addresses, material for pupil exercise, demonstrations, good ideas, possibility to take basic studies as distance education, receiving the current information and every kinds of material supporting the teaching of astronomy.

7.1.6 Search for convergences and divergences

Convergences between variables were looked for with cross tabulations from the results of the first part of the questionnaire. Statistical parameters like frequencies and means were calculated from the data. Missing values were left empty. In some variables number zero is a significant value, the meaning of which was examined according to the variable in connection with tabulating. Because of the small amount of data and frequencies, a qualitative interpretation was done from the cross tabulation. On the other hand, only direction giving connections were looked for and not accurate statistical test results. This was because precise, only slightly separable results have no significance in this part.

For cross tabulation (some examples are presented in appendix 7.3), 15 most appropriate variables were chosen from the variables of the first part. For each examination, three variables were taken of which one is a background variable. Four background variables were used in analyses: age, sex, school level and teaching experience. In the following, the conclusions of these analyses are presented.

Differences between lower and upper comprehensive schools in different time periods

Older teachers of the upper comprehensive school have more university studies of astronomy. Middle-aged teachers of upper comprehensive school have taken also more special courses than teachers in lower comprehensive school. Instead, the teachers of both levels have self-studied almost equally. Over a half of the respondents had some kinds of astronomical studies, teachers in upper level more than the teachers in lower level of comprehensive school.

In upper comprehensive school the astronomy has been taught most in courses of physics. Mainly senior teachers have taught it. In lower comprehensive school all the teachers who answered have taught astronomy in connection with lessons of environment and biology. Older teachers of upper comprehensive school have kept short courses whereas clubs have been kept mainly in lower school.

For teaching astronomy less than four hours have been used in general, but especially the older teachers of the upper comprehensive school may have used even 12 hours. This is the situation in upper comprehensive school. In lower comprehensive school the distribution is mostly biased into a small amount of teaching hours.

Of teaching methods the most used ones in the upper comprehensive school are teaching with the blackboard, discussion and working in groups, whereas in lower comprehensive school both observational and integrative teaching are used. Blackboard teaching, discussion and self-studying are used in all age categories according to the distribution.

The teachers of the upper comprehensive school have felt the teaching of astronomy as motivating and giving positive experience in all age categories according to the distribution.

Most of the respondents had a readiness of teaching. This included teachers in the upper level more than those in the lower level, in all age categories. However, most saw their own readiness weak. Only 20% of the respondents had no readiness or they considered them as insignificant.

Of the respondents, 75% wanted further education and the teachers in upper level of comprehensive school wanted it more. Majority would prefer courses in their own locality. Also self-studying with ready material was widely supported.

Impact of astronomical studies in different age periods

Astronomy is taught most in connection with the courses of physics in the upper comprehensive school and with lessons of environmental science and biology in the lower comprehensive school. In the upper comprehensive school astronomy is taught by all the teachers who generally like to teach it, also those who themselves have no studies on astronomy. In the lower comprehensive school mainly those teachers, who have studied astronomy, teach it.

Older teachers give more lessons of astronomy regardless of their own studies on astronomy. Rather small amount of university studies have been taken compared to self-studies, which is also seen in results. It was pleasing to notice that older and more experienced teachers have strength enough to teach astronomy over 9 hours.

Teaching on the blackboard and discussion are the most common teaching methods in all age categories and study levels. Older teachers who have studied astronomy independently, use Internet and an integrative teaching as well as working in groups.

Astronomical studies of the teacher had no effect on consciousness of the motivation of pupils. Older teachers felt that astronomy has a positive influence on pupils. Negative influences were seen only in a couple of age classes.

The way astronomical studies have carried out has no impact on actions containing in astronomy in school. Older teachers realise those actions in every class level. About half of the respondents organize some happenings and half nothing.

Majority of the respondents saw themselves to have some kinds of possibilities to teach astronomy. Those who had a degree in astronomy considered their studies to be only weak or satisfying, however. Of the young adults all had possibilities to teach astronomy. The fifth of the teachers considered their possibilities to teach astronomy even good in all age categories and study levels.

Studies in astronomy had no impact on the willingness to get further education in astronomy in any age class. In particular the older teachers liked the courses in Heinola. In the Middle Ages the courses in ones own locality were favoured and especially women preferred them. Also self-studying with ready material was a good option for middle-aged teachers, even though the courses in Heinola had also supporters besides the courses in own locality. Especially men desired this kind of courses.

Impact of main subject in men and women

Here it is appropriate to group the respondents in two bigger groups: teachers of mathematical-scientific subjects (MFK = mathematics, physics and chemistry) and else. Grouping is for the reason that in general the teachers of mathematical subjects have all the three subjects to teach: mathematics, physics and chemistry.

MFK male teachers have studied astronomy mostly in special courses and by self-studying. For other male teachers self-studying has been the most popular option. MFK female teachers have taken more university degrees besides separate courses and self-studying. Other female teachers have chosen self-studying like men.

The main subject has no effect on the amount of teaching hours for men. They teach a small amount of astronomy. For women, the MFK teachers have less teaching hours whereas other female teachers have teaching hours in all time categories.

For teaching methods, readiness to teach and option for further education the distributions are similar to those declared before.

Impact of astronomical studies in men and women

There are no differences of astronomical studies between the sexes connected with teaching the astronomy.

The amount of hours used to astronomy teaching follows the distribution found before: for men usually less than eight hours according to amount of studies. For women there is astronomy teaching in every time categories following the distribution of the amount of studies.

The choice of teaching methods has the same distribution as stated before. The teaching happens in relation to the amount of studies.

Men and women having studied astronomy felt their possibilities to teach astronomy good or satisfying. Instead, the self-studied men considered their capability weak, whereas women even satisfying.

Impact of astronomical studies in lower and upper comprehensive school

In upper comprehensive school the astronomy is taught mostly in connection with physics and slightly in geography, in short courses or in other ways of teaching independent of astronomical studies even by those who have no such studies. In lower comprehensive school mostly those teach who have self-studied or who have no astronomical studies. Teaching is given almost entirely in lessons of environment and biology.

The amount of teaching hours in upper comprehensive school is smaller, if the teacher has no astronomical studies or has self-studied at most. Still a positive observation has to be mentioned: independent of their astronomical studies, the amount of the lessons was the same in all the categories given in the questionnaire. In lower comprehensive school there is more variation meaning that astronomy is taught there in variable amounts of teaching hours.

There are no significant differences between upper and lower comprehensive schools related to the actions connected to astronomy, to the ability of teachers to teach and to the further education of teachers. Single cases alternate between these levels. The astronomical studies of the teacher have no significant impact on these. Moreover it apparently depends on the personality and attitude of the teacher to both astronomy and teaching in general.

Impact of astronomy teaching in different school levels

Time used for teaching astronomy in physics on the upper level of the comprehensive school varies between 0 and 12 hours. In geography it is less than 4 hours, on short courses even more than 12 hours. On the lower level of the comprehensive school in environmental and natural sciences the time used for teaching astronomy varies within all options. On the lower level also club has been held 4 to 8 hours.

On the upper level in teaching astronomy as part of physics course mostly normal classroom teaching is used, but also discussion and group work. While teaching in other connections mostly only classroom teaching is used. On the lower level in addition to mostly used discussion there are also group works, classroom teaching and project work.

The impact of astronomy on pupils is mostly positive and motivating in both degrees in all the teaching situations. Negative impacts occur quite rarely, only 10 percent of respondents in both degrees see them.

Impacts of astronomy teaching according to teacher experience

More experienced teachers of physics teach more astronomy, even if the amount of lessons does not correlate so much with the experience. Also on lower level of the comprehensive school by the more experienced teachers teach astronomy, but on lower level the total number of lessons is bigger. Surprisingly rarely these respondents teach astronomy as part of geography. Just graduated teachers hardly teach astronomy at all, not even as short course.

More experienced teachers teaching astronomy both related to physics and environmental and natural science use in their teaching multiple teaching methods. On short courses have been used nearly all methods, but the total amount of courses is very small. In geography only classroom teaching has been used. Different activities connected to astronomy are mostly in the most experienced teachers' answers. More experienced teachers have naturally worked longer and that way different experiments have been tried more. In addition a majority of the respondents were older teachers.

Teachers of physics find their own abilities teaching astronomy as satisfactory or poor, irrespective of their experience. In teachers of environmental and natural sciences there are more teachers with good abilities for teaching astronomy. Experience does not have big impact on the willingness for further education, however young teachers are more passive also here. The course in own commune, Heinola course or self-studying are the most wanted education methods irrespective of experience.

Impacts of the abilities for teaching astronomy according to teacher experience

Teachers having longer teacher experience are ready to teach astronomy also with less ability. This teaching is carried out mostly as part of physics, environmental and natural science studies. Few short courses have been held.

The low level of teaching abilities impacts also the number of astronomy lessons irrespective of experience. Teachers with good abilities exist in each time category irrespective of experience, however again the young teachers make a difference. Also in this table can be seen the more experienced teachers using various teaching methods irrespective of abilities. Astronomy seems to have motivating impact on pupils, the impact is clearly more positive; there were few negative impacts.

> The supply of further education suits mostly to teachers having poor or satisfactory abilities. The teachers with good abilities in their own opinion study astronomy by choice themselves, however they wish that the learning material would be readily available. They can take astronomy course also in their own commune. Teacher experience does not have impact on these wishes, when just graduated are not taken into account.

The studies presented before are connected most closely to the aims of this thesis. It was also interesting to study other dependencies, even if taking advantage of those results is quite marginal in this thesis. But they may be used as source materials when presenting the results of this thesis in other connections.

7.2 Curricula

7.2.1 Curriculum

Many changes have happened in the school world during the last couple of decades. They have been related mostly to social issues, value basis and curricula. In addition to social changes, the rapid scientific development of different fields has also had an impact on the renewal of the school. According to *The framework curriculum for the comprehensive school 1994* by the National Board of Education (Anon. 1994), the need for renewing the curricula is based on these three changes: social change, change of value basis and theoretical change of the curriculum (see chapters 2.2 and 3.1.3).

<u>The social changes</u> get impacted from changes of governmental, political and economic systems. Internationalisation has brought a lot of different movement. Movement of persons has become easier, both on fields of tourism and work. This way culture and know-how spread both across and within our borders. The citizens have had to form their opinion on many issues of foreign culture, which has called for the Finns' ability to accept diversity. With the development of employment and source of livelihood, continuous education is almost a necessary pre-condition in order to carry out the job duties successfully. Also, responsibility and co-operation skills are more important tools than before. The impacts of these aspects and requirements coming up more than before extend to the educational system, family life as well as leisure. The school system has had to be developed with quite short intervals and the development still continues. Reading benefits the study programs, the length of the education and the grades becoming more flexible raises the ability of school to serve and gives the pupil a possibility to build his education as long as possible according to his own needs and preferences. De-centralisation along with the movement of decision powers more and more to the communes has also impacted largely the supply of education.

The questions related to the change of <u>value basis,</u> on the other hand, emerge from the universal declaration of human rights by the United Nations. In the current world situation, a wide issue handling the taking into account of various aspects is needed, as well as the ability to accept different cultures and ways of living and the ability to change one's own life according to the circumstances. Keeping one's own identity and fostering the national cultural tradition are the individual's most important aims in the changing world. Also, value and moral issues are important, as well as questions related to health and welfare and social skills.

<u>The theoretical change of the curriculum</u> brought with it the idea of continuous renewal. The curriculum is not a set of guidelines that is created as a one-time job, but it is a continuously develop-

ing, renewing and diversifying process, that reacts to the changes and estimates results of the environment. This process needs the teachers and the whole staff of the school to commit to the development and renewal of the process. The teachers have to see themselves as the developers of their own work. The work contribution of everyone involved and responsible for the operation of the school is an important part of the operation and development of the school.

The need for renewing the curriculum can thus be summed up to three points: raising the level of education, renewing the contents of education, individualizing the teaching and increasing optionality. (The framework curriculum for the comprehensive school 1994.)

The curriculum lists all of the issues related to the activity of school such as planning the schoolwork, evaluation and terms of reference. The National Board of Education has given the basic instructions for the communes. Based on them is created an individual curriculum that develops and guides the teaching work in communes and schools. Visible in the curriculum is the distinctiveness of each commune, education policy and specialities. For the best possible conditions, according to the book *the framework curriculum for the comprehensive school,* it is important that schools are created to specify their own needs by themselves and define the content and practices from their own perspectives. This way the schools commit to implementing the programs better than before. Also, the active responsibility and development role of the commune will be emphasised. The purpose of the co-operation between communes and schools is to provide the pupils with diverse educational services.

Curriculum has to include the role, distinctiveness and mission of the school. The overall curriculum has to include the aims of different subjects and contents based on national basis. Also, the teaching methods and the special activities of the school are mentioned in that.

Creating a curriculum requires, from the school society and especially teachers, a continuous development work. The social changes, development of the science and technology and the change of situations in life cause the conditions to change continuously. As a result, the aims and activities of the school also have to change. It is not enough that the school changes as a consequence of these changes coming from outside of the school, but the school also has to change by predicting the upcoming events and development trends. This requires continuous and efficient co-operation between government and all parties involved in the school operation.

The importance of the curriculum is emphasised especially as the guideline of the internal operation of the school. The internal changes of the school, such as personnel movement, should not prevent continuing the schoolwork smoothly. As the pupils move from one school to another, the curriculum of the school helps the pupil and his parents to get briefly familiar with the activity and supplies of the new school. In order to create their own curriculum, they need information of the needed options. Also, the pupil evaluation has to be independent of the school. For this reason, the common evaluation guidelines are a necessity for securing comparison possibilities.

In the following is taken a glance at two curricula valid during the last decade in order to map the learning contents of astronomy, both on lower and upper levels of comprehensive school. At the same time the position of astronomy in these national guidelines can be examined.

7.2.2 Curriculum of 1985

The aims of teaching and education in the comprehensive school have, until now, been set by the Law for Elementary school and the first intermediate report of the Comprehensive school curriculum committee (Anon. 1970, Committee report 1970:A4). Nowadays, the aims are defined in the Law for Comprehensive school. As the internal development of the school is a continuous process, the principles mentioned in the report can also be used in creating the curriculum for a commune and planning the teaching overall. (Anon. 1985, The framework curriculum for the comprehensive school 1985)

According to the framework curriculum, the aims have to be understood mostly as guidelines given by the legislator to advise teaching and other activity of the school. The operations model reasonable from the perspective of achieving the aims that take shape in each education and teaching situation of the school, without a possibility that each of them could be written as separate guideline into the curriculum. In the choice of aims, the question is about values and appreciations. A young person's growth as an adult requires finding the kind of values, norms and ways of life that are relevant from the current situation point-of-view. A young person's set of values does not develop if he is not encouraged to make choices related to values.

Creating the picture of the world for a pupil begins from home and near environment and expands with age to a wider area. A child watches his environment and is interested in everything he sees. These observations also include the phenomena of the sky, the Sun, the Moon, stars, light and dark etc. Therefore, observing astronomical phenomena already begins at a very early age. These phenomena are already handled in the learning contents of the lower level of the comprehensive school within environmental studies. In the upper level of the comprehensive school, they are included into learning contents of both physics and mathematics. This way the astronomy has an important position in forming a pupil's worldview.

The current trend to decrease the learning contents of astronomy as a whole entity is very unfortunate. It is not enough that the issues related to astronomy are included only when it fits to other contexts in physics, but astronomy should also be taught as an own entity in order to create a coherent picture of it for the pupils.

Lower level of comprehensive school

Astronomy is included in the lower level of comprehensive school mostly in the contents of environmental studies. According to the framework curriculum for the comprehensive school in 1985, the general aim of teaching environmental studies is to give pupils information, skills and values that everyone needs in socializing with the society and human culture, and in orienting to biological and physical environment. The aim of informal education is to present the environmental phenomena as problems of which a solution is dependent on observed facts and logical thinking and promotes shaping and organizing the worldview.

According to the curriculum, the contents of astronomy in different grades are the following:

1st grade: The Earth and Sun
The spherical form of the Earth is considered in general as well as the importance of the Sun as a source of light and warmth for the Earth. In addition, the difference between day and night is examined and time concepts are familiarized.

2nd grade: The Earth and Sun
The globe is examined and found to be a model of the Earth. The necessity of light and warmth for the organisms radiated by the Sun is taught as well as seasons and time concepts.

Starting from the third grade the natural sciences learning contents being taught on the lower level of the comprehensive school have been included mainly in contents of biology, geography and craft.

5th grade: The Earth
The map and motions of the Earth as well as the consequent phenomena of those motions, the connection between the motion of the Earth and the time period of day and night as well as the seasons.

6th grade: The Earth
The map and motions of the Earth, as well as the consequent phenomena of those motions, and the planetary nature of the Earth are the basis for the zones, gravity and magnetism.

Upper level of comprehensive school

According to the framework curriculum for the comprehensive school in 1985, one of the aims in teaching physics in the comprehensive school is to expand the pupil's all-round education in natural sciences. At the same time, the idea is to encourage the pupil to pro-actively search for and observe new information. The pupils are given abilities to form their picture of the world.

The contents of astronomy are included in the physics of 7th grade as examples of phenomena of different sectors, *e.g.* the concept of gravity as "gravity on different planets". On the ninth level, astronomy has its own chapter and the structure of the universe is covered there.

The general aim of teaching geography is to give pupils abilities to form a realistic picture of the world with the help of teaching that creates new outlooks and considers various alternative solutions.

7.2.3 Curriculum of 1994

The renewal of the curriculum and related issues are handled in the beginning of chapter 2. An important reform was the less strict national guidelines so that the schools were given the best possible conditions to focus the aims of their own work and define its contents and methods from their own perspective. This way the schools committed to implement the plans more effectively than before. Laying emphasis on the pro-activeness of the schools in creating the curriculum, the active and new development role of the commune becomes emphasized. (Anon. 1994, The framework curriculum for the comprehensive school 1994)

Lower level of the comprehensive school

Environmental and natural sciences is a subject entity where is included the aims and contents of biology, geography, environmental science and civics. The learning process usually goes from observing the phenomena to organizing the basic concepts and using the learned information in the situations of normal life. Environmental and natural science forms a basis for development of natural scientific thinking. The aim of studies is that the pupil learns to form an organized picture of the Earth as a heavenly body and geographical entity and familiarizes with the human activities in different areas of the Earth.

In different fields of environmental and natural sciences there are contents related to astronomy as follows:

> Observing and studying the phenomena of the ground, atmosphere and hydrosphere, seasons, rotating globe, time and times of day. The basis for studying is the pupil's own experiences and observations that can be acquired from different sources. Environment and phenomena of the nature are researched by means that are typical for the stage of life and by using simple means of research and tools. (Anon. 1994)

Upper level of the comprehensive school

Teaching physics gives to the pupil materials that are necessary for developing the personality and modern picture of the world, and it helps to understand the importance of natural sciences and technology as part of the culture. For teaching physics, it is practical to proceed by observing and making measurements to understand the dependencies and interactions of the phenomena in the nature.

Astronomy is included in the relevant contents of physics under the theme ”Structures and systems”. Under that theme are studied basic structures and systems created by both the nature and man that are necessary to understand the picture of the world. As one system of the nature are mentioned galaxies as well as star and planet systems.

Geography has an important responsibility in shaping the global picture of the world for the pupils and helping to understand its regional basis. The aim is that the pupil learns to understand the position and special details of the planet Earth, as well as form the world map. For example, essential contents are the globe, the man's home planet, and its changing environments as well as interaction relationships between the nature and man.

7.2.4 Astronomy in the curricula of my own school

For teaching astronomy, I have created my own curriculum at the very beginning of my teaching career in the decade of 1970. As in the national framework curriculum there is only a short mention of the subjects related to the universe and space research. My curriculum has been adapted for many years according to the pupils, sizes of groups and other physical activities of the school. According to this curriculum, astronomy is taught as part of physics – both as its own chapter and also at other times when it fits the context (*e.g*. in the applications of other sectors). In addition, astronomy courses are provided as optional in 8th and 9th grades. A hobby club for pupils interested in astronomy has been a good way to expand on more details in the subjects that are of interest for the pupils. The possibility for this kind of club is weak in case some of the pupils are dependent on school transport and in that way the return to school is hard to organize. Also, holding the club in the afternoon does not seem possible as the transports are organized every day at the same time after the lessons. This kind of situation is mostly in the schools of the countryside, where pupils come quite far from the other villages. Having been a teacher in Järvenpää near to Helsinki, I had the possibility to act in the astronomy club, but in the countryside school of Vehmersalmi in the middle part of Finland, I did not have this chance for the reasons mentioned before.

The same projects have not been run every year, and the subjects have not been handled in the same extent. Here can be mentioned the kind of main points in the curriculum that have been possible to realize in some form most often. The order of handling the subjects has been always the same in my own teaching of astronomy: from the near environment via the subjects of the Solar System to the phenomena of outer space.

The Solar System: Handling the subject has been started from the near space, planets and Moon and, of course, the Sun. Pupils have been familiarized with the qualities and specialities of each planet. A planet diagram has been built in order to figure out the whole, both in scales of size and distance. These diagrams have been painted on the wall both in the corridor of the school and the classroom. In addition, the phenomena that can be observed from the Earth has been handled, such as seasons, times of day, concept of time, comets, meteors and eclipses.

In handling the subject of outer space, the pupils have been familiarised with galaxies, nebulas, constellations and the Milky Way with the help of videos, slides and pictures. Also, the black hole, formation and death of a star, double stars, quasars, different life cycles of stars and the Big Bang with all the speculations of the future have been handled.

Space research and conquest of space have been covered a little bit less, mostly in project works.

In project work, the pupils have expanded a bit more on the subject they have chosen and have written an essay on it. In group or pair work, as well, they have made posters or written a short essay on that. In general, these works are presented to the whole class in a common feedback session. Project work can also be practical work, like the paintings on the wall mentioned before. Only a short description is written of them listing the steps of the work.

7.2.5 Position of astronomy in curricula in Europe

The international association EAAE (see chapter 1) has organised training courses in astronomy for teachers since the year 1997. Almost all European countries have participated in this action. For the overview of curricula in other countries, I have interviewed representatives of the four countries, which are most active in organising the EAAE training courses during the summer school in Germany in summer 2001. These countries are Germany, Latvia, Spain and Portugal. Sweden was included for two reasons. The situation in the neighbouring country is interesting because of the similarity of our societies. On the other hand, I was lucky to know a teacher there who was willing to be interviewed and enthusiastic to present everyday functions in his school. I had first come to know him at the 3rd EAAE summer school in France in 1999. The situations in the five countries are presented as reviews. Any statistical comparisons or analyses are not convenient here. However, it is interesting to compare in ones mind the different kinds of practices.

Germany

Germany includes 16 states, where each of them has an own ministry of education (Warland 2001). Both the state and the regional administration are responsible for the education in the comprehensive school and in the upper secondary school. The responsibility of the state is limited mainly in making the general instructions and in supporting the scientific research. When lacking the national ministry of education, the conference of the authorities of education gives directions concerning the structures of schools, curricula and contents. So it is obvious that various curricula and practical teaching methods are also seen in astronomy teaching. There are no common directions, which concern the whole state of Germany, nor any practical verification. In the other countries, the amount and the quality of astronomy teaching alter school-by-school and even teacher-by-teacher.

Comprehensive school (10-16 year)
Compulsory courses: In several eastern states astronomy is a compulsory discipline in the 10th grade. The fundamental principle in teaching is 'from near to far'. There is one lesson of astronomy per week. The course includes among other things the components of the universe, observing methods, the solar system, Kepler's laws, stars, galaxies, the aims of the astronomical research and observation.

Optional courses: In each state, astronomy can be taught in the optional course in the 9th and 10th grades. The offering depends very much on the enthusiastic teachers and their astronomical knowledge. Generally these are physics teachers. There are 2-3 lessons of astronomy per week. The contents include: the basics of astronomy and optics, the history of astronomy, observation and observation tools, the structure and motions of planets, the Sun and its importance in the Earth, the physics of stars and star systems and cosmology.

Clubs: There are schools in every state, where astronomy is taught outside of the curriculum for example in the clubs. The lack of teaching and observing tools discriminates however this work.

Astronomy in the ordinary physics: Astronomical applications can be found in geography and mathematics. Physics is the closest application area, but it once again depends on the teacher, if he uses this opportunity or not. Pupils are interested for instance in questions containing in space exploration and solar system. Astronomical associations organise courses in astronomy, general meetings, lending of tools and training courses. The last mentioned training is organised by the European Association of Astronomy Education EAAE.

Latvia

The comprehensive school in Latvia is compulsory and the secondary school is optional (Vilks, 2000 and 2001). Textbooks, even in the lower levels of the comprehensive school, include some astronomical subjects. The most active teachers teach astronomy despite the curriculum, for example: stars, planets and other celestial objects. Some teachers have no courage to teach it even if they wanted to, because they think of not having knowledge enough themselves. The situation is the worst in the highest levels of the comprehensive school. Physics include subjects like gravitation, spectra and eclipses; geography on the other side the Earth, seasons and tides. In the near future, it is expected to have changes because of the new curriculum.

Latvia is one of those few countries where astronomy has been a separated discipline in the secondary school. About 10% of the pupils take this 70-hour lasting course. The curriculum in the upper secondary school will be renewed, and it will include also astronomical subjects. It is disheartening that in the school reform in 2001-2003, astronomy is not any more a separated discipline, but is included in physics and science courses. Although the course consists of only 20 hours, it can be seen as positive that all the pupils go through it in connection to one or another discipline.

A few astronomical textbooks have been published, but teaching tools are quite a few. There are no Internet-connections necessarily in all the schools. Instead, pupils have participated in annual competitions in astronomy and also in the 'Astronomy-On-Line' – a competition organised by EAAE.

Spain

The education system in Spain has been renewed during the last few years, but still both the new and the old systems are in use (Ros, 2000 and 2001). The states may define by themselves the educational affairs, but the government defines the general instructions. Curricula in different areas deviate only a little from each other. There is a general curriculum for all pupils in the upper levels of the comprehensive school, but it is possible to make emphases in different sciences. In addition, two optional disciplines can be chosen.

> Astronomical contents include in scientific subjects. They are:
> - solar system, and sizes and distances of its components
> - position of the Earth in the universe
> - Earth as a planet, motions of the Earth and Moon, phases of the Moon, seasons and eclipses
> - universe, its components, dimensions, and observation methods.
>
> In connection to these, also greater subject matters are covered, for example the prediction of the motions of the Sun and planets, the connection of the natural phenomena in the motions of the Earth and Moon, observation by naked eye and with simple observation tools, the explanation of the day and night, the utilisation of the scales when exploring the universe, and the idea of the various universal models in the history of mankind and the comparison between them.

Teaching astronomy and the time used on it depend, as also in other countries, in a great part on an interest of the teacher himself and the background of his studies. The share of astronomy in teacher training is unfortunately small.

Portugal

In the lower levels of the comprehensive school (6-10 year), the basis of astronomy is taught in sciences (Martins, 2001). As the first subject comes the Earth, and locations of different countries on the globe will be clarified. After that a perception of the Earth as a planet will be broadened; the Earth will be placed as a part of the solar system. The Sun and its importance on the Earth will be generally studied, as well as the significance of the light. This leads to ponder differences between the day and night, maybe also the seasons in general. Locations of other planets and the essence of stars can also be considered a little bit, and also other phenomena – like for instance, the life.

In the upper levels, on 7th grade (12-13 year), pupils study sciences. The subject Earth will be covered in detail in many points of view. These are, for example, its geological and historical background, motions and structure. In addition, the astronomical position of the Earth and its significance as a component of the solar system will be specified, also as the importance of the Sun for the Earth and the location of the solar system in the universe. On the 8th level of the comprehensive school (13-14 year), physical and chemical studies will be started. Matters, which humans and the universe are consisted of, will be studied in chemistry. In physics, astronomical subjects mainly come out when clarifying the structure of the universe, but also in electricity, acoustics and optics.

Sweden

Astronomy is not a separate discipline in the comprehensive school (Grindahl, 2000). Subjects contained in it are included in the contents of physics, for instance in the contents of cosmology and atom and nuclear physics. For the first place in physics, dimensions from the largest distances in space to the smallest parts of the atom are covered. Also, concept of time from the birth and the age of the universe to the tiny time periods in the atom world are studied. Pupils need to understand events and preconditions contained in the birth of the Earth and the origin of life. These lead us to discussions about the existence and the opinion of the evaluation. Also, aesthetic values are worth learning to know.

After the fifth school year, pupils should understand the motion of the planets round the Sun and the motions of the Earth and Moon. They should also to know how to combine chronology and seasons in these motions. They should already have some kind of astronomical and cosmological worldview.

After the ninth school year, pupils should have a conception about the structure of the universe and the development of the worldview in the course of times. In addition, they should know our solar system and development of stars.

7.3 Textbooks

Textbooks reflect each era's social and educational trends. They also include teaching curricula and other directions. Astronomical themes have always been included in almost all series of textbooks. The most important source materials for astronomy are, however, scientific books and newspapers as well as the Internet.

In this survey it is not the aim to analyse every textbook published during the period of investigation, but the group of textbooks from four publishers on physics, geography as well as on environmental and natural sciences, has been chosen, mainly one on each theme. On the other hand, Weilin+Göös and WSOY have recently merged, so there actually are only three publishers. Since these publishers still use their own names as publishers, the books will be handled here in separate groups. Other publishers are Otava and Kirjayhtymä.

Astronomical themes are searched in the textbooks chosen (listed in appendix 7.4, including abbreviations used of the textbooks under survey) to find out what the facilities are for teaching astronomy. The survey of themes is qualitative. The main purpose is to examine the contents of how astronomy is taught in the textbooks, not to rank the publishers. The results have been presented in appendix 7.5. Included in web page (web 7.3) is a list of the most essential concepts and themes made, book-by-book. Of the textbooks on environmental and natural sciences surveyed, three are textbooks to the 5th and 6th grade. In addition to that, a couple of books for lower level have been included; the first one is for the 3rd grade and the other for pre-school teaching. From the textbooks for the upper grades, only textbooks on physics and geography have been included. That is because the astronomical themes are naturally very common in them. In the textbooks on other subjects, there may be only some occasional mentions as examples of application. .

In the column of themes (see app. 7.5), only the largest themes have been mentioned. More detailed themes have not been separately mentioned. The margin between some themes is a little bit vague because the books use different expressions to indicate the same themes and some themes are handled in a more detailed extent. For example, the concepts “planet system” and “solar system” can mean the same, or “solar system” is a larger entity also including other parts in addition to the planets. The table does not indicate the depth of the theme, either. In the books for lower grades, the topic may be passed over with a mention. The same theme on the upper grades, however, may be handled in a more detailed manner. The difference is not only between the grades, but also on the same grade. Depending on the textbook, the topic may be handled in a cursory or a profound manner. A deeper understanding of the teaching contents of astronomy in these books can be acquired by reading the accurate expressions of the contents (web 7.3). This work tries to give an overall picture of the role the textbooks have in improving the facilities for astronomy teaching. The table shows that the astronomical basics are well included in the textbooks. The books, however, almost totally lack the material on the construction hierarchy (see Chapter 5) and the development of the worldview, which is an essential factor in the development of the child’s personality (see Chapters 4 and 6). The topics are not covered in sequence along with construction hierarchy but in most books there is no logical order. The topics being handled are almost randomly either from the near to the far or from far to the near, some separate topics including.

7.4 Teacher training during the survey

Internationally, the level of the Finnish teacher training is generally regarded as high. Yet both teacher training and pedagogics still have challenges to meet (Karjalainen 1996). One of the reasons to be proud is the university level of training and the broadness of degree requirements for teachers and subject teachers, as well as for kindergarten teachers. Another positive factor is the selecting of university students. A large amount of applicants to the university makes it possible to select only the best of the secondary school graduates. The motivation of the applicants guarantees the normal progress and completion of studies. Going out to work, on its part, helps the student to maintain his motivation. According to the head of the department for teacher education in Oulu, professor Leena Syrjälä, the contents of training and the requirements of degree deserve more attention: that is quality with no simple indicators. The continuous change in the surrounding environment also requires that the teachers keep up with the changes. At the present time, the institutions for teacher training and the schools are far behind.

The head of the department for teacher education in Tampere University, professor Hannele Niemi, also agrees with Syrjälä. She adds that this lag can be clearly seen in technological training as well as in the applications of open surroundings for learning like Internet, hyper media and multimedia. The level of equipment in many of these institutes is far behind the level at home. Niemi states that two important criteria can be set to the teacher training: how does it serve the society and the children and the young at school. The teacher must be able to be independent and critical, and he must have facility to evaluate his work and environment and change his way of action if needed. In addition to that, he must have a desire to influence the society by education. This leads us to survey how those selecting students perceive the concept of a teacher. Do we need innovative and brave teachers who have the courage to approach the child? Both new teachers and teachers with experience and their working community must be encouraged and guided by arranging complementary training. It must give skills to mutual changing of teacher’s know-how, as well as to plan and work together, *i.e.* to familiarize teachers with teamwork.

Syrjälä tells that the ability to co-operate is also needed between class and subject teachers and between institutions. Increasing the flexibility of regulations has a contribution to this. The selection of students to subject teachers should occur earlier than it now happens. Niemi states that the pressure to reform is stronger in subject teacher training than in class teacher training. When starting their teaching the subject, teachers would need at least some kind of supportive training in confronting students' crises and difficulties in learning. Theory and practice should go hand in hand all the time, especially practising in classes and preparing the master's graduate thesis. Teacher training also needs the support of other sciences, such as learning psychology, informational sciences and information technology. Pedagogics itself also needs regeneration so that its appreciation would be higher. Chances to post-graduate studies as well as international publishing should be increased. Although the teaching in various universities is in principle on the same high level, at least the branch institutes can maintain the quality of teaching in spite of restricted options by specializing and taking a good use of local specialities.

Nieminen ponders the weak state of school teaching stating that the level of school in Finland is in international comparisons usually found to be good (Nieminen 1995). However, as a counter example he mentions a weak condition of astronomy, first of all in the curricula, then in textbooks and finally as to the time spent to teaching astronomy. In some schools the situation is reasonable due to a teacher who is competent and enthusiastic. On the contrary, the pupils are very often interested in the subject. Lack of time is the most usual reason for failing to teach astronomy. Lack of teaching materials another, and the third reason is that the physics curriculum has lost one weekly lesson to other subjects. This is why they have been compelled to drop off some teaching material. The teacher, of course, drops off subjects and themes for which he lacks competence. However, the fact is that astronomy is the basis for many things and those things can be found in the curricula of many subjects. There are some propositions for solving the problem. The teacher can guide the pupils to acquire information independently. He can also encourage them to take part in a star club or activities in a local star association if there is one in the region. There is a lot to do in the area of teacher training and a lot to hope for. Astronomy should be included as "almost compulsory" in both lower grade and upper grade teacher studies. Also, astronomical associations could arrange astronomical courses to the teachers. However, it is not certain that the teachers themselves are interested in astronomy and want to study it during their studies or take extra courses while they are working. It is surprising how small the interest is; even the interest that physics teachers may show towards astronomy. The pupils in upper grades are especially mentally in a phase where the perceptions of the dimensions of life might help them to see themselves and their problems in a right size.

It is possible to include astronomical studies into optional studies or study astronomy in addition to the curriculum, merely because of interest. Astronomical studies have usually included lessons and exercises. The status of observation has diminished due to current computer science as well as modern measuring device and photographing equipment. The class-teacher training curriculum has included astronomy in environmental and natural sciences' curricula. The theme there is, however, very narrow, including mainly topics of the globe and the nearest universe, as well as the most usual topics of day and night and seasonal phenomena. The schedule of the class-teacher training curriculum is very tight, only a keen interest in astronomy may allow extra studies in the weekly program.

The expression of opinion of all-round educational school lesson timetable by MAOL ry. presented to Minister of Education, Maija Rask, states among other things that our society needs an adequate amount of citizens who can secure the competitiveness of our industry and the methods to solve environmental problems (web 4.5, see chapter 4.2.2). Reaching of the aims requires from all-round education that sufficient resources be allocated to training in mathematics, physics, chemistry and computer sciences. A good mastery of natural sciences gives a person an understanding of nature and its phenomena, qualifications to understand the meaning of technology and technique in nature protection and in continuous evolution. Improving opportunities to study mathematics, physics and chemistry is related to the increase of the lessons in the basic teaching of these subjects. In the lesson reform in 1985, mathematics and physics-chemistry lost both one weekly lesson per year, causing a clear slow-down in the progress of the studies. The next curriculum reform did not bring any improvement either, although optional parts were increased.

The expression of opinion especially states that the freedom of choice does not work if it only enables a person to drop off the subjects that seem to be difficult. The right to get basic teaching, which meets the needs of the society in a broad sense, must be emphasized. According to the civil servant team set 27.9.1999 by the division of educational and science policy in the Ministry of Education, one weekly lesson per year from 1st grade to 6th grade, from subject groups of biology, geography, environmental studies and civics would be transferred to arts and practical subjects. In addition, a new subject, health education would be included. From 1st grade to 6th grade, physics and chemistry are not taught at all at the time of this research work, a defect that has been noticed also in the LUMA-project. Since the amount of lessons of natural sciences has decreased by one lesson, physics and chemistry teaching cannot be included in the curriculum of these age groups. Studying these subjects should be started as early as possible because the child is naturally curious to natural phenomena and technical solutions. According to the expression of opinion, a good and competent teaching of physics and chemistry creates opportunities to a lasting interest in natural sciences.

In its final statement MAOL ry. presents that when making a reform in lesson timetable attention must also be given to the needs to strengthen the skills in mathematics and natural sciences. This administrative solution helps to reach the goals of the LUMA project and brings an answer to the need of mathematically and natural scientifically skilled people in a society that becomes more and more technical. The association suggests that in age group grades 1-6, subjects such as biology, geography, environmental studies and civics would be replaced by physics and chemistry, and that the curriculum would include an extra weekly lesson per year. In the age group grades 7-9, an increase of one weekly lesson per year is suggested to both mathematics and physics-chemistry. In the upper secondary school, there would also be two courses in physics instead of one and an increase of one advanced course in chemistry (web 1.1 and web4.4).

8 Attitude survey about astronomy and astronomy teaching

The realization of the aims of astronomy teaching is affected not only by educational backgrounds and qualifications of teachers, but also by their attitudes and opinions. The survey of those aspects was made using a questionnaire. In addition to that, some voluntary teachers, who responded to the questionnaire, were interviewed in order to specify their opinions.

8.1 Respondents' opinions on astronomy teaching and on status of astronomy

Respondents' opinions about the astronomy teaching and about the position of astronomy in society were asked in the second part of the questionnaire (App. 7.2, see chapter 7.1). The questions are grouped in six subject matters, with six questions in each group. The subject matters follow mainly the distribution of matters in the first part of the questionnaire, but a more exact picture about teachers' attitudes to astronomy has got by adding some questions about their worldview and social influence. The subject matters in the questionnaire are:

I subject matter - teacher's astronomical education
II subject matter - teaching of astronomy
III subject matter - tools of astronomy
IV subject matter – worldview
V subject matter – teacher training in astronomy
VI subject matter – social influencing

Responding was made by circling the best option in respondent's opinion, using the Likert' scale, where the value 5 means 'strongly agree', 4 'agree', 3 'undecided', 2 'disagree and the value 1 'strongly disagree'. Some statistical calculations will be made for the data, *e.g.* factor analysis, cross-tabulation and correlation analysis.

For analysing the results the subject matters are named by the signs k41-k46 (the last 'official' question in the part I of the questionnaire is numbered by 40). Inside the subject matters the questions are numbered by 1-6, which will be added as the third number in the sign. The signs of the variables are then k411-k466. (Karma 1992)

The factor analysis with five and eight factors will be made about the data. When comparing the results of both analyses one can see, that the contents of the first three factors are almost the same. The contents of next two factors are in reverse order, but because of the small difference of these communalities the order is not significant. The last three factors in the result of the analysis of eight factors are so weak, that for the interpretation of the results only five factors were included, without loosing any important data in the final result. (*cf.* Norusis 1985)

The description of the main stages of the analysis can be seen in the following text.

> The factor analysis was made in many ways. First the rotated matrix (App. 8.1) was taken for the basic data, where the missing values were not replaced with the mean value. Then the oblique rotation was taken to the transformed data, where the missing values were replaced for the mean value. These two matrixes were compared with each other. The factor points (values) were loaded up highest on the same factors in both matrixes except two single values of variables. This means better reliability for the result. The eigenvalues of the factors in percent are 10.7, 6.5, 6.2, 6.0 and 5.2. The total communality of the variables is 34,5 %.

> The analysis for the reliability (Cronbach alpha) will be done to each factor. The highest value in the five correlation matrixes is 0.56, which means that the contents of these two variables are almost the same. The mutual correlations of all the variables in the interpretation of the factors are positive, mostly between 0,2-0,3. The higher correlation means the higher unity of the statements. The correlation between the statements without any sensitive connection to each other is almost zero also in these matrixes (the value of the parameter KMO describing the unity = 0.610 is not very good, see Perkkilä 2002, 164).

The eigenvalues of the factors will be presented as a function of the factors ([factor, eigenvalue] – curve), it is a hyperbolic-shaped, asymptotically the horizontal axis approaching curve (App. 8.2). When checking the start point of the curve or the highest values of the eigenvalues, the same result as deduced from the tables can be seen, it means that only first five factors may be worth including in the analysis of results. With other factors their eigenvalues are too small.

As result of the analysis, next five factors describing astronomy teaching and status of astronomy arise from the data (see chapter 4.4). They will be interpreted according to the contents of variables loaded highest to that factor. The correlations of factors are presented in appendix 8.2.

F1 The all-round educational influence of astronomy
Getting astronomical knowledge actively in many different ways is seen to be very necessary. The Man needs this knowledge in building his own picture of world. The study of astronomy gives the possibility to form a harmonious, on the real world based picture of the surrounding world and the universe. The human being may understand better his position in the universe. Astronomical knowledge can be got in different trainings, by observing, using naked eyes or observing tools, and by following actively the news in the media. Having the basic knowledge in astronomy teachers will be eager to teach it more. The continuing in-service training is also considered important for obtaining all the time changing knowledge.

F2 The emotional influence of astronomy
People feel astronomical phenomena and events emotionally. They invoke in them exotic and aesthetic feelings. These experiences influence on their everyday lives either as an emotional attitude or as reshaping of opinions. These affects can be seen at least indirectly also in the comments of a person both in his private life and in his social decisions. It is very important to teach a constructional picture of the world to the pupils. There is no limit to get some tools for observations.

F3 The interaction with the space technology
The development of the space technology has required the astronomical knowledge. Along with the space flights people’s astronomical knowledge has increased. The interaction has been mutual. Without the development of technology the recent stage of the astronomical knowledge would not be so good. People need astronomy in analysing new information they have got using space technology. The developed technology facilitates also an independent acquisition of astronomical information and thus gives better possibilities to teach it in schools.

F4 The political significance of astronomy
The highest loaded value in the analysis describes exactly the political significance of astronomy. In addition to that astronomy has its importance in the social and international solutions. Indirectly its influence reaches even in warfare, at least through space armaments. The astronomical knowledge is needed also in mapping views of the future of the globe.

F5 The significance of the astronomical education
All teachers who give lessons in astronomy should have at least the basic knowledge about it. Especially in the high school studies astronomy should be an obligatory course. Added to this, it is recommended that basic studies in astronomy should be provided in curricula to be given to all pupils.

8.2 Attitude survey by using an interview

Respondents were asked to give their contact information, if they are willing for an interview. About ten respondents gave their contact information. Four science teachers from the upper levels of the comprehensive school were elected for interviewing. In addition to them, one Swedish science teacher was interviewed because of a very lucky coincidence (see chapter 7.2.5). The same questions (App. 8.3) as to the Finnish teachers were put in English to him.

I made 14 questions on the basis of the both questionnaires to deepen the items and clarify some aspects respondents had given in their responses. I included also in the questions some remarks, which I told to the interviewee for to clarify him or her my intention. Questions were open ones. I made an analysis of the responses by an interpretation. I put together all the responses to the same question and made the interpretation in an essay-like form.

The opinions of the respondents are presented next as listed interpretations of the subject matters. At the end of each interpretation there is a link to the factor (see chapter 8.1) with the same content. Swedish teacher's responses were very much alike with the answers of the Finnish respondents.

Position of astronomy in science teaching (questions 1 and 2)

Astronomy is an advanced and complementary, nearly physics related discipline. There is no more time to teach astronomy if the number of physics lessons will not be added. Astronomy as an optional subject could be separated, but otherwise connected in physics only the basics will be enough. The teacher could improve his astronomy teaching by studying it himself. Astronomy has an impact in building a picture of the world and it inspires pupils very much. (F1 The all-round educational influence of astronomy and F5 The significance of the astronomical education)

Astronomy should be taught in connection with physics or geography, not so much as a separated subject. It could be integrated in physics, in geography and in biology. Astronomy could be taught in an extra course or in an optional course. It influences in the picture of the world at least in the geography; in physics it could be taught in connection with interactions and optics. Its recent position in sciences is too insignificant, thus the number of astronomy lessons should be added in order to teach astronomy more. Some applications of astronomy could be found also in mathematics. (F1)

Astronomy in building a picture of the world (questions 3-5, 7 and 14)

Astronomy has a great significance in building a picture of the world. A person will learn to see his smallness, his position in the universe. Through astronomy teaching the misconceptions about the universe could be corrected. In addition to this astronomy encourages aesthetic feelings and gives a happy state of mind. (F1 and F2 The emotional influence of astronomy)

Astronomical knowledge should give the right concept about human's position in the universe. For instance, the birth of the universe, its development and future, a life of a star, interactions, the solar system, an expansion of space, constitutional parts of the near space, also their sizes and distances – that is dimensions of space, the recent concept of the universe, an observation, effects of forces and all recent subjects in media are important for getting an entire picture of the world. (F1 and F2)

The newest information about astronomy can be obtained in reading literature and magazines. It is important to be a member in an astronomical association. An astronomy club will motivate pupils. Self-learning and participating the courses will keep your own interest in and updates continuously your knowledge. Also TV-programs and acquainting with researches about astronomy are useful. There is a need to develop a person's own astronomical picture of world. (F2 and F5)

Astronomy teaching has an influence in building pupil's picture of world, if the pupil understands astronomical concepts, dimensions of the space and the structure of the universe. Discussion about astronomical subjects will expand pupil's conceptions and increase his interest. It also corrects possible misunderstandings. (F1)

Astronomy has an important significance in people's life attitudes and ways of life. A person will experience very personally the significances of the astronomical subjects. It is good for a person to recognize his own smallness in the universe. Astrology has to be regarded as separated from the astronomy teaching. (F1 and F2)

Contents and methods in astronomy teaching (questions 8-11)

The origin of the elements, the Big Bang, the structure of the universe and physical laws, the globe and the near space, interactions, the difference between a star and a planet, the seasons and the times of day, the Milky Way, the galaxies, the dimensions, different models and the theory of relativity. (F1 and F5)

For instance the rotation of the Earth and the Sun and, in connection with them, the day, astronomical concepts for eliminating misconceptions, the structure of space and the birth of elements, constructing models, determining dimensions of space, properties and distances of the planets, the structure of the solar system and also the distant objects, powers of ten in distances and things near the globe. (F1 and F5)

Rather correct conceptions than correct concepts should be taught. It is important to correct misunderstandings in teaching. The concepts have been specified universally, and they are exact. The conceptions are personal. Conceptions should be tested in the school exam rather than concepts. The hands-on test is better. The general impression will be constructed with different concepts. (F1 and F2)

Events in the sky progress slowly, so long-time observations and long-time empirical experiments are not relevant in the school world. Telling about things, discussion, storytelling, drawings, computer programs, models, videos, slides, different kind of presentations, hand measures, preparing simple tools and reading literature or magazines are good methods. They inspire or add pupils' interest in the astronomical subjects. (F1 and F2)

Teacher training in astronomy (questions 6, 12 and 13)

Teacher may study new astronomical concepts and knowledge on his own, and apply them in teaching physics, mathematics and chemistry. There should be more new computer programs. Astronomy courses and different kind of activities should be organized much more, too. Astronomy teachers should participate in them, and so improve the quality of their teaching. The lack of tools could be a limitation to teach astronomy, but it has not to be like that. The lack of the teaching instructions and materials requires the teacher to develop them himself in addition to teaching. Observation is often experienced as difficult, as well as lack of money, weather conditions and lack of tools. (F1 and F5)

Teachers should have basics about astronomy. Teacher himself should have the correct conception about the structure of the universe. Self-studying, the use of the experimental and observational methods should be taught. Astronomy courses mainly on their own place are desired, but collective education could make the quality of teaching better, because more experts can be used as teachers for the bigger group of teachers. More astronomy courses should be added in the teacher training programs. In addition to that the didactic courses should also be offered to the astronomy teachers. (F1 and F5)

All the teachers should have a conception about the structure and the dimensions of the universe. Teachers from the different levels of the school should get a different kind of astronomical education. The didactical education in astronomy should be included, as well as methods for observation. In the teacher training there should be a compulsory course in astronomy. Also the use of Internet should be taught teachers. (F1 and F5)

Evaluation of the questions as a feedback of the interviewees

Interviewees felt the questions as understandable. Responding is sometimes difficult because they don’t remember everything, which happened with the pupils. Some questions go deep to the philosophical thoughts, but mainly they are diverse and clear, not leading. They are targeted very well to the significance of astronomy. Many questions are difficult to answer right away. Some of them are difficult to answer because of their depth. The questions cover well the conception of the problems in the school teaching of astronomy, and the need to develop science teaching is seen very well in them.

When comparing the results of the interview with those of the factor analysis we can see that *e.g.* the space technology was not mentioned at all in the interviews, neither the politics. The most underlined thing was, as expected, the all-round educational influence of astronomy (F1). As the second interest in common there is the significance of the astronomical education (F5), maybe the similar contents of them. The feelings join very closely in the astronomy education and observations (F2). The positive experiences will increase the motivation for studying, as in all the other subjects, too.

8.3 Consideration about questionnaire and about attitude survey – study on validity and reliability

The questionnaire in order to map preconditions for astronomy teaching (see chapter 7 and 8) was tested by ten other teachers from the same school level as the teachers in the research. The testers and the ordinary respondents filled in the questionnaire on the same way considering particularly the circumstances (precision, honesty, intelligibility). All the testers returned the questionnaire, but only 52 % of the ordinary sample did the same (see chapter 7.1). In addition to that, it is arguable to assume that the responds of the non-respondents would make the same distribution as the recent result. All these remarks will support the validity of the questionnaire (Cohen 2000, 128-133).

In consideration of the reliability Cohen compares with the strong and weak points of the questionnaire and the interview. Returning a questionnaire anonymously will guarantee in his opinion a greater honesty in responding. In addition to that the questionnaire is economic – the postages are small compared with the expenses when making interviews in different places. As disadvantages Cohen mentions the minor return percentage and the different kinds of interpretation of the questions. When planning a questionnaire it has to be taken into account also the quantity of the open and closed questions. Too many open questions may not be answered because of the lack of time or because of the unwillingness. Too many closed questions may attempt them to answer ‘lightly’ without thinking about the subject more deeply. In this sense the interview is more reliable, because the circumstances could be changed during the interview, if needed, and make some extra specifying questions and thus ‘force’ the respondent to speak out about the subject under discussion (Cohen 2000, 253-282).

When planning my own questionnaire I tried to take into account those points of view mentioned before. In the questionnaire there are both open and closed questions – the former ones nevertheless obviously less. Some questions are so called half-open, which means that they have pat answers, but the last choice is open. The respondents used this possibility very rarely. The open questions were the most non-answered questions, so the small amount of those questions was a good guess.

The quite good return percentage of the questionnaire depends partly on all those aspects mentioned before, maybe the possibility of responding anonymously and in a short time, and the intelligibility of the questions were the most inspiring points. The intelligibility came out when analysing the results, because there were no ‘misunderstandings’ or counter-questions. These aspects will add the reliability of the research. In my opinion the low number of the interviewees was sufficient, because there was no intention to make extended statistical explorations at all, but only to deepen the description of the teachers’ attitudes. This aspect had to be taken into account when determining the size of the sample – big enough but not too big. (*cf.* Perkkilä 2002, 161-166)

The results of the questionnaire and of the interview (see chapters 7 and 8) show clearly, that teachers wish training courses in astronomy both during their studies and later in the in-service training education. On the same way in all the results concerning the exploration of preconditions one can see appreciation to astronomy and significance in the all-round education, in the emotional education (see chapter 6) and in building a worldview. The parallel results from the questionnaire and the interview will confirm the reliability those results. The same conclusion can be made when comparing these results with those of other mappings (see chapters 4 and 5). The scope of the results has to be seen as good, because the schools in the sample were elected systematically, after determining the start point randomly, and the sample covers, in regional, linguistic and educational aspect, equally the whole guild. The explorations can be repeated with the same kind of practical arrangements. There is no need to reformulate questions - perhaps some specific questions may be removed.

IIIB Overview of experiences

9 Experiences and thoughts about astronomy teaching

At first in this chapter, certain persons convey their opinions about the contents of astronomy courses and their experiences about the ideas for astronomy teaching. Even if these opinions and experiences are individual attitudes and are not based on the scientific research or mapping, in this study they still have their own significance when making choices about contents and methods in planning astronomy teaching. Next I present some experiences in other countries. Third, I will present my experiences about different kinds of activities in my own astronomy teaching and in the international summer schools of astronomy education (*cf.* web 1.2). The purpose is to give an incentive for putting into practice the structural astronomy teaching presented in chapter 10. Hopefully, some teachers would like to develop additional ideas on this, thus further improving the development of astronomy teaching.

9.1 Experiences in Finland

In the public discussion about teaching astronomy in schools at the astronomy festival in Tampere (1986), a representative of the National Board of Education presented research results concerning learning astronomy in school (Mäkinen 1986). According to the research, about one third of the pupils on the ninth level had adopted the physical conception of the world and knew the structure of the universe. In Mäkinen's opinion, if there are no changes in teaching, only the most intelligent pupils will get an updated conception of the universe, because they are going to familiarize astronomy by themselves. According to that existing curriculum, some subjects about the Sun and the Earth and the position of the dates of times will be covered on the first level of the lower comprehensive school. The same subjects are also covered on the second level. Handled in the fifth level are the consequences of the motion of the globe, while on the sixth level the climate and the vegetation zones caused by the planetary properties of the globe will be discussed. It is not until the last level of the comprehensive school that the universe will be handled more exactly (see Chapter 7.2.2.).

Mäkinen also tells about the other discussion in the astronomy festival, where some teachers conveyed their opinions and experiences about the school teaching of astronomy (Mäkinen 1986). Teachers think the understanding that pupils obtain about astronomy depends much on the textbook used. In addition, it depends on the teachers and the time used in astronomy teaching. These teachers have given astronomy lessons mostly on the two lowest levels of the comprehensive school. Some suggestions for improvement were also revealed. One teacher was told to have changed the period of astronomy teaching to the beginning of the term, so there would surely be time for astronomy. Discussed during the first three lessons, would be space exploration, the recent conception about an origin of the universe, the stars' activity and structure, and some information about the particle physics in finding out the structure of the picture of world. On the second lesson they have discussed the solar system, planets and data received from the probes. On the third lesson they have studied more exactly the universe, the life of the star, the possibility of life in the outer space, galaxies and the future of the universe. One teacher thought that astronomy teaching in school was too formal, lacking the human dimension, thus he felt that school clubs were very important in giving inspirations in astronomy teaching.

As in one remedy against teachers' weak astronomical knowledge, there came out a suggestion that a teacher should study those subjects himself that he is going to teach. Another suggestion concerned having in-service teacher training for improved astronomical knowledge. In the discussions it also came out that many science teachers have been disappointed with replacing astronomy in the geography teaching. If possible, the use of a planetarium in astronomy teaching was commonly seen as desirable. For school children there are special programs about astronomy in addition to the commercial planetarium programmes. According to a reader survey made by a magazine 'Tiede 2000', astronomy is kept as a most interesting discipline. The reasons for that are 'Star Wars', space flights, science fiction and new findings. In teachers' opinions the growth of astronomical concepts and information requires an increase of the astronomy teaching. In addition to the preceding astronomy clubs, experts from outside the school are also useful. They can be asked from different kinds of associations or institutions. Usually they have with them some supplementary materials, which cannot be acquired for the school. In the festival, astronomical associations were encouraged to offer to the schools their experts to instruct about the stars and the universe (Mäkinen 1986).

During the festival, pupils in the seminar also had an opportunity to express their opinions about astronomy teaching (Mäkinen 1986). Among them was the opinion that in the upper comprehensive school, astronomy teaching in geography has concentrated on the solar system while the rest of the universe was handled in six lines of the textbook. In physics one can find only some hints about astronomy. Pupils think that the teaching of astronomy should be expanded, but only by deducting from the other disciplines. In the upper secondary school, astronomy can be found mostly in the courses of history, in connection of subjects related to ancient conceptions. In pupils' opinion, although it is known that the Earth is no more located physically in the centre of the universe, in the minds it is easily placed in the forefront in the historical way, particularly in the context of classical physics. There are two worlds in the worldview in school: the Earth, and the space which they think to be useless and insignificant for us. Even if astronomy is seen to be interesting, the cause in its weak position, especially in the secondary school, is taken for granted to be on the student exam. There is not much astronomy asked in that! To integrate astronomy with the other disciplines has been used a little, but the teachers' weak astronomical knowledge will make it more difficult.

Karttunen explains "one should be able to take the ordinary things about astronomy in the teaching and not only play games with exciting and exotic subjects" (Karttunen 1982). In his opinion, it is more important to explain the idea of the theory of relativity than to consider the secret of the black holes. In the environmental studies in the primary school, the day and night period and the seasons are taught. Also, the phases of the Moon are explored. It is of no use to teach detailed numeric data, even in the upper levels, if they can be found in the tables when needed. Karttunen includes in the syllabus of astronomy the solar system with the planets, stars, the Milky Way and the galaxy systems and some information about the distances and scales. The solar system is the nearest for us and we can observe its parts, so it has to be taught most exactly. For instance, the birth of planets, their contents and motions around the Sun, the Kepler's Laws about the revolution and the influence of the gravitation to the motions of propagation and revolution belong to this subject. In illustrating this, Karttunen believes it is a good idea to use different kinds of models.

Pyykkönen considers it very important in the all-round education to teach the composition and the behaviour of the universe (Pyykkönen 1995). The exact nature of laws rule the space and everyone should know his position in the universe. Pyykkönen classifies clearly the most important contents and methods in four basic groups:

- In the first subject there belongs the formation of the solar system and its parts, Kepler's and Newton's laws taking into account the level of pupils, the Northern lights as a phenomenon of atmosphere, the halo effect, thunderstorms and luminous night clouds.

- The second subject includes basics of the space outside the solar system, such as the structure of galaxies, the location of the solar system in our galaxy and the scale of the space. It is important to also teach the lives of stars, categories of spectra, powers of ten and production of energy.
- In the third subject the composition of galaxies, groups of galaxies, their movements and connection to the birth of the universe are considered more specifically. The cosmological subjects are seen as interesting problems.
- The fourth subject consists of teaching methods and teaching materials. Pyykkönen wants to highlight the old good blackboard again. A lot of written materials are available nowadays. The outside expert of astronomy may give a presentation about the favourite subject. Also the visit to an observatory or a planetarium gives emotional experiences in teaching. Every pupil should have experiences about the very important night sky observation by naked eye or by binoculars.

Tuomi suggests to explore the most common phenomena and objects (Tuomi 1999). He thinks it is good to start astronomy teaching from the Sun and the sunspots. About the constellations, he would teach the most well known ones which are seen in Finland. Also, he believes it is useful to observe planets, the Moon, artificial satellites and auroras. When observing by telescope the objects of interest are satellites of Jupiter, galaxies and clusters of stars. The students may observe their favourite objects also by binocular instead of observing by telescope. If there is no possibility to obtain a telescope in school, binoculars are the only sufficient enough tool in addition to their own eyes.

Markkanen explains that the teaching of astronomy is seen very important in nearly all areas (Markkanen 1982). In his opinion, the astronomical subjects can be found in the contents of environmental subjects, geography, physics and even history. These contents have to be selected very exactly because of the lack of time used in teaching. He also thinks that *an astronomer* should determine the contents of astronomy for schools, and that after that the schoolteachers make a decision about the period and methods. Markkanen groups the topics in the six subject matters and recommends that in addition to these, certain basics, such as the Moon phases and the seasons, be taught to every pupil.

- The first subject consists of the Sun as a star. The stars are, in his mind, the central unit of structure in the concrete universe. The greatest part of the observed matter in the universe is in the stars. The composition of the Sun, its age, temperature and radiated energy are the most important concepts contained in the Sun. Also it is important to tell about the significance of the Sun to the Earth, about the development of life and about the energy stored in different ways.
- In the second subject the evolution of stars and the production of elements are discussed. The possible lives of stars tell us that space is continuously under construction.
- At the third subject, we explore more specifically the birth of stars and generations of stars. In the stars, more and more heavy elements are born and when the star is dying they may be ejected to the space and be used as building material for new stars.
- The fourth subject consists of the system of stars and interstellar material as well as the Milky Way more exactly. The distances of both celestial objects and stars are compared with each other through the distance travelled of light. The depth of the space can be illustrated by different kinds of scale models. Also the spiral structure of the Milky Way, its dimensions and the locations of stars in it can be illustrated by simple tools.
- The fifth subject discusses different kinds of galaxies. Markkanen thinks that it is useful to concentrate to teach only different forms of galaxies, observation of galaxies and their mutual interactions.
- The sixth subject discusses cosmology, where the future of the universe is considered. The interesting findings are the connection between the escape velocity of galaxies and the distance, and the connection between Hubble's constant and the age of the universe (*cf*. Karttunen 2000, 536-538; Gribbin 1996, 19 and 209-211), and the unique microwave radiation from all over space.

Astronomical subjects in the research area of geography contain in the qualities of the Earth, like the shape, the size, the spatial location and the movements, and their determinations. Rikkinen includes in the geographical thinking, for example, the Earth as a spherical planet circulating the Sun (Rikkinen 1998). The teacher should be able to contain the environmental geography taught in schools to the more expanded spatial entity based on the planet-like phenomena. For instance, these kinds of subjects are the alternations of day-night period and seasons, and a concept of time.

Rikkinen also underlines that in the environmental science the global subjects are in focus (Rikkinen 1998). In her opinion, modern children have lived all their lives in “the space age”. They know very well, for example, concepts such as space flight, satellite, dockings of spacecrafts and the Mars explorer. They obtain more knowledge about these subjects from the astronomical adventure stories, novels and movies. Thus, the geographical worldview of the children who now start their schooling is quite different from the one of children in the 1960s (see chapter 4.3.1). On the other hand, there might be a threat that the teacher may imagine his pupils knowing about things much more than they really know. The teacher might overlook many things as self-explanatory, thus providing some misunderstandings to the pupils.

A visiting researcher offers experiences and can expand pupils’ point of view in the subjects they learned (Valtaoja, Engeström 1995). Valtaoja thinks that it is easy to entertain pupils with astronomy. Physical phenomena could be contained in all the astronomical events. For example, everyone is interested in the black holes and in time travelling, without speaking about astrological things like UFOs and horoscopes. Even if pupils know quite a lot about the universe, it doesn’t mean that the astronomy teaching is in order. Valtaoja believes that learning about astronomy depends very much in the teacher’s interest on the subject. Astronomy should be included in the curriculum and it should be taken into account in the teacher training. When speaking about astronomy, what generally comes to mind first is an observation by telescope, an astronomy club or a visit to a planetarium or science centre.

Valtaoja tells of another way to benefit the knowledge of an expert by inviting a visiting lecturer to the school. The excited pupils have planned their own series of lectures by asking experts to speak about different subjects and a chance, for instance, to visit the observatory. The aim of this “course of the conquest of the universe”, as pupils named the course, has been that the school children interested in astronomy can have discussions with the experts in this field. As the second aim, there came out a possibility to get actual knowledge. The third aim was that all the pupils interested in the same subject could come together from the several schools. Since the series of lectures has been organized outside the school and not on school time, it gives much more appreciation to the pupils interested in astronomy.

Quite an unusual teaching method was used in the Järvenpää upper secondary school. They made observations by computer, using an Internet to connect their computer with the computer in Mount Wilson near Pasadena in USA (Ketolainen 2000, web 9.1). As the first school in Europe, the pupils have been connected by modem. With the help of the local system manager on the big telescope, they have taken pictures and looked at those pictures on their own screen. Live on the phone, the system manager gives hints about nice objects and right exposure times for photographing. The pupils can steer the telescope with the computer program in Mount Wilson. It has been a historical moment to print out the first pictures: the first school and the first pupils in Europe steering by computer the telescope in Mount Wilson! The location of Finland to America is very suitable for using the telescope. When the schools start their work in the mornings, in America it is midnight, an excellent moment to observe the starry sky and take pictures. However, everything does not always go well. The weak connection with a modem or breaks in connection may prevent the unbroken printing of pictures. The local weather conditions also have to be considered.

A great experience to both the pupils and the teacher is photographing celestial objects together. When photographing the night sky on the sensitive film, Von Bagh has fixed the camera in the telescope's side and has turned the scope so that no chinks of light are formed on the film, *i.e.* stars are seen as point-like in the picture (von Bagh 2000). The completed pictures can be clued on the black cardboard, and then scanned for reducing in the computer. The printed 'reduced' pictures can also be copied as transparencies. Thus, a great number of pupils may explore the sky at the same time. Photographing the Sun requires secure protection methods. When observing the Sun together with the pupils, the safest method is to make a projection of the image of the Sun in the large cardboard box with the white paper sheet in the bottom. More than one pupil at the same time, can observe the large enough projected image. They may see sunspots, an alternation of the brightness on the surface of the Sun, a quivering of the atmosphere, and also realize the rotation of the Earth because the image of the Sun is not stable for a minute. The image of the Sun could be photographed even in sequence on some days, so the changes in the location of the sunspots, their shapes and sizes can be explored. The orientation of the telescope to the Sun can be done most successfully with the help of the shadow of the scope. The scope is pointing to the Sun when the shadow is smallest and most circular. It is wise to remove the ocular when orientating the scope.

Virtasola explains in her article about the astronomy club in Kinnula, that a club may 'give rise to' an incredible amount of activities, such as ones that wouldn't even occur to the uninitiated (Virtasola 1985). In the article, Arvo Kuusela, the person who maintains this club, describes the action of the club as follows: "In addition to observing and learning the subjects of the solar system and the starry sky, many club members have had the possibility to plan and draw posters and brochures, to devise and to construct different kinds of equipments, to fill in forms and to write letters, to learn to type, to photography, to making computer programmes and to program and steer the machines in the planetarium. Club members may also watch some programmes by video, and be with to plan and set up astronomy exhibitions in different places. Therefore, the hobby is not so one-sided as it sounds at the first hearing, and in addition to the 'heavenly' things, the young children learn many facts and skills as if an offshoot".

9.2 Experiences in other countries

Sneider tells about his many kinds of teaching experiences in astronomy and presents five methodical based ideas in the learning process of astronomy (Fraknoi 1995). He believes the most important teaching methods are learning by questioning, amending misunderstandings, explaining phenomena and happenings, understanding phenomena and constructing a picture of world by observing and by using models (see chapter 6.3.1). Sneider wants to teach his pupils to be an astronomer. He allows his pupils to use tools and measure equipments, and let them construct models about phenomena they observe. These teaching methods are used instead of studying theory. He gives an example about one situation in teaching, where the pupils have difficulty understanding and explaining the phases of the Moon, the shadow caused by the Earth on the Moon's surface at the time of the eclipse of the Moon, or the clouds in front of the Moon. Sometimes the conception has been that the dark area on the crescent phase of the Moon is caused by the shadow of the Earth!

It is not a new thing to reform science teaching, as a high-level science teaching has been available for decades. As Sneider says: "the educators, the scientists and the teachers have considered about reforming science teaching since at least the year 1980" (Fraknoi 1995). Among other things, the most important problems that came out in these discussions are:

- utilise national special characteristics and personal skills
- persuade special groups of persons (girls, ethnic minorities) to study sciences
- encourage to explore phenomena and to solve problems instead of studies of concepts and theory
- know specific astronomical subjects at the end of studies and
- find connections between science, mathematics and humanities.

The same kind of considerations and concern can be seen in the list as in the developmental discussions contained in the modern school and curricula. Teachers are encouraged to use new teaching methods in their teaching instead of teaching theory, like exploring phenomena, creativity, empiricism and problem solving. The best teaching methods in astronomy are both educationally efficient and humorous. Sneider thinks that teachers who use new teaching methods besides the textbooks, allow their pupils to spend extra time in the laboratory for exploring and questioning.

Hubble has presented a conception about the methodology of astronomy teaching, according to weather an original approaching method in astronomy teaching has been an observation and experimental working (Crowe 1994, 1-5; see chapter 5.4). He sees history as a long series of experiments and science as an only cumulative and progressive field in learning. Observation and theory should be separated branches, because theories are, in his opinion, temporary and astronomical observations and laws permanent. The discovery of new observation tools and the development of the properties of old tools have improved in the development of astronomical knowledge and teaching methods, too. As an example Hubble gives the discovery of the telescope.

One of the most modern exploration tools is a CCD-camera (charged-coupled device), which is easy to use even in schools and which can be connected in the computer. It can be used when taking photos about the numerous phenomena of physics and also of astronomy. The computer is used to record and handle the data received from the research object. With the combination of these devices, it is possible to construct many astronomical events, to change circumstantial factors and to find out their influence in events. Pinto has used this devise with his pupils, and he highlights in the article the pedagogical importance of this kind of teaching method (Pinto 1995). When the computer makes the calculations and the analyses fast, there is plenty of time left to discuss with pupils in classroom about the phenomenon and to think over the reasons and consequences when circumstances change. For example, on the construction of the celestial event recorded by the camera, Pinto mentions illustrations of Kepler's Laws, the discovering of Neptune and a precession of the perihelion of Mercury. The possibility of the use of technology described in the article may enrich in parts of the curricula and the contents of these sciences.

Astronomy and history may utilize each other in a very interesting way. Blais describes the idea he figured out to present the historical events with the distances travelled of light (Blais 1993). The distance of every star is expressed in light years, so he connects the historical event to that star, whose distance in light years is as much as the number of years from the event. Blais explains that especially the younger pupils' search eagerly for that star from which the light has emitted at the time of their birth. As a bad side of this method, it has to be mentioned that this mapping should be done over and over again, because the period from the historical event grows all the time and the star connected to that event will change. As a merit of this method, it could be mentioned an illustration of tri-dimensionality (depth) of the celestial sphere. Also the religious and social events in addition to history could be illustrated with this method.

Burris has made a funny astronomical mathematical exercise with his pupils for motivating them to study physics (Burris 1993). There are many kinds of motions in the universe, which cause an explanation of the stage of the celestial object as very complicated. For instance, a person on the surface of the Earth moves in different directions, the globe is rotating around its axis and is orbiting the Sun, the whole solar system is orbiting the centre of the Milky Way and so on. Burris starts his astronomy teaching on the familiar environment of every pupil, by driving by car in traffic. It is a penalty of speeding we are talking about. Besides the normal penalty, he is fined the speed when rotating on the surface of the Earth and when orbiting the Sun and the centre of the Milky Way. The latest speeds are astronomically big compared to the speed of the car, so the penalty calculated from every speeding is millions. He illustrates motions within each other by showing a model containing in every new speeding and by demonstrating concretely a person's movements that belong in each situation.

Burris finds many other interesting subjects from the micro- and macrocosm for motivating to study physics. Even correcting misunderstandings may inspire interest for pupils in science. Burris gives three good examples about this. First he tells about the incorrect picture of mind containing the present time. The light emitted from the stars outside the solar system has been travelling for years, so the light we see tells us about the situation in the past years, not in the recent days. When we look at the starry sky in the evenings, we almost never remember that the sight is very old and we don't know anything about the recent moment. Another example contains in the construction of matter. Atoms are in a great part an empty space. So the matter is mostly an empty space. The third example is contained in the mental picture about staying still. We are falling all the time in the field of gravity. Burris gives – a little out of question – an illustrative example about this. He thinks that a person is then falling parallel with the field!

Tebbutt tells about various illustrations and empirical experiments (Tebbutt 1994). At first he explains the use of the traditional sources. For instance, such things are maps, posters, books, slides and videos. The pupil may observe himself the celestial objects and phenomena, and learn through them. Pictures inspire an imagination in constructing pupil's own view of the world. The computer programs and materials from the Internet interest pupils to get themselves more knowledge about the universe around them. Tebbutt thinks that phenomena can be simulated very impressively. As examples, he mentions the phases of the Moon, the motions of the satellites of Jupiter and the motions in the solar system. Pupils may also 'travel' in the spacecraft and make different kinds of 'real' activities during the trip. Even a great number of the newest images can be loaded from CD's. The databases, various other packages of data and hypermedia are available very commonly for the pupils in these days. Pupils may be set in groups, and every group will prepare one subpart of the subject to be studied, and presents it to the others. At the same time, they learn scientific writing. Secondly, Tebbutt demonstrates the construction and the use of various teaching aids. The most common may be a sundial. It is easy to make in every school from cheap materials. Also simple star maps and plan-spheres can be prepared. In addition to the sundial, there also exists the more unknown night clock. The photos from the night sky can be found also in puzzles. Tebbutt thinks that simple models are popular subjects in building models. The most common may be the model of the solar system build as two-dimensional or three-dimensional. Also, it is easy to show the phases of the Moon and the eclipses to all the pupils in classroom at one time. The model of the celestial sphere can be found at least in the planetarium of mini-size. It can also be made on the transparent material and paint in the several levels and celestial bodies. When rotating this celestial sphere around the north-south axis, pupils may sketch in their minds the movements in the sky. Visit to a large planetarium is very educational for pupils, too. They may feel there to be in the focus of 'real' happenings, just as in nature.

Nielsen tells about the International Astronomy Olympiad (IAO), which has been arranged in the autumns in Mount Caucasus since 1996 (Nielsen 2000). There, the talented pupils will compete about their knowledge in astronomy and astrophysics, meet new friends and get familiar in the foreign languages and cultures. Olympiad was founded by an Eurasian astronomical association. Nielsen states that the purpose of the game is to help young people develop their astronomical knowledge, to guide them to choose scientific subjects and to encourage them to teach these subjects in school. The competition consists of three parts: theoretical, practical and an observation based part. The pupils may use only a calculator when solving the problems in the theoretical section. In practical sections, for instance, they have to analyse results of measurements and make some calculations. For example, as the observational-based task they have had to explore sunspots, to make them in a graphic representation and to compare the results with those values got by the large telescope. Also observation by naked eyes and by telescope has been done during the dark hours of the evenings.

Meidav and Netzer have tested an extraordinary teaching method in the first International Astronomy Olympiad (Meidav 1995). In this experiment, the competitors were tested in their real understanding and knowing. The public was able to follow this competition all the time. The competitors got a handout of pulsars, which included intentional factual errors. They had five minutes to try to find from the text in the next-door classroom as many errors as they could. Meanwhile, the public was informed about the pulsars, so that it would be easier for them to follow the evaluation of the results. The weak result of the test could be explained, in addition to the ignorance of competitors, also their misreading or misunderstanding. Even the right things were marked as errors. As comfort can be seen, the same competitors were very successful in the traditional parts of the competition.

Levy tells about the use of a notebook or a club diary in his teaching (Levy et al. 1997). Pupils write down celestial events whether together in the lessons or in the club, or each one at home. They document about their own observations made by the naked eyes or by a telescope, or they write down astronomical measurements. Levy organizes also astro-camps for pupils, whose program includes – in addition to observations – discussions about ‘eternal’ problems and existence.

On his part, Francis, uses role-play games in his astronomy teaching (Francis 1999, web 9.2). He groups the pupils into small teams, with two or three persons in each, and provides a worksheet to each group. The group members ponder, first by themselves, a solution of the problem or the mystery presented in the worksheet. They may visit other groups, too, and have discussions about their facts. The group, which first finds a solution to their problem, will win the competition. Francis has noticed that pupils are generally very concentrated working with their exercise. In his opinion, the same kind of teaching method is also suitable in physics, especially on the upper levels.

Hickman illustrates the phases of Moon and the eclipses with the simple model of Earth-Moon-Sun (Hickman 1993). A pupil may imagine himself as a globe and explore different phases of the Moon with a lamp and a small ball. With this model the day-night period and the eclipses of the Sun and the Moon can be demonstrated. Hickman may ask his pupils to find answers concerning the location of the Moon, its phases and the period. For example, they have to determine the location of the Moon, when the period and the phase of the Moon are known. On the other hand, they may be asked to determine the phase of the Moon, when the period and the location of the Moon are known, and finally the period, when the phase and the location of the Moon are known. In solving these problems pupils certainly have to consider the occasions. Using a model makes it much easier to find the solution. With this model, Hickman thinks it is also easy to prove that the first quarter could be seen together with the Sun only from the midday to the sunset time, and the last quarter only from the sunrise time to the midday. Hickman also claims to be able to prove with this model, that the full Moon can never be seen in the midday! In reality the full Moon can be seen in the midday, *e.g.* in the northern Lapland in midwinter.

Some of the simple astronomy teaching tools can be used in an illustration of the common physical phenomena. Mancuso and Long have used for this purpose a tool by the name Astro-Blaster (Mancuso 1995). There are different sized elastic balls stuck on the stick, in order from the biggest to the smallest, and the stick is thicker at the end where the small balls are. The biggest ball on the bottom is fixed on the stick. The two balls in the middle may move free, but on the top they are stuck because of the thicker stick. With this model, many an astronomical phenomena can be illustrated, like the preservation laws of momentum and energy in the birth of supernova, the explosion of the outer shells as an impact of a shock wave, the origin of the cosmic radiation and the collapse of the dying star because of gravity.

Eckroth has prepared from cheap materials various tools for modelling a curvature of space (Eckroth 1995). For instance a saddle-shaped model will occur, when the thin sheet is stretched between the two flexible strings of metal or band, and they are bent in different shaped bows. The intersection of the ends may be parable or hyperbola. The surface of the sheet is a negatively bent two-dimensional space presenting one of the theories of the Big Bang. In Euclidian space (curvature is zero) the lines are straight.

The reason why we have the seasons is not often clear for pupils. Eckroth claims that this faulty conception is caused almost solely on the use of two-dimensional models in presentations, like slides, drawings and movies (Eckroth 1993). He constructed a three-dimensional model, where four globes with their axis have been stuck in the circle-shaped medal string representing the orbit of the Earth (the orbit ellipse is very close like a circle) at even distances. The illustration has become more perfect by painting the surface of each globe in different colours on the side towards the Sun as in the shadow. In the middle of the circle, as a bulb, is the Sun. When trying to find the cause of the seasons it is a good opportunity to discuss with pupils about the effects in the different areas of the globe during all the seasons, such as the direction angle of the sunrays, the tilt of the Earth's axis and the circular orbit of the Earth.

The Greek philosopher Aristarkhos had determined the distance between the Earth and the Moon using the eclipse of the Moon. Sawicki brought a new method for this determination using a solar eclipse (Sawicki 1996). The movement and the speed of the shadow of the Moon is explored and measured through the eclipse area. The Moon's speed relative to the Earth can be calculated when determining the speed of the shadow to the centre of the Earth. By multiplying that speed with the time of one rotation, the length the Moon has moved and the radius of the orbit can be calculated. The result Aristarkhos got is very similar to this result obtained by new methods.

Hansgen determines the exact direction of the north-south line by searching the line to the Sun in the midday (Hansgen 1995). The moment of the midday is easy to calculate using the times of the sunrise and the sunset. In small groups, pupils may mark a shadow of a stock on the sheet of paper on the ground like in Eratosthenes' method. The Greek geographer Eratosthenes (235 BC) determined the size of the Earth by measuring the shadow of the stock and by calculating the angle between the stock and the sunrays.

The moment of the midday happens when the shadow is shortest. The line from the bottom of the stock to the top of the shortest shadow is parallel with the north-south line. Pupils can also see the rotation of the Earth during this measurement, even if the motion of the Foucault's pendulum will proof this phenomenon better. Pupils may mark in the picture the direction to the magnetic pole using a compass, and they may also measure an angle of inclination. In evaluation of the results for instance, it is again important to discuss with pupils why the midday was not in the midday and does the length of the shadow change with the days. Pupils can make some extra experiments by determining the latitude of their place. It can best be done with the simplest calculations at the time of autumnal and vernal equinoxes, when the declination of the Sun is 0º. Only the pure measurements of length and angle and the use of the basic trigonometry are needed in this experiment and in the analysing of results.

9.3 Experiences of my own astronomy teaching

In this chapter I will tell my own experiences about astronomy teaching in the comprehensive school and in the university, as well as some experiences about the international summer schools of astronomy. I shall describe the subjects quite widely, because the systematic planning of astronomy teaching in chapter 10 is based very strongly on my own experiences as well as on the mappings.

9.3.1 Ordinary course of physics

During the decades-long career as teacher, I have realised over and over again that the contents of astronomy have been placed in the last part of many, especially the older, textbooks. If the teacher has used these to teach the subjects in order starting from the beginning – like many seem to do – he will get the astronomical subjects at the end of the term, which means in May. This period is not good for observations, because the days are already so light and the starry sky is not seen any more. The astronomical subjects in physical textbooks should be placed at the beginning of the course. The astronomical subjects are an excellent start point to the physics. In addition to that, the nights in August and in September, even in Finland, will darken quite early, so this period is very suitable for astronomy teaching.

When I was a teacher in the comprehensive school, I used to keep an astronomy course on the ninth level before the ordinary physics lessons in every autumn, despite where in the textbook the astronomical subjects are or if they existed at all. We have astronomical studies for several weeks. As teaching methods, I used working in pairs, working in groups, self-studying, using Internet and observation. The traditional method 'chalk and blackboard' was used very seldom. In my astronomy teaching, I used to proceed from the near environment to the larger entities. The syllabus of astronomy in the local curriculum included following subject matters with the descriptions of the contents:

> *Human being-Earth-Moon-Sun*
> Starting point is a human being, *e.g*. a pupil or a teacher. The human being is a part of the globe. In the environmental studies in the primary school pupils have studied phenomena, which belong to every day life and can be observed by sense. The Sun, the Earth, the Moon, day and night, the names of the seasons and the sky are familiar by name even to the smaller pupils. In the upper levels pupils explore more specific events and reasons in them. Also phenomena in atmosphere, like auroras, halo effects and thunderstorms, can be studied on these levels, depending on the pupils' stage of development. The construction of worldview begins from this visual world of phenomena. The significance of the Sun to the life on the Earth is an especially meaningful subject on the upper levels. Pupils will get introductory mental images about an interaction between the celestial bodies, by exploring the motion of the Moon round the Earth and the revolution of the Earth round the Sun.

Solar system
The globe is on its own place among the other planets and we may start to illustrate the scales of the space. It is easy to make comparisons between the sizes and between the distances, and adopt correct mental images. Exploring motions and rotations of planets gives a basis for physics, *e.g.* in connection to gravity. Exploring eclipses of Jupiter satellites may verify for instance a finite value of the speed of light. Also the other bodies in the solar system, like comets, asteroids and meteors, may be discussed.

Stars and constellations
The Sun is presented as a star among other stars. In this we make a big step out of the familiar world known before. We will consider theories in nuclear radiations when we get acquainted with the paths of the lives of stars. It would be very useful for pupils to get to know the most common constellations in our own hemisphere. The teacher may get his teaching more inspired by telling mythological stories containing the constellations. A very exceptional subject is the Zodiac. A connection between its constellations and the signs of horoscope interests pupils, but in this we have to remember to explain the difference between astronomy and astrology. It is an excellent opportunity to teach photography of the stars during the studies of the sky with stars.

Galaxies and other groupings of stars
The Sun's position in the universe as a part of the Milky Way takes a researcher to quite new dimensions, where the scale of distances and the shape and the size of the structure will become more unspecified. Making observations is not the same. The object cannot be seen as a whole from outside, but in the contrary the observer himself is 'inside' the galaxy. He is also inside the solar system, but he may observe anyway at the same time *e.g.* the Sun, the Moon and some planets, like an onlooker. Perception about the Milky Way will be easier by using a mini-model of it. Pupils may observe by binoculars the Andromeda galaxy, and they may also photograph it. Our galaxy is a part of the Local galaxy group, which is still a part of a greater group of galaxies. These groups form an enormous great, in imagination almost mythical giant group. Human's understanding is not capable to perceive these dimensions, but still it is surely a great fun to ponder these miraculous structures with pupils. Perhaps in this situation, teacher may drop some hints about the largeness and the smallness of the human being as a part of the cosmos.

Stages in the development of astronomy and some astronomical wonders
An overview of the history of astronomy is at the same time an overview of the development of the societies and the physics. Romantic and sometimes naive theories, observations and worldviews inspire always people, but they are also interested in the developmental stages on the modern stage. Pupils are curious for instance of human's perceptions in ancient time, about the world and the phenomena in the universe, about the great revolutions and the changes in the worldview. They have been wonders to people in that time. The modern wonders are more the ones of the microcosm than of the macrocosm, even though things not explored yet can be found in both. For instance a lot of controversial interpretations can be found about the future of the universe. The known extreme limit has 'moved' periodically farther, thanks to the better exploring equipments, and we do not know anything about the parts behind it. The largest and the smallest unknown is, and - has to be said – will be for the mankind further unattainable.

Model
Sometimes it is more educational to use a model instead of making observations in nature, because several different phenomena can be explored at the same time. In nature only one situation is seen at one time. For instance one can explore the phases of the Moon with small lamp and ball, assuming one's own head to be the Earth. Thus he will see the events as the same as in nature when looking at the Moon. The mini-model from the solar system may be built as two- or three-dimensional on many ways. The most natural way is to make it comparable with the nature in the scale of both distances and sizes. Nevertheless this might be hard to carry out in school circumstances. So the model built either in the classroom or in the corridor of the school, has various scales for the distances and the sizes of planets (see chapter 9.3.3). Pupils especially have to be told that only one concept (size or

distance) at one time may be discussed. The motion of the Earth round the Sun and phenomena containing in it, and the cases containing in the Earth and the Moon or in the Earth and the other planets, can be illustrated with this three-dimensional model. It is easy to explore the behaviour of a comet near the Sun, too.
In addition to concrete models mentioned before, phenomena and events may be modelled using pictures, drawings and computer programs. Phenomena, which are very hard to illustrate in other ways, can be made quite real with the programs of animation. A good example about this exists in an animation video about falling into the black hole or passing it by. Also the animations for presenting a curving of the space are excellent (WebPages). It is possible to repeat explorations of phenomena with the model for several times. By changing the circumstances various propositions of solutions are available and to be discussed. Pupils may make prognoses and test them afterwards. With this teaching method, pupils will get familiar in planning a scientific research, in making the investigation and in analysing the results.

I haven't included any specific remarks about methods or tools in the explanations, because this curriculum was made for my own teaching work, and I was the only astronomy teacher in my school in those days. I had two reasons for that: on one hand I had clear in my mind all the things concerning the teaching practices of these subject matters. On the other hand I wanted to leave space for impulsive ideas and for temporary choices in methods. I didn't want to limit myself to any certain plan of action or methodology.

Next I will present the methods I used most often, and some projects.

Knowledge searching and structuring by using videos, slides, magazines, Internet, computer programs and science literacy were studied in all the teaching periods and the optional courses. Pupils were encouraged and advised to make observations by themselves both days and evenings. Discussions, talking about mental pictures and inspiring them were used to reconstruct the pupils' worldview. There were surprisingly a lot of misunderstandings – perhaps most of them related to the distances and the physical essence of the celestial objects. Pupils had presentations about the delivered subjects, they worked in pairs and in groups, and they carried out some bigger projects (see chapter 9.3.3.).

During some years, pupils had to make a research about the given, or an extensive subject elected by themselves. They were given many months for this after the teaching period of astronomy, to finish the work at home on their free time and at their own pace. Research works have usually been individual tasks. Their minimum size has been one sheet of paper. In an evaluation session, I have told the pupils a general structure of the report of the research, which includes introduction, background theory, making the research, its results and conclusion. The aim of doing the research has been to teach the pupils *e.g.* how to handle and explore an extensive subject matter, how to work persistently, with self-discipline to finish the work and scientific research. There were many kinds of surprises in the results. Some of the researches were like 'real' ones, including pupil's own opinions and criticism. Some of those were quite like a short scribbling as a copy. The basic hypothesis "Talented pupils produce also good researches" was not always true. Even some talented pupils didn't get motivated in this job. Whenever a pupil, who was weak in other studies, was stimulated in his astronomical subject, he would make quite an in-depth study of his source material. Pupils got evaluations about their researches in writing. In the presentation session there was a good possibility to highlight rewards of everyone's work and to gently remark on the most important things it lacked. The criticism together with the discussions didn't feel quite so critical. No numerical grades were used in evaluation of researches and project works. I made observations continuously about everyone's working and checked their results. The physics test included some questions about astronomy, which I evaluated using a normal scale. So knowing astronomical things had an influence in the score of physics.

Pupils have had an opportunity to make some projects as a group work instead of the research work. They had to write only a short description about the stages of the work. Some of these subjects are explained as follows.

> Planets were painted in the same picture in two different scales concerning the distances and the sizes, as described before. An exception is the Sun, which couldn't be painted in the same scale with the planets. The pictures are painted with different coloured paints both in the classroom of mathematics and on the wall of the corridor outside the classroom near the ceiling. Pupils calculated themselves all the dimensions, starting from the maximum distance of the length of the classroom, which was elected to represent the distance between the Sun and the Pluto. They matched colours after real 'colours' of the planets pictured in science books.
>
> A sundial was made according to the 'most sensible' instructions found in the literacy. As the designer there were a group of boys, who started the work 'haughtily'. They didn't need any theories and follow any instructions. They thought they could build the clock in the picture, unassisted without questions. I knew those boys and I predicted that only a small part of the group with five persons would really work. In fact, only two boys. This was, in any case, the better option, to let the three, lazy boys still be a part of the group. This was because they seemed to be a little bit interested in this job and because an alternative work, meaning a written task, would have been overwhelmingly hard for them. The two boys, who finished the clock, even calibrated it. The result was in my opinion unreliable, because the calibration work was done by themselves and because there was no possibility to make it again.
>
> Zodiac has been a greatest project in our school. This job was made by a group of four girls, by painting the picture on the wall in school. The diameter of the painting is about four metres. Girls matched the colours themselves and placed the figures with artistic freedom. In figure 9.1 this artistic view is seen, in placing the Zodiacal constellations and their mythological figures on the right places on the Zodiac. A more exact description of this work is seen in chapter 9.3.3.
>
> A poster has been almost obligatory in each term without depending on that, if the researches are made or not. The posters have been prepared at the greatest part as teamwork. Pupils look for knowledge from various sources about the subject, given or chosen by them, worked it out for a presentation and prepared a poster on the wall of the school. These productions were presented then to all other pupils in the evaluation session. Now and then, an oral presentation has replaced a poster. When the astronomy teaching was kept at the beginning of terms, many productions were hung on the wall during the entire term, reminding them of the things they learned. The most popular subjects for a teamwork have been year-by-ear the following: a planet, the Sun, the Moon, a meteor, a comet, a galaxy, the Milky Way, the Andromeda galaxy, rockets, the seasons, a model of planets, a black hole, a path of star life, UFOs and the Big Bang. Many of these subjects were also subjects for research – nevertheless to different pupils. When comparing these subjects with those presented in chapter 7.2, it is not surprising that the lists are very similar. Some of the subjects figured out by pupils and not belonging truly in astronomy – like the UFOs, were accepted because pupils were very motivated to investigate them.

Pupils have liked teamwork and projects. It has been a pleasure to see many groups who have been so motivated in their work that they didn't want to go out for free time, but rather kept on working all that time. In this case I have checked very carefully, that they really are working and not avoiding go out.

In my school there were almost no astronomical tools at all before 1997. The old ineffective reflector was in the box for many years. We temporarily used binoculars in the dark season. We were almost at the starting point concerning the tools. The change came in the year 1997. Since then, I have participated every summer at the EAAE international summer school in different European countries (see chapters 7.2.5 and 9.2) for a weeklong course. Many of the instructors were active in developing observation tools. In these courses, I have acquired a lot of ideas and models for simple and cheap tools, which every teacher may prepare with pupils with materials that the school had.

9.3.2 Optional astronomy course

In starting the first optional astronomy course, there was an annoying episode. Because of the lack of money two optional courses were combined. Those subject matters differed substantially from each other. Another course was ‘Mathematics at home’. The group of pupils was a bit ‘confused’ as to their interest in the subject of astronomy. During this time, some of the pupils did not get interested at all in astronomy because they had selected mathematics. I myself thought that by definition, pupils who had taken this course were as interested as I was. The first curriculum of the course was too optimistic. Because of combining two different courses, contents of the subject matters in both fields had to be reduced. Thus, teaching was compromised. However I had to use a separation. In my opinion – regarding astronomy – this was very annoying since those pupils who had taken it could not totally concentrate, as I had wished, on the astronomical subjects.

As teaching materials we used literature, newspapers, videos, slides and materials from Internet. Pupils were advised to make observations at evenings. On this basis, we searched actual observing objects from annuals and constellations from the star maps. For instance, such objects were planets, auroras, artificial satellites and meteors. Yet we recognized the most common constellations in the northern sky and the brightest stars. I did receive feedback a lot about strange ‘findings’ during the night walk. Pupils also prepared a presentation about the subject they liked.

The astronomical content in an optional course was planned so that subjects and teaching methods were different as those in the ordinary physics course. For instance, the properties and essence of planets were not handled more exact than a mention in the optional course. Pupils filled an evaluation form after the course had finished, and they evaluated the content and development of the course, along with their own motivation and success. I felt as positive feedback that those pupils on the ninth level, who participated in the optional astronomy course on the eighth level, clearly showed more astronomical knowledge than the others

9.3.3 Teaching project in astronomy

In my physics teaching there has been one more extensive subject matter – which pupils work alone or in a group both in school and at home. They have to study their topic so completely that they can also present it to the other pupils. They can make this project work either as a written study or as a practical work according to given instructions or to their own planning. It is important with the practical subjects that the teacher has supplied some sources about the topic. For example, when a pupil sees a picture of the sundial, he immediately gets a basic mental image about the task, and he may evaluate himself and his talents to work it out. The teacher knows the skills and ability of his pupils, so he may encourage them in the correct way.

Related to this, I present here a project carried out as an illustration and perception method by name, "Sun moves along the zodiac circle – the annual revolution of the Earth". This project was carried out in 1997 as teamwork on the ninth level. Throughout this project I wanted to investigate a perception of the phenomenon besides the theoretical approach through the practical work. The aim of the project was to get pupils to consider and to distinguish the annual revolution of the Earth and its terrestrial phenomena or influences. Here are some stages of the project.

> When I talked up the task to the pupils, I explained to them, that it would be the case to make a big painting on the wall in the corridor. Pupils got an opportunity to interpret dimensions and shapes of figures a little bit more freely, because this product is intended to be besides scientific, also an artistic work. I promised them also, that only one sheet of paper would be enough for their report. In connection to these discussions, I had a great opportunity to come up with nice mental images about how the painting would seem, and how wonderful it would be to use their own creativity and artistic ability in making this work. It should remain in the history as a precious gift to the school, and the next generations could use it in teaching! After considering this a few days, a group of four girls became interested in the job. Later one boy joined them. I saw they didn't seem to have any problems in motivation to start this job.
>
> First we discussed practical things related to the planning of the work. For example, the content of the picture, the tools and materials, the deadline and the daily working time related to lectures. We also had to negotiate with other teachers for possible, temporary free times. Together we tried to find compromises with various plans for execution. We found consensus to all stages of the work, with the help of discussions and scientific grounds.
>
> At first the members of the group figured on paper their own schedules about the subject. Thus they constructed themselves frames of the becoming picture. Then they checked the textbooks and the scientific writings in school, finding information about the constellations of the Zodiac, the motion of the Earth around the Sun, explanations for seasons and about the astrological signs. In the library of URSA in Helsinki we borrowed science books about this subject. We found in that library, the most 'precious' source for this work (Lovi et al. 1973) in that there are printed all the fancied figures on the background of the Zodiacal constellations. We thought that these figures might enliven the picture, and give it more artistic value. Pupils' imagination and mystic fascination conjured up marvellous plans, but making them true was first such a big question mark for us. In the book "Tähtitaivaan opas" ("Guide for studying the starry sky", Kaila 1979), we found the constellations we needed. With a mini-model charted on paper sheet, presenting the orbit of the Earth around the Sun and the inclination of the Earth's axis, we had an image about the cause of the seasons. With the help of the star map of the Northern Hemisphere, we placed the Zodiacal constellations in the right order on the plane of the ecliptic. The greatest problem in their work was to clarify an apparent motion of the Sun. It has to be remembered to highlight in this case, that the apparent position of the Sun has moved along the ecliptic for several degrees. For instance the position of the vernal equinox is no more on the constellation of Aries, but has moved onto the one of Pisces.
>
> Pupils planned very actively stages in their work. A few times I needed to give some hints for solving their problem. The following essay-like story will bring up the most significant stages and feelings in production:
>
>> Pre-preparations included these acquisitions for materials:
>> - transparencies for painting figures on the background of the constellations
>> - transparencies for painting constellations on the figures
>> - paints, brushes and other materials for painting.
>>
>> A final mini-model on the cardboard of one and a half square metre was made for making it easier to put the constellations in their right places. We drew the Zodiacal line as an ellipse, and in the middle of it, a little bit aside from the centre, we placed the Sun and round it the

elliptic orbit of the Earth. The Sun is located in one of the two focuses. It is the wintertime when the Earth is nearest to the Sun, it means in perihelion, and the summertime when the Earth is at furthest from the Sun, in aphelion. The autumn time and the springtime are located between them, on the places ordered by the minor diameter of the ellipse. When looking on the Earth at the direction to the Sun, there is always the constellation behind the Sun through which it seems to move. It was much easier to divide the Zodiacal orbit in the even parts on paper than on the wall. Pupils draw by pencil the line of the Zodiacal ellipse. From the mini-model we then 'copied' the places of constellations in the enlarged form on the wall. With pencil we circled the about same-sized areas for every constellation. The Earth's orbit and the Sun were painted freehand without any transparencies or models. Remember that they had got an artistic freedom within certain limits, so the technical drawing became forgotten sometimes..

The place of the overhead projector was marked on the floor by adhesive tape. So the distance from the wall kept unchanged during all the drawing work. Pupils participated in lessons when not working on project, so all the tools had to be set again when continuing the work. We had another reason for this act, too. There were a lot of people in the corridor in the free periods, and it could not be avoided that someone would push the projector by accident, not in purpose, of course. Any indiscipline was not recognized in the whole time. Pupils charted the outlines of the figures by pencil on the wall, using a projected model. The Virgin and the Leo on the lower part of the picture would have been drawn upside down, that's why we decided, for visual reasons, to turn those figures upwards. We explained this reconstruction with artistic points of view. We had all the necessary tools and equipments in the working place. We covered the floor with brown cardboard paper. We reserved a big table for paints and materials, yet we used it when we painted the upper parts of the picture. Pupils wore protective clothing, like long coats, caps and uppers, which we borrowed from the technical classroom. They felt no shame about their 'strange' outward appearance. Rather they were proud of being a member of such a special group. This feeling grew a lot when the schoolfellows admired their work. Unsure working at the beginning changed later to working like real artists do.

A particular painting work was made at one period. Pupils got one day off from the schoolwork. They finished the most part of the paintings on that day. The rest were made on the free hours and sometimes after the school time. There was no use to open paint tins or to make paint compounds. The art teacher advised them with colours and mixing the coloured paints, but pupils did themselves the selections of colours and shades in different objects. They followed a certain line in selecting colours. Four samples of colours represented four elements: earth, fire, water and air. In each subpart they made compounds of different shades of the main colour, and succeeded in this very well. *E.g.* Zodiacal figures representing water got blue and green blue pastels. The drying of paints took time before repainting was possible. There was no need to repaint a lot, a few make-ups.

A surprisingly great job was to prepare a stencil. An A3-sized white paper was fixed on the wall by scotch. Pupils drew the constellation in it by using a transparency. We marked once again the place of the over-head projector on the floor. The distance to the wall was fixed so that the dimension of the constellation would be, as much as possible, the same as the one of the figure, and the stars hit the right points in figure. From each constellation those stars with the three greatest magnitudes were marked on paper. The three categories of sizes had their own symbols. Stars with the greatest magnitude were marked with an asterisk, and stars with two fainter magnitudes with circles of different sizes. With quite a sharp knife, we cut the holes in paper on a chopping board. This work tested their patience and demanded precision work and power. The stencils were fixed on the wall onto the figure as described before. Even the constellations of the two upside down figures were also upside down, but this incorrectness didn't distract the wholeness. We used wads of cotton when painting stars with gold yellow pastel. They were seen, thanks to exceptional colour, very easily towards the background, and without any specific outlines. Finally, pupils painted the bright yellow Sun and the blue-green Earth on its elliptic orbit. We used no scale with this picture. In these elections we explained ourselves with artistry as painters. The basic mental image was still carried out about the reality. *E.g.* one half of the major axis of the Earth's orbit is in picture one tenth of the one of the Zodiacal orbit, and the diameter of the Earth is apparently smaller than the one of the Sun. In teaching these things have to be highlighted to pupils, and they also have to get informed about the real magnitudes of dimensions.

Evaluation

All practical works have purely two aims. First the planning of the task, the mapping of the steps in doing and carrying out teach the pupils a long-span scientific working, criticism and persistence. It is not easy for a teenager to concentrate in getting knowledge and ponder his own solutions for finishing the work. Secondly, the theory and the knowledge included in the picture, a pupil has to internalise himself in his own picture of world, so that the illustrated phenomena could stay in his mind permanently. A pupil has to configure positions and motions of celestial bodies in the picture and their significance in our lives. We tried to make the painting as truthful as possible. The exceptions about the reality we told to other pupils and at the same time we highlighted to approve choices made in the name of art. We reduced the picture quite much, *e.g.* numerous stars were dropped out from the constellations. In addition to the Zodiac we included in the picture only the most necessary celestial bodies, like the Earth and the Sun. With these solutions we tried to get clarity in the picture.

Pupils had to find out the significance of the whole of the work already in the planning stage. For example, what does it mean that in the middle of winter there is a period of Sagittarius or Capricorn? When pupils place the zodiacal constellations, they have to know, which point in the orbit presents a situation in winter or in summer, and how it can be taken into account in placing the figures. They had to know the consequence of the tilt of Earth's axis in the seasons, also the dimensions in general. Drawing a miniature model was definitely helpful. A pen and a ruler were used in orientation of the sight of a beholder. It was easier for pupils to imagine themselves to be on the globe and look at the direction a pen pointed – for instance behind the Sun – and consider, which constellations have to be placed in this position in Zodiac.

All the time the work was going on, I made an evaluation of the learning. When I discussed this with the pupils, I found out their conception about these phenomena and about the perception of movements. I had an opportunity to correct wrong perceptions during the discussions. Pupils made questions themselves to me about the things in the picture they didn't understand. They also reported me the stages in the proceeding of the work, both in the point of view of scientific and technological processes. I could see the stages of social process all the time in their working. Besides that, I was also able to evaluate their work by listening to the explanations about the picture to other pupils. They taught their fellow schoolmates these things when working and also after having finished it. On the basis of these stories they had learned the subject matter very well. With this picture I could teach many things that about celestial mechanics and in worldview. Pupils could reconstruct their picture of the world on behalf of the scales and the locations of celestial bodies. A pupil could also clarify his conceptions about the day and night period and the seasons, and about the planes of different orbits. It's not necessary to underline the artistic contribution too much. If so, then the astronomical facts may remain unclear and thus the significance of the project as a teaching method will decrease.

The follow-up evaluation using an interview

An interview of those pupils, who carried out the picture as a project, was made after two years from the accomplishment of the work. Initially there were no plans to interview pupils after so long period. As a matter of fact there were no plans to interview at all. The idea of this came up in the seminars at the graduate school, from the achievements of the researches presented there and from the discussions with the supervisors. A request for an interview was a complete surprise for the members of the group. As follows, I shall briefly discuss some details and feelings from them.

All members of the group accepted the request at once. The only doubt or suspicion concerned their forgetfulness. Some of them were perfectly sure that they could not remember anything about the whole project, and therefore an interview would be in vain. When I convinced them that things come back to them, step by step and thinking back at leisure, at last they were encouraged. Some of them didn't feel comfortable with the recorder, but got used to it quickly. They felt funny to hear their own voice on the tape, and it inspired them to talk much more.

First I gave them the general instructions for the run of the interview. I would read every question slowly and only once. The interviewer cannot say a word to either prompt or as comments for making it easier to remember. Pupils had to try to remember calmly, ignoring my silence. I would not correct wrong details. There was no limited time for answering. The questions were as follows:

1. What kind of stages did you have in your work?
2. What things had you thought about in planning?
3. How was the work done in practice?
4. How did you feel doing this job?
5. What things are presented in the picture? Can you also use it later in teaching?
6. Which astronomical subjects did you learn about it?
7. Could you teach the same subjects to your fellow schoolmates?
8. Was this kind of study/work nicer than studying from textbooks?
9. Did you understand the subject included in this picture better with the help of the picture and textbooks than just by studying in textbooks? What kind of significance had this work for you?
10. What were the good and bad sides of this work?

With the first interviewee, I noticed a couple of mistakes in the matter of questions. Question 8 is too prompting, directly begging the positive answer. Question 9 is also too prompting, but in the second part of the question an interviewee had to think a little bit more about his answer. The role of the interviewer changed a bit by reason of the interviewee. I had to do this with two pupils despite the instructions at the beginning. They were told some extra words about an intention of the question, without giving any hints for helping them to remember. The rest of the interviewees understood the question presented in the original form. In the web page (web 9.3), the pure texts written from the tape of the interview are seen, that why the linguistic form is like spoken language. As a positive remark in the results of the interview, it has to be said that the subjects included in this account did quite well in remembering when they told the stages of the work. In my opinion, many important keywords had been forgotten, but the basic ideas were still in their minds. Their picture has served over and over again as a teaching and revising tool in the school.

9.3.4 Astronomy club

Astronomy club NOVA was founded in Järvenpää in the autumn of 1979 as a common club for the comprehensive school and for the secondary school, organized by MSc Agnes Airola and myself. For seven years the club had meetings almost regularly in the physics classroom. Thereafter, the club has had activities to this very day, under several persons. Next I shall tell about the activities in the club, during the time that I was one of the instructors.

The idea to start an astronomy club developed from discussions between MSc Airola and myself. Even though we both had taught astronomy in physics courses for years, and the subjects were well known, leading a club felt in the first moment to be an overwhelming task. On the evening the club began we were very excited, waiting to see if any pupils would come to the school. When we arrived upstairs to the physics classroom, we saw through the open door that almost half of the classroom was occupied. This sight encouraged us very much and we started the seven-year long period of the club under our guidance.

The aim of the club was to bring together those pupils interested in astronomy. In bringing them together, it would further their awareness of the subject allowing them to learn more about astronomy, providing them with relationships with other pupils interested in the same thing, and to get them familiarized with the scientific working, in accordance to everyone's ability. Many activities and outsider actions taught the club members to work in groups for a common purpose, to accept the rules and to enjoy the company of different kinds of people. The Lions Club Järvenpää association donated a telescope to the club. It is a reflector Celestron 8 with electrical rotation techniques. In the beginning of club activities, we had to take the telescope out in the schoolyard and make our observations there, because we didn't have a fixed stand for it. This caused problems sometimes, such as when the eager observers unintentionally pushed the desk down in the darkness while waiting their turn to observe.

Later, in connection with the re-building of our school, we acquired our own observatory on the top floor of school, with a cupola and concrete stand for a telescope. Around the stand there is a stair frame on wheels. About 5-6 pupils may stand on the top level of the frame. In the cupola there are hinged small doors and you can rotate the cupola manually. We decorated our observatory inside with the paper sheets and posters made by club members. For example, on the wall inside the cupola we placed the constellations of Zodiac. In these constellations the apparent magnitudes of the stars have been presented as coloured circles of different sizes. The names of the constellations were written in Latin. Considerable harm to our observations there was the location of the school in the centre of the city. The pollution of light was sometimes so enormous, to a great extent because of the lights in the ice hockey rink.

The activities in the club consisted of theoretical studies, acquisition of observational and visual materials, and theme sessions with visitors, visits to other observatories and other clubs and, of course, a lot of observations. The club activity became livelier after getting our own observatory. The faithful crowd stayed together from year to year, from the comprehensive school to the upper secondary school. Club members from the secondary school were like big brothers or sisters to the younger members. They also worked sometimes as an assisting teacher or as a guide in observations. One of the former club members presently works as a leader in the larger astronomical association. The atmosphere in our club was spontaneous, impulsive and natural. The members may do their explorations in accordance with their interests. Sometimes we asked them to prepare presentations about interesting subjects and present them at the club. Only the theoretical teaching periods were 'obligatory'.

A social net in the club is surprisingly diverse. The club members have to take contacts with persons from several different 'levels' like teachers, fellow schoolmates of different ages and people outside the school. The original group grew up together in team spirit. They had their own shared 'things'. All these factors helped club members to develop also in the field of science. They encouraged themselves and presented facts they had discovered to the others. They took responsibility about great tasks and figured out spontaneously several events and campaigns. On excursions and visits they behaved perfectly, schooled and grew with each other and at the same time with us, the instructors.

Of course, the most important activity in the club was observing – by naked eyes, binocular and telescope. We succeeded to find Saturn with its rings, a comet and many clusters in addition to the 'ordinary' objects. The satellites of Jupiter, seen even by binocular, various constellations by naked eyes, meteors, artificial satellites, Venus, Mars and the Moon with its various phases were the very common objects, of course. Once we tried to photograph an eclipse of the Moon. We also had lectures and presentations quite often. Club members, instructors and visiting lecturers acted as presenters. The duration and the quality of a presentation depended very much on not only the subject but also the presenter. The visiting lecturer might keep a lecture over one hour, whereas pupils' lectures were short, also because of the more concise subject. We teachers kept lectures mostly as a series of themes, it means we chose a greater subject matter, and presented a small part of it in the club evenings, so creating a bigger entity. This also gave a certain consistency and coherence instead of pure small packages of facts. We preferred practical activities and hands-on working. That's why pupils were asked to make hands-on tasks. Those included, in addition to the regular observations, making posters, messing around the tools and setting up exhibitions.

We visited observatories in the neighbourhood. Most often we visited the observatory of URSA association in Helsinki. Our club was like 'a foster child' of URSA, because people there helped us and took care of us a lot. From there we got most of the visitors, from which Mr. Matti Suhonen became the most familiar to us. We also visited Hyvinkää and Lahti, and the observatory of Mr. Risto Heikkilä in Forssa, too. Professor Kaarle Kurki-Suonio and Docent Tapio Markkanen were the most well known of our lecturers. In the evenings when we had a subject about a special theme, reporters made a story with pictures in their newspaper. In the magazine "Stars and the Space" (in Finnish "Tähdet ja avaruus") there was also an article about our club. A wide, much publicized collected exhibition was set up in the physics classroom. Pupils gathered many sorts of materials for that: photographs, brochures, posters, leaflets, source books and tools. The other pupils from our schools and a staff visited an exhibition and an observatory during the school day. In the evening the public was invited to visit the exhibition. A co-operation with URSA was so close and intensive, that we decided to organize in the school a national festival in astronomy. The club was the host of the arrangements. For several years our club has been listed in the catalogue of the official astronomical associations, printed in the magazine "Stars and the Space".

9.3.5 International experiences

From the year 1997 EAAE (European Association for Astronomy Education) has organized an international summer school in astronomy for teachers from all the school levels. I am lucky in having been able to participate in all of them. Although I had taught astronomy in the comprehensive school for over twenty years, I still saw here an opportunity to get new ideas, methods and tools in my teaching work. All these wishes have become true, even more than I imagined. The basic idea in these summer schools is the study of astronomical subjects using practical methods. There are no lectures in the workshops, the working is very practical – preparing tools, making observations by them or by the equipments, or making measurements and calculations. As gifts from these courses, I have brought simple observation tools, mini-models, ideas about the teaching practices and research arrangements, a lot of written material, a precious, yearly expanding circle of friends through Internet, and beautiful memories about the social interaction in the international 'family'.

Based on my experiences in astronomy teaching and on the international summer schools in astronomy, I have planned astronomy courses for teacher students in the university of Helsinki and for the in-service teachers for further education. With more information and depth in contents in planning these courses at the university, I have obtained the results of a Socrates project, carried out by EAAE in years 1999-2002 (Ros, R. M. 1999-2001). About ten members of EAAE, from different European countries, were invited to be members of the working group, and I was one of the two representatives there from Finland. The aim of the project was to plan a common curriculum of astronomy for the European countries. As a base in this planning, we used subjects and contents of the workshops in the international summer schools of astronomy (Ros 1997-2002). The instructors in these workshops are experienced astronomy teachers from all over the European countries. A framework of the curriculum as result of the project can be seen on the web page (web 10.1).

III C Planning

10 Problem of planning

In this chapter I shall build my recommendation for the contents and methodological principles for astronomy teaching on the grounds of mappings of chapters 4 to 6. For each subject area and principle, I shall present the bases for selection and use, in the light of the significance of astronomy teaching, the conceptual structure of astronomy and the development of the pupil's astronomical worldview. In addition, I shall view these bases in the light of preconditions of teaching, teachers' attitudes and teaching experiences presented in chapters 7 to 9. From the significances of astronomy five basic themes, came out as specific viewpoints, which direct my choices: 1. *worldview*, 2. *observing*, 3. *existence of life*, 4. *space technology* and 5, *culture*. The first theme was clearly emphasized also by the two other mappings. Mapping of the conceptual structure suggests that 6. *conceptual hierarchy* should be taken as the sixth important theme.

Even if a pupil himself is constructing his own worldview, the importance of external influences cannot be ignored in this process. The teacher is a central influential person, who should himself have a structured mental image of the subject area he is going to teach. He has to make anyway the final selection of subjects in his lesson plans. Plenty of materials are available in the literature and on the Internet. In the middle of the flow of information the teacher may direct the development of the pupil's mental images towards the scientific picture of reality. It is also important that the teacher is willing to improve his competence of astronomy teaching either by teacher training courses or by self-studies, particularly, if his astronomical knowledge is insufficient,.

10.1 Contents

Choosing contents for astronomy teaching is not easy. The difficulty occurs mainly because of two, mutually opposite situations. The teacher interested in astronomy may suffer when discarding subjects he feels important because of the lack of time or resources. He sees all the subjects as interesting, and he should like also pupils to see them in the same way. It would be hard for him to admit that just the very basics, an elementary knowledge, are sufficient. On the other hand, the teacher with fewer studies in astronomy, may suffer for a different reason. It might be difficult for him to pick up, from the great amount of subjects, that fundamental syllabus, which should be learned. He may also feel insecurity in astronomy teaching, because of the lack of knowledge. The level of astronomical knowledge and understanding changes a lot with pupils. The teacher has to recognize terms, caused by pupils' capability, for contents and methods. Teaching should proceed from pupils' immediate surroundings and comprehension of concepts, hierarchically broadening to wider environments and concepts.

Essential aims in planning the contents are
- as for the scientific viewpoint, assimilating basics of astronomy
- as for the historical viewpoint, perceiving stages of development of astronomical worldview and history of astronomy
- as for the viewpoint of the development of astronomical worldview, understanding of philosophical thoughts in science.
- as for the observational and technological viewpoint, acquaintance with development of observation tools and space technology belongs also in essential aims.

My recommendation is based on the idea that the *hierarchical structure* of the universe should form the structural core of astronomy teaching. The successive structural levels of this hierarchy will form the natural *thematic entities* of the syllabus, starting from the objects and phenomena of the human order of magnitude and proceeding successively from one level of structural hierarchy to the next. This is an inevitable conclusion supported similarly by all three basic mappings. This gives rise to six thematic entities: 1. *Everyday phenomena.* 2. *Earth-Moon-Sun system.* 3. *The solar system.* 4. *Stars and constellations.* 5. *Galaxies.* 6. *The Universe*

The second theme, observing, deserves a position as an additional thematic entity: 7. *Observation and exploration.* Also this choice is supported by all three basic mappings. Observation is the basis of all astronomical information, and the history of astronomy is governed by the development of observing methods and tools. The significance factors of astronomy are largely based on the useful information, which has become available through these tools. Empirical meanings of concepts form the core of understanding astronomical subjects and construction of ones worldview. Therefore observing is a central factor as for the development of astronomical worldview as well as of the conceptual structure.

The choice of subject matter and teaching methods within each of the thematic entities will be guided by the six basic themes in which the idea concerning fulfilment of significances and aims of astronomy teaching is focused. In chapter 10.1.1 these themes will be discussed more specifically, as for principles for choosing the contents and methods on their basis. Then, in chapter 10.1.2 a general core syllabus of astronomy teaching is presented as built from the thematic entities.

10.1.1 The basic themes

Worldview

As stated above, this theme arises similarly from all three mappings, from the significance and structural hierarchy of astronomy as well as from development of astronomical worldview. Therefore it becomes a leading theme, which should have an influence both on the large-scale structure of the syllabus in terms of thematic entities and on formation of contents within each thematic entity.

As discussed earlier in chapter 5.3, the *structural hierarchy of the universe* as such makes the universe understandable as a chain of systems of successive orders of magnitude. Objects of each hierarchical level are composed of in-size-smaller structural units, which are objects of the next-lower level, while objects of the same level form together in-size-larger systems, which are objects of the next-higher level.

The structuring principle is the principle of formation of the hierarchical chain of structural units. It can be seen to arise from a chain of interactions of different orders of strength. It covers, thus, the whole universe, all its structural units of different sizes, their structural relations and interactions, starting from the invisible microcosm, passing through our visible world and extending to macrocosm, again invisible for our eyes because of its immense dimensions, up to the outermost limits of the known universe.

In the human's perspective the chain is bidirectional, starting from the middle, from the human order of magnitude and proceeding separately towards the larger structural units and towards the smaller ones. This corresponds also to the way, how the scientific knowledge has developed in the history of science. From the viewpoint of the development of astronomical worldview, the same applies in teaching of science. One should start from the level of child's understanding, from the pupil's immediate surroundings, and proceed in two directions in the chain.

When proceeding to the larger entities, the structural units are Earth, solar system, galaxy, groups of galaxies and giant clusters of galaxies. The division can be made denser if wanted, including also 'subdivisions'. This part of the chain can be called macrocosm. The successive structural units mentioned are traditionally understood to be 'astronomical objects'.

When proceeding to the smaller entities, the structural units are molecules, atoms, nuclei, nucleons and quarks. This part of the chain, invisible for the human eye, can be called microcosm, regarded traditionally as the era of physics. Structural units in organic nature, familiar in pupil's surroundings, such as individual beings, organs, cells and structural elements of cells, can be included in the chain, thus, giving space for biology.

Astronomical explorations in microcosm can also be made by way of research of advanced space technology and particle physics. These kinds of subjects are for example development of stars, radiation and power production.

On each level of the structural hierarchy, the theme of worldview warrants consideration of the objects of this level, their structure, development, interactions and dynamics. In addition, it requires fixation of the objects in the chain in accordance with the structuring principle.

The general view will be constructed after the principles of concept formation and construction of pupil's worldview (Fig. 10.1). The concept formation is proceeding from conceptions based on concrete observations and experiences gradually to ever more abstract concepts. In concept formation one should follow the hierarchy of generality, proceeding from simple, special and concrete concepts gradually to more sophisticated, general and abstract ones. Also here the stages follow those of the development of both the history of astronomy and pupil's worldview. By gradual broadening of the subject area and the concepts, pupils will get the possibility to construct their own entire picture of the world.

Observing

This theme indicates consideration of the development of getting information. It has to be made understandable how it is possible to acquire empirical information on structures, dynamics and development of objects on each level of structural hierarchy. The pupils should be aided to become aware of the empirical basics of the worldview and its development: where and how the necessary information has been gained, and what kind of possibilities pupils have themselves to make observations and explorations for verification of the knowledge. Understanding of empirical meanings on the basis of their own experiences helps pupils to understand also empirical meanings beyond their own possibilities of observation, where they have to trust in narrated empiry.

Observation is one of the most significant research methods in astronomy, and the eye is the most important observation tool in all astronomy teaching. Observing by naked eye is going to change to 'technical' observing with more advanced equipment even in school. Stages of observing are parallel with the development stages of the history of astronomy and pupil's worldview. At first one's own immediate surrounding world and natural phenomena will be observed. Then planets and starry sky are explored by naked eye. An opportunity to use a telescope opens a new research area to pupils. It is a great step outwards from the immediate surroundings, when the distances of observed objects become enormous. Better possibilities for observation motivate pupils also to get information independently. With most advanced observation tools, people can observe still fainter objects, and through it they can see deeper and deeper in space, even to the outermost limit of the universe. These evidences are available in schools via literature and Internet, and so it becomes possible to make ‘own observations’ of actual interesting objects.

This theme necessarily penetrates all subjects on each level of the structural hierarchy since it is the basis of all empirical evidence supporting the knowledge, concepts and models. Because of the immense differences of the dimensions and distances involved in the different levels of structural hierarchy, the possibilities of observation are also very different and there will always be new specific aspects of this theme to be introduced when proceeding from one level to the next one. There is also a corresponding hierarchy of the methods of observation.

Existence of life

Consideration of the existence of life brings an interesting, human-centred viewpoint in astronomy teaching. The question about possibility of life in the universe has kept people occupied at all times. The two opposite viewpoints of this subject are equally miraculous: is the Earth the only celestial body where life exists, or where are others? Pondering chances of life is as important as looking for life elsewhere. Is life necessarily born in certain conditions, or is it only an extremely rare ’coincidence’?

Such ideological pondering is connected with philosophical and religious viewpoints. Discussing these questions together with pupils is important as for the development and formation of their astronomical worldview. It increases pupils’ interest in universal things and motivates them to study more science. With new effective observation and measuring tools people are looking for indications about life on other planets both in the solar system and outside of it and even trying to pick up possible signals sent by alien civilisations. Also probes have been released in space to bring information of our own civilisation to potential receivers. The spatial structure and the existence of molecules and elements, necessary in the birth of life from the Big Bang to the present time, are being investigated with spectrum analysis. These evidences available in literature and Internet can be studied in schools and utilised in teaching if possible.

Space technology

In common language space technology is understood mainly as technology related to artificial satellites, space stations and rockets. In the present context, consideration of space technology involves the more general viewpoint of application of the astronomical knowledge, including its utilisation. This theme is connected, at the same time, with the themes of observing, existence of life and worldview. In teaching it means mainly looking for opportunities for observing, and utilisation of the resources in one’s own school. The teacher should discuss with pupils about what kind of equipment and methods have been developed to solve different kinds of research problems.

The development of space technology has yielded, in addition to more qualified observation tools, also an improvement of mobility. The human has got up from the Earth to space, visited the Moon and lived in space stations orbiting the Earth for quite a long time. Probes have been launched from the Earth to other celestial bodies, from which samples can be analysed right away on site with methods of advanced technology, results being sent to the Earth. Reports about the immediate extraterrestrial space, based on space travellers’ own experiences, increase inquisitiveness and interest in pupils inviting them to ponder human’s position in the universe and also future in space. These ponderings and discussions are a significant part in pupil's scientific and personal development process.

Cultural impacts of astronomy

Science, technology, arts, social culture and economic life belong in the culture of each society. The cultural viewpoint indicates in this connection the status of astronomy in the totality of culture – its significance and influence on other sciences and sub-areas of culture, and conversely. As for the teaching aims, it indicates broadening of the worldview in the conception of the world. A human has always been interested in not only the universe, but also foreign countries and cultures. An interaction between these cultures has improved in its part the development of astronomy. It has had to ponder for example what is essential in these various cultures. Within expeditions astronomical knowledge has spread out from one country to the other, causing even conflicts because of different kinds of interpretations. Also every pupil has a connection with his own culture and conceptions of the universe. He processes information he has got in a personal way, affiliating it in the structure of his picture of the world. His worldview will be constructed through inner interpretations according to his own culture and values.

Conceptual hierarchy

The viewpoint of conceptual hierarchy is coupled separately to all subjects on each level of structural hierarchy, involving both the generalisation hierarchy and the quantification hierarchy as discussed in chapter 5. As for the content aims, in handling of a thematic entity, those scientific concepts will become understood by which the subject under discussion can be structured. This means that one will learn to discuss things under consideration, to call them correctly and to know interdependencies between them.

As for the development of astronomical worldview, the conceptual hierarchy is a most important factor to be taken into account both in setting aims and in treatment of any subject matter, in order help the pupils to proceed properly in their understanding of the subject matter and in constructing their worldview. Teaching has to proceed along 'the ladders of understanding' (see chapter 5.2.3) taking into account the pupils' level of conceptual understanding right from the start and throughout the progress of teaching. It is not good to start from abstract formulations of laws, nor is it advisable to begin teaching with quarks, black holes and theories of them. Quantitative treatment of problems is rather useless, if it cannot be based on qualitative understanding of the empirical meanings behind.

This theme is closely connected with the two 'main themes', worldview and observing, because proceeding in the structural hierarchy necessarily requires introduction of more general and abstract concepts and, thus, progress in the conceptual hierarchy, and because empirical meanings created by observation form the starting point of the 'ladders of understanding' in each subject.

Guiding then pupils along the path of the developing hierarchy follows, in fact, at the same time the main features of development of science in history. This theme is therefore closely connected also with the significance factors of astronomy. In generalisation hierarchy, it may, though, be possible to include simplified ideas about concepts and models of more general levels as 'looks at future' or motivating examples of subjects and problems which will become more thoroughly understandable in some later stage of the studies.

The conceptual hierarchy is an important viewpoint belonging in all the planning of teaching. It should help to determine the order in which concepts are adopted in teaching so that concepts needed later, in treatment of new subjects or as the basis of further concepts, are introduced early enough to rely upon their meanings in the new context. It is also important in the planning to evaluate properly the conceptual level to be aimed at in teaching of different subjects as well as the starting level. The definite choice of contents and the depth of study belong to the teacher's duties. Besides his or her own capabilities, the stage of pupils' personal and scientific development influence these selections.

10.1.2 The thematic entities

The thematic entities form the structural core for the course. The teachers may use them as a guide when planning their own astronomy teaching. The same core structure can be used in all levels from the primary school to the university. Each thematic entity includes contents of this subject area, and its potential subdivisions. Selection of subjects is considered in the light of the six basic themes. Support is also sought from the results of the mapping of preconditions (chapters 7 and 8) and experiences (chapter 9).

The teacher has to make a decision of the extent and depth in his course, as for the stage of his pupils and the time available. Differentiation to various school levels will occur within each thematic entity, accentuating the initial stage of the development of concept structure, and leaving out concepts, which are high in hierarchy and distant in generality.

Everyday phenomena

It is advisable to start with pupils' familiar immediate surroundings and everyday phenomena. This thematic entity includes subjects, which pupils can see and observe by naked eye, three-dimensional 'snapshots' of their surroundings.

> *Earth*
> Day and night. Seasons. Day and night in different areas of the Earth and in different seasons. Midnight Sun (Nightless night) and kaamos (Winter twilight). Seasons in different parts of the Earth. Shadows on Earth's surface.
>
> *Moon*
> The Moon as seen from the Earth. Phases of the Moon.
>
> *Sun*
> Sun's role in everyday life. Daily path of the Sun. Tropics. Path of the Sun: in different areas of the Earth and in different seasons. Path of the Sun in the area between the tropics. Radiation of the Sun.
>
> *Light phenomena in the sky*
> Rainbow. Lightning. Auroras. Halos. Luminous night clouds. Green flash. Zodiacal light. 'Falling stars'.

The pupil should learn to understand the relation between the Earth and the Sun, the influence of the Sun and the Moon in everyday life as well as the explanations of their visual appearance in different situations in terms of the mutual positions of Sun, Moon and Earth. He should also learn to figure out the difference when observing phenomena in space or on earth, to get a conception of the distances and explanations for people's beliefs and popular explanations. The pupil may himself get information about his environment by observing it in nature by naked eye. No observation tools are needed, excepting binoculars. On the other hand, acquisition and dissemination of information comes best in the social process, in people's mutual dealings with each other.

Life on the Earth, humans and animals, belong to pupil's daily experiences and are very familiar and close. The immediate surroundings are felt as a safe environment for growing – it is easy to explore it. The worldview consists of the entire visible immediate surroundings.
Entities, phenomena and properties on the qualitative level will be perceived as the primary phase of formation of concept structure, but information about their dynamics will not be got in this level.

Earth-Moon-Sun - system

This thematic entity includes things from quite a limited area in the universal scale. One shall become familiarized with events in the Earth's immediate surroundings. The objects can be seen by naked eye, but their mutual motions can be perceived as three-dimensional only by using a model. One shall explore relative motions of three celestial bodies, the Earth, the Moon and the Sun, paying attention to important special cases.

Earth
Earth as a celestial body. Shape of the Earth. Day. Year. Motion of the Earth round the Sun. Orbit of the Earth. Origin of seasons. Longitude and latitude. Motion of the shadow. Twilight time. Magnetosphere. Origin and visibility of auroras.

Moon
Moon as a celestial body. Motion of the Moon round the Earth. Origin of the phases of the Moon. Eclipse of the Moon. Effect on the Earth. Tide. Surface of the Moon.

Sun
Sun as celestial body. Effects of the radiation of the Sun on different areas of the Earth. Sunspots. Visibility of the Sun in different seasons and in different parts of the Earth. Sunrise and sunset. Visibility of the Moon at the same time with the Sun in different phases, in different orientations and in different times of the day. Apparent path of the Sun. Ecliptic. Vernal and autumnal equinox. Summer and Winter solstice. Solar eclipse. Calendar. Sundial.

Celestial mechanics
Celestial sphere. Coordinates. Equatorial system. Right ascension. Declination. Ecliptic system. Longitude. Latitude. Determination of the degree of longitude by zero-degree meridian. Motions in the solar system according to Newton's theory of gravitation.

Pupils should learn to understand, how daily life depends on the Sun and how motions of the Earth, the Moon and the Sun influence each other. They should explore circumstances caused by the motions of these three celestial bodies, on different areas of the globe in one moment of the year or in one day. They should also understand variations in circumstances in different global areas during all the year. For example problems containing in Midnight Sun, period of darkness, twilight time, zero-length shadow, and days of both equinoxes and solstices, will be solved best by modelling observed phenomena. Through this, the origin of phenomena is intended to find out. Positioning system of celestial bodies, time determination and time measuring can be studied as advanced subjects.

As for the worldview, this thematic entity includes concrete things observable by naked eye. One's own eyes are sufficient as observation tool, the Moon may be observed by binoculars, and telescope can be used to observe more details. Life on the Earth is evident, but it is more a question of life conditions in this thematic entity. One should consider whether conditions convenient for the existence of life would be preserved, such as influence of sunlight, thermal balance and quality of climate. In addition to life on the Earth, the Moon (during the last years 2004 and 2005 also Mars and Titan, the satellite of planet Saturn) has been explored for finding traces of life.

In different cultures, many kinds of solutions have been invented for following the flow of time and measuring time. Interpretation of the role of the Sun varies from realistic conception to magic beliefs between cultures and periods. These considerations have impacts in formation of the worldview.

As for the conceptual structure, certain basic concepts of the qualitative level will be quantified to quantities an laws, particularly those necessary for representation of motion, like time, position, velocity, and angular velocity,. Consideration of dynamics includes for instance an exploration of the motion of the Moon related to the Sun, and its connection with the phases of the Moon. In the generalisation hierarchy, the case of individual celestial bodies will be changed in the system of several bodies, and in its properties.

Solar system

In this thematic entity one shall move on from the immediate surroundings of the Earth to the planetary system, including also the rest of known objects in the solar system, as comets, asteroids and meteors. This is an enormously big step towards the great distances.

Planets
Planets in solar system. Planet. Sizes. Distances from the Sun. Prediction of location by mathematical model. Rotation periods. Orbital periods. Periods of day and night and seasons. Orbital speed. Angular velocity of rotation determined by the wavelengths of light. Catalogues of planets. Comparison of properties of planets. Peculiarities. Motions. Retrograde motion. Orbits. Satellites. Determination of the size of the Earth. Age of the Earth. Mini-model of the solar system. Visibility of planets. Elongation. Use of Internet. Mutual interactions of planets. Theories of motions. Kepler's laws. Annual parallax. Advance of perihelion of inner planets. Planet survey. Probes. Space exploration. New planets.

Sun
Composition. Location in space. Fixed star. Sunlight. Energy of the Sun. Temperature. Difference between the planets and the Sun. Influence of the Sun on the atmosphere of the Earth and phenomena in the magnetosphere. Origin and future of the solar system. Star. Natural laboratory.

Planetary system
Chronology of systems. Aristotle's spherical symmetric worldview. Four elements. Geocentric system. Heliocentric system. Physical worldview. Periodic motions. Predictions. Newton's mechanics. Gravitational interaction. Fundamental laws of dynamics. Law of gravity. Laws of electromagnetic forces in solar system. Asteroids.

Meteors
Meteor as a celestial body. Structure. Composition. Visibility. Falling star. Meteorite. History. Prediction.

Comets
Comet as a celestial body. Composition. Structure. Motions. Origin. Visibility. History. Prediction. Catalogue. Exploration.

In this subject area one shall turn, from examination of short-term events, to observation of objects, which move slowly against the stars, and follow their motions. The purpose is to learn to perceive motions of components of a large circulating system, to observe objects invisible by naked eye and to understand the heliocentric system. Especially the zodiacal level as connected to motions of objects will be perceived with a model for visualisation and understanding the entirety. Also the structure and motions of all the other objects in this thematic entity will be modelled. Phases of the inner planets are explored by comparing them with phases of the Moon.

The worldview expands out of the familiar immediate neighbourhood to the structural part of by-naked-eye visible and invisible objects, which is impossible to explore as entirety. Time causes limitations. All happens so slowly, that it cannot be perceived in short-term teaching. As for the worldview, this structural unit can be explored with a ‘standstill’ model, which illustrates the distances and sizes.

In observation one will learn to distinguish planets from stars and to follow their slow, even retrograde motion against the stars. Getting information provides almost always the use of observation tools. Own eyes are sufficient just for objects closest to the Earth, but no more exact information for example of their structure and composition is available in this way.

It has been possible to explore objects of this structural unit concretely, because it has been possible to launch probes to them or flying by them, with help of the latest space technology and technological proficiency. The competition between countries about the conquest of near space is growing all the time, while a more compact united front would be needed instead because of the same aims. New exploring equipment has been produced by space technology, for instance, to analyse samples from the Mars soil and to send resulting data to the Earth.

Life searching is going most eagerly at present on Mars, but also outer objects have already been explored through fly-bys of probes. The newest exploration object is the comet, which is going to be explored also by probe.

By exploring motions of components of the solar system and their dynamics, the level of laws in the hierarchy of quantification can be achieved. One can get even to the level of theories. In the hierarchy of generality, we progress from the level of single named objects to recognition of classes of objects on the basis of their characteristic properties.

Stars and constellations

In this thematic entity we move on outside the solar system. We acquaint ourselves with new entities, stars and phases of their development. We learn to recognise most common constellations in the northern hemisphere, most famous representatives of them with special names, and deep-sky objects in the area of the constellation.

Star
Difference between star and planet. Birth, structure and development of a star. Phases of life of a low-mass star. Phases of life of a massive star. Observing a star. Magnitude. Identification of stars. Spectrum. Spectrum analysis. Constitution. Determination of distance. Parallax. Proper motion. Radial velocity. Variations of brightness. Variable stars. Motion of stars. Doppler effect. Multiple stars. Colour of star. Star catalogue. Radius of gravitation or Schwarzschild radius. Nova. Supernova.

Cepheid. Black hole. Neutron star. Pulsar. White and brown dwarf. Red giant. Quasar. Explosion of star.

Constellation
Star map. Constellations in northern hemisphere. Special names of the brightest stars. Zodiac. Location and order of zodiacal constellations. Model of Zodiac. Calendar. Horoscopes. Mythology. Star atlas.

In this thematic entity a long step is taken outwards to space because the distances grow incredibly large. Pupils should understand the connection between the Sun and the stars, and the location of the solar system among the stars. They should get a conception about the distances of stars compared to the size of the solar system and a mental image about the course of life of stars – their birth and death. Pupils should observe sky and stars, to feel enjoyable emotional moments under the starry sky, and thus to get motivated in making individual space explorations.

Perceiving enormous distances, numbers and sizes of stars will broaden pupils' worldview in the field of the unimaginably large structural units. Stars may be observed by naked eye, but when observing other objects we have to use observation tools.

Interpretations about astronomical objects in different cultures become familiar in mythic stories of constellations. The subject area will be connected at the same time with pupils' own environmental history and people's conceptions. This has an influence on the development of pupil's astronomical worldview.

In concept structure new entities, phenomena and properties of them are determined. Quantities and laws, even theories will be quantified in these. In the hierarchy of generality we proceed to large stellar systems.

Galaxies

Stars and constellations form an enormously large stellar system. Stars can be observed by naked eye, clusters of stars by binocular or telescope. Visible stars belong all to our own galaxy. In this thematic entity the scope is broadened to formation of the structure of space outside of our galaxy. We are going to explore distribution of galaxies in the universe.

Milky Way
Star system. Star groups. Interstellar matter. Nebulas. Size. Structure and components of the Milky Way. Motion of Milky Way. Dynamics of a star system. Observation of Milky Way.

Galaxies
Types of galaxies. Andromeda. Occurrence of galaxies. Sizes and distances. Distribution of galaxies in space. Observation of galaxies. Motions of galaxies. Red shift. Doppler effect. Local group. Galaxy group. Giant group. Problem of dark matter.

After being acquainted with stars, pupils should learn to know our own location in our galaxy and ponder possibilities and impediments of observations as for our galaxy. In addition, they should perceive distances and sizes of objects outside of our galaxy, learn to appreciate the limits for observing them, and to realise the solar system as a small particle in the large galactic system.

With efficient observation tools developed by space technology, we will get information about the constitution and dynamics of objects in the structural unit (*cf*. chapter 10.1.1). Large telescopes on earth and in orbit round the Earth can produce images even of very faint objects. These images are seen on the Internet, so everyone may observe the universe 'by naked eye' on the screen of his own computer.

Universe

In this thematic entity the whole universe is handled as one large system. For finding out its structure a simple model can be prepared according to the structuring principle (see chapter 10.1.1, theme Worldview).

> *Structure*
> Expanding chain of environments from microcosm to macrocosm. Quarks. Elementary particles. Nuclei of atoms. Atoms. Molecules. Bodies. Planets. Solar system. Galaxy. Galaxy groups. Giant galaxy clusters. Man's position in the chain. Inorganic and organic nature. Cell as a structural unit of organic nature in chain. Modelling.
>
> *Problem of space*
> Infinity. Number of galactic systems. Dimensions. Systems similar to solar system. Background radiation of space. Radiation of black body. Big Bang. Quasars. Cosmos with geometrical regularities. Radius of space. Distribution of matter. Interstellar matter. Cosmology. Dynamics of galaxies. Theory of relativity.

Pupils should get a mental image about the structure of the whole universe, get familiarised also in the small structural units of the structural hierarchy, and understand the chain of units as a whole from the small structural units to the large ones. They should accept the fact that there exist insolvable problems, learn to know different kinds of explanatory models, participate in discussion of the future of the world and in search of answers, and think about the problem of space and time.

Observation and exploration

In treatment of the levels of structural hierarchy as thematic entities, the emphasis is necessarily in getting acquainted with and learning to understand objects and phenomena of the different levels. In that context discussion of the tools of the methods of observation and their development will necessarily be limited. Therefore, in order to give an idea about the multitude of astronomical observing methods and tools and their development as a whole, it is advisable to have this theme included in the syllabus also as an additional thematic entity in itself.

It is important to observe the Sun, the Moon and the stellar sky in nature. Photographing of stars should be included as one teaching method. Also other observation methods, such as the use of web camera or CCD-camera in observations can be tested.

In appendix 10.1 there are listed a lot of subject matters, which would naturally belong in the astronomy course or be themes in the teamwork or project work. The list in its entirety would give an overall picture of the subject area of this thematic entity (see chapter 10.2, teaching of experimentalism). It is the teacher's option to decide which items of the list are included in the six preceding thematic entities and what part of the list remains to be included here for completion and deepening of the general picture.

This thematic entity can be divided in three sub-areas: 1. *observation*, 2. *observation tools* and 3. *space technology*, depending on the way of handling of subjects or the methodological selections. The first sub-area will naturally have been covered to a considerable extent in the previous context, at least more than the other two.

Observation

This subject matter concentrates especially on human's viewpoint in making observations through all the preceding thematic entities, starting from observations by naked eye to those of objects in the outermost areas of the universe by equipment of modern technology. The purpose is to study development of acquisition of information.

Observation tools

In this area one becomes familiarised with different kinds of tools in acquisition of astronomical information. It is recommendable to prepare simple tools and test them. One should also learn to use a few available tools and to make some measurements. Also, use and usability of various tools and their limitations should be discussed, as well as evidence produced by modern observation tools, and their reliability.

Space technology

In this area possibilities and restrictions of space exploring, new equipment for observation and new research methods are investigated. In this context one should think about possible different interpretations and utilisation possibilities of research results and observation findings. One should get acquainted with the actual findings in our solar system and measuring results, and, more generally, with achievements in astronomy, contributed by way of space technology, including considerations of their scientific significance, evidence supporting the interpretations, and expectations for future development. There is also a good opportunity to discuss co-operation of the scientific and the technological process in astronomy.

10.2 Methods

This chapter suggests specific methods suitable for examination of entities, phenomena and properties within each thematic entity and structural unit. The purpose is to present methods and tools which would aid the pupils in acquiring knowledge and understanding of the different astronomical entities, pointing out objects, which pupils can observe in the sky, methods of observation available or possible, and models, which can be used to illustrate the structure and phenomena of the objects. In addition to these choices or instead of them, the teacher may, of course, freely use other, self-chosen methods.

The main method in the entire course is *the perceptional approach*, where perception of empirical meanings of concepts is understood as the primary basis of understanding as described in chapter 5.4. According to this, the teaching should proceed from observations to concepts and theories, from concrete to abstract, and from specific to general, thus, following the progress of conceptual hierarchy of science in sense of the hierarchies discussed in chapter 5.2.2, and, at the same time, taking into account the development of astronomical worldview.

In addition, in planning and selecting methods of teaching, the process structure of science and learning, as described in chapter 5.2.2, has to be taken into account. This means particularly, that the procedures should support the three basic processes, the scientific, technological and social process evenly. The methodological choice in scientific process concerns the relation between inquiry and theory in teaching, in other words the emphasis between inquiry and theoretical considerations. Choices in technological process concern the share of pupils’ own activity in planning and preparing observation and experiments and the methods in application of knowledge in teaching situations. Social process is activated by methods involving interaction and co-operation of pupils, such as discussions and teamwork.

The general aim of all teaching procedures is to aid the construction of mutually understood meanings of concepts in the pupils' minds. Teaching should include considerations, which contain these meanings and their use in practical applications, and co-operation in the classroom (for example inquiry and discussion), that consensus about meanings of concepts can be achieved. Also the interaction between teacher and pupil is a part of the social process. There the aim is much more than to deliver information. The teacher's task is to guide the pupils' perception process, to *motivate* pupils to search for information by themselves, to find out methods of getting information, and to work out for common orientation. The teacher makes choices concerning all the processes separately for each teaching event, taking into account the level of pupils’ personal development (*cf.* chapter 6.2.1).

Freedom in choosing one’s teaching activities can be seen as a motivation for the teacher. It has to be noticed, however, that following the path of *structural hierarchy* is also a methodological choice, based on the development of pupil’s astronomical worldview (*cf.* chapters 6.1.1 and 6.3.1). Teachers’ attitudes influence also the use of an arguable method, which may form an obstacle to realise the teaching (*cf.* chapter 8.1.3). These attitudes can be changed for instance in teacher training.

Even if the immense extent of space and amazing celestial phenomena have always fed people’s imagination and inspired inquisitiveness and wondering, there may still be problems in motivation (see chapter 4.4.5). A pupil is curious by nature, wants to see and hear everything nice and new, wonder ‘miracles’ and particularly in boys’ opinion to take fright at ‘strong bangs’! Problems in motivation come into the picture for example when there is a long-term, monotonic and ‘quiet’ research work, where nothing illustrative is going to happen, and whose results should be handled by ‘boring’ calculations or formulas. A common phrase is that ‘an inspiring and expert teacher is able to raise pupils’ interest. No doubt, so must be the case. Fortunately these pupils of space age are accustomed to use new available tools without problems. Modern technology has developed qualified measuring and exploring tools, which utilise the among-pupils-popular information technology in many ways.

10.2.1 Consideration of methods in the environs of thematic entities

Next six specific teaching methods: 1. *observation, 2. 'concrete' modelling, 3. preparing of observation tools, 4. use of source material, 5. presentation and discussion, and 6. experimental activities.* are considered in the context of the thematic entities presented in chapter 10.1.2.

Observation

Observation is the principal teaching method in astronomy. Pupils will learn through their own observations to understand, in which way concepts are based on observations. They should also learn to understand how empirical meanings are born, even if objects in the larger structural units are not observable. There are always three components present in the common observation event observation tools, observations, and discussion about findings.

The research object of astronomy, the stars and the whole universe, is concretely surrounding each pupil all the time. Teacher should encourage pupils to look at sky. Observation in natural surroundings may inspire pupils to make their own examinations.

When observing everyday phenomena, one's own eyes are the best tools for a start. The Moon in sight, location of the Sun and the light phenomena in the atmosphere can be observed without any tools. Influences of the Sun on the Earth can be explored in nature. Watching the dark starry sky is one of the most important activities in astronomy teaching. Stars, planets, auroras, meteors and comets can be directly observed. Galaxies, clusters of stars and nebulae are observed generally by telescope, but some of these objects are seen also by binocular.

Observation in natural environment is the best way to study constellations. Only one expert in the group is sufficient to tell about the objects observed. The whole group can see at the same time the object and listen to the explanation. Pupils may familiarise themselves with constellations by a map – maybe, in the background they have systematic studies of constellations, and now they observe them in nature. Teaching of constellations can, of course, also be started with observations, which then will act as a pre-organizer for perception of the structure of the entire visible stellar sky.

Modelling

Models are needed to form mental images about the structures of different sizes in the structural chain. In a teaching situation there should be discussion with pupils about which way the model is connected with the observations, how does it illustrate the reality, what are its limitations, and in which way it is inadequate.

Observing by naked eye is most important when familiarising oneself with every day phenomena. Various cases can be explored best by modelling them in the darkened classroom using a lamp and small balls. A grill stick may illustrate an axis of the Earth made of Styrofoam, and short pieces of the stick can be put in different sides of the Earth as things or observers. Pupils carry the Earth tilted in the right angle round the lamp representing the Sun. For examining regional differences, it is useful to draw equator, polar circles, tropics and meridian circle in the Earth. The path of the Sun can be explored for example by following motions of the shadows of the sticks.

Phases of the Moon can be explored in the darkened classroom using one's own head as the Earth and a small ball made of Styrofoam as the Moon. One bright lamp in the middle of the classroom is sufficient for the Sun. It is easy for everybody to look at these events as seen from the Earth, and vary them by circulating the Moon round one's own head. Pupils explore phases either by making open research or by searching for answers to given questions. The observed phases of the Moon will be drawn in the schematic picture. Also the eclipses and the location of the Moon in different seasons and periods can be explored using this kind of arrangements.

Motions of the Earth, Moon and the Sun can be illustrated by explorations both with models in the darkened classroom and by observation in nature. Motions of the Sun may be explored for example by the shadow of the stick in the ground, by preparing models of the sundial or by marking regularly on a spherical dome the hitting points of the sunray directed straight towards the centre of the sphere. Special cases, including the seasons and the annual path of the Sun, kaamos, the Midnight

Sun and the zero-length shadow, should be explored carefully in the classroom with the model, and the pupils' understanding about them should be tested several times.

The amount of the sunlight in different areas of the Earth can be explored using a larger Earth-ball by keeping its axis in the right direction and moving the Earth in its orbit round the lamp-Sun. If the sunlight comes on the Earth as a beam of parallel rays, one can perceive clearly alternations of the illuminated area and the angle of the rays to the Earth in different latitudes. To determine the radiation power of the Sun, all the necessary measurements have to be made in nature.

The model of the solar eclipse can be built in the school corridor or on the schoolyard in a suitable relative with correct relative sizes and distances. In this case one can observe the Moon to cover the far off Sun totally.

The most common model made in schools is the planetary model of the solar system. It is placed in the classroom, corridor or on the schoolyard. To perceive the dimensions correctly, the model should be constructed in scale. This is often difficult to realize because of practical restrictions; there is no room large enough in the school for the model. Pupils can be given calculated values for the dimensions of the model or they calculate them first by themselves, depending on their age and capabilities. The best situation is if the model could stay permanently for instance in the neighbourhood of the school. In this case it would be easy to come up to the model if needed; it would work all the time as inspirer and review tool. Another possibility is to build the model in two different scales, one for size and another distance. Then it is important to impress this difference many times on the pupils. A three-dimensional model is the most illustrative one, also a two-dimensional model is satisfactory, but more time is needed for discussing and pondering about the limitations of the model.

Comets can be illustrated for example by gluing strips or threads in a small ball, and by moving it round the imagined Sun so that on the place of the Sun there is a ball blowing air in all the directions. So the motions of the tail can be illustrated very well.

Using the model of Zodiac the mutual motion of the Earth and the Sun round the year will become perceived. The pupils can prepare first as teamwork a poster of each zodiacal constellation. The posters will be placed in the classroom to show the apparent path of the Sun. The most illustrative way is to use a 'living' model in addition to posters, where pupils represent each part of the model (see chapter 9.3.3).

Constellations of the northern sky can be placed on a transparent hemisphere, for example an umbrella, and then one can look at 'the starry sky' from inside of the hemisphere. Equatorial and ecliptic circles can be drawn on the surface. A small camera placed in the middle of the hemisphere gives a picture on the screen of a computer for all the class to observe. The umbrella can be fixed in the horizontal plane and its inclination can be varied using the scale fixed in the plane. By rotating the dome with different inclinations, motions of the celestial sphere in different latitudes from equator to North Pole can be illustrated. If we fix the Sun in the ecliptic circle in different zodiacal constellations, the path of the Sun in different seasons can be illustrated. One can use this model when teaching coordinates of celestial bodies according to different coordinate systems.

Stars can be 'sampled' in a large stellar system by preparing a model of the spiral galaxy of Milky Way to scale, and then examine the galaxy 'from outside'. Outside of the spiral plane small balls may be fixed by wire to illustrate the globular clusters of stars. A coloured pearl will mark the place of the solar system, a larger one than in scale, for figuring out more easily the place. It is easy to explore with the model different situations in the vicinity of the Milky Way from outside.

Structural units of macro- and microcosm form a coherent structural chain, which can be illustrated by pictures of environs extending gradually in successively larger scales. A model of this chain can be prepared by gathering structural units in a booklet, where each double page represents the environment in one scale of the chain. The Earth is placed in the middle pages, from which one may move on in two directions to the micro- and macrocosm. Each double page may have condensed information of the structural unit it illustrates, one may draw or glue pictures on it, or write the title in several languages. This is a good opportunity to integrate disciplines. For perceiving sizes the dimensions of the unit can be marked as powers of ten.

Preparing observation tools

Astronomical information is found in the literature and Internet. But there are unfortunately few materials in didactical astronomy. Astronomy teachers have had to develop their teaching methods by themselves, very often their teaching tools, too (see chapter 7.1). Fortunately, quite simple and cheap tools can well illustrate astronomical phenomena and events. Then, lack of money will not become an obstacle for astronomy teaching.

Tools for exploring astronomical phenomena by models (like lamp and balls) can be found in every school. Illustration of phenomena using them is clear. Situations can be changed fast and differences are seen clearly. It is easy for the teacher when walking around in the classroom to test pupils' understanding for instance by asking them to demonstrate some particular situation with these tools. At the same time he may ask more specified questions. This subject area is naturally easiest and most illustrative for the teacher himself, and there should not be any attitudinal obstacles for astronomy teaching.

Simple observation tools can be self-prepared either by making them of materials according to instructions or by sampling ready models. It is important and necessary to teach how to use them. In addition, the use of ready observation tools and research equipment is good to learn. One of the most important aims is to learn to use the telescope, but observation by binocular is sufficient so far. Observation by naked eye should be emphasized.

The sundial is one of the most common self-prepared observation tools. Many models are found on the Internet. The dial has to be calibrated after sampling and tested in use. The dial can be made in the classroom as teamwork; it can be tested together in the darkened classroom with the lamp-Sun or outdoors in the sunlight. The group may prepare a dial, for instance in the lessons of shop, of the 'hard' materials (*e.g.* wood, metal or plastic sheet) to be placed out.

An Astrolabe is easy to prepare as individual or teamwork using hobby materials. With that for example declination of the Sun, latitudes and mutual angular distances of stars can be determined. It has to be emphasized, in connection with the determination of the declination of the Sun that one must not look at the Sun straight through the tube or straw. The direction of the Sun will be defined by locating the luminous point on the palm or paper.

Use of source material

One should practice acquisition of knowledge from different sources throughout the school time. Astronomical information for all the school levels is readily available in various sources. Because the quality of this information varies much, it would be wise to teach pupils to be critical with the found information. Besides surfing in Internet, the teacher should inspire pupils to read astronomical books and search for information also in them. The use of this method requires getting elementary astronomical books in the school library or subject classes. The astronomical association Ursa publishes plenty of books and magazines for the public and school use. One may borrow from Ursa also whole teaching packages and an inflatable planetarium for schools.

The use of the Internet is a key in astronomy studies especially when one studies deep sky objects outside the solar system, and acquaints oneself with latest research results and discoveries. It is possible to get information in Internet even of such objects, which cannot be observed and explored by oneself. Images taken by most qualified equipment are available for all. The networks join all willing individuals in the vast group of observers. It is difficult to learn to filter information about stars and universe obtained from Internet, *i.e.* to find just the essential information sufficient in each thematic entity. One of the newest teaching methods is the teaching of the use of Internet.

It is easy to prepare a mini-model for example of the Milky Way. When familiarising oneself with other galaxy types it is sufficient to use Internet or literature. In the school one may prepare as project work mini-models of the most common types of galaxies and hang them in the ceiling. They serve there as permanent teaching and review tools.

It is difficult to illustrate phases of life span of stars, but one may get familiarised with them also in Internet and literature. There exist illustrative and educational video clips of the behaviour of objects, which move near a black hole. There are also video or simulation presentations of the motions of planets. The greatest utilisation of these is a quick repeatability and possibility of variation. By changing parameters and original values almost any motion of the object in the solar system can be illustrated.

Internet

Internet in these days is one of the most popular tools in getting information about astronomical topics. But there are also some more special opportunities to benefit of it. For instance, it is possible to utilize teaching sessions on the other side of the Earth via Internet in real-time. A good example of this is the connection by computer to the spaceport in Pasadena, explained in chapter 9.1. The Finnish pupils could use large telescopes as if they were in the observatory themselves.

Presentation and discussion

Narration is very useful if you want to describe historical events and phenomena. It is useful also when you describe such kind of actions and research works, which could not be modelled in the classroom or explored empirically. You may deepen and improve the teaching and increase pupils' interest in subjects to be taught. This method may be called 'narrated inquiry'. The base of this method should include 'real' explorations and a verification of the reliability of results, so that pupils should became convinced of the scientific validity and reliability of the results. Thus also narrated inquiry can be accepted in the classroom as an example of astronomical research.

Narration may be used to describe astronomers' life work, present various abstract models and ponder theoretical conflicts. It is an excellent 'snack' between different stages in teaching some subject area.

In this context, presentation means a solid coherent presentation by the teacher, where a phenomenon or event included in thematic entity is taught in an illustrative way making use of any suitable supporting aids. Slides, videos, transparencies or other tools are useful as support of oral or computer-based teaching. Narration is very convenient when you want present such kind of research arrangements, backgrounds or equipment, which cannot be illustrated or explored in the classroom.

The teacher's presentation is good when studying constellations. It would start from the most familiar constellation or Big Dipper proceeding step by step so that in every stage new constellations close to known ones are introduced and studied. Thus, the whole northern starry sky becomes constructed as one large net of constellations. There is something familiar and new in every stage. The known constellations are kept in mind both for repetition and for combining new constellations in them. The brightest stars, clusters, nebulas and galaxies in the area of each constellation become will be presented by their names.

Discussion

Discussion with pupils is a good method for mapping of the background knowledge and the conceptual level of the pupils as well as an advance organiser of the subject to be started. Besides discussions ready models are very illustrative in teaching. Pupils should be allowed to think and present freely their own conceptions, they should also learn to listen to other people's opinions and take part in common discussion in a controlled way. This method is excellent when teaching social abilities to pupils.

'Thought experiments' are good provoking subjects for discussion. They may be very motivating. They activate construction of pupils' worldview and give them inspirations and experiences. Pupils like to ponder various 'impossibilities'. For instance riffling through the pages of structural model of the universe is a good opportunity to ponder with pupils problems related to the beginning and end of the universe, to think about connections between micro- and macrocosm, and to play with thoughts 'what if'. As an example, one may consider what would happen if you jump from the area of microcosm in the model straight through the booklet to macrocosm?! Or what would the world be like without friction? What if Jupiter should have became a sun? What kind of seasons we would have if the orientation of the axis of the Earth would be different? When started, the pupils are able to invent their own thought experiments endlessly.

Experimental work

Experimental investigations should activate pupils in independent research and, at the same time, get them familiarized in method of scientific research. Subjective explorations of astronomical phenomena will help pupils in their construction of worldview (see chapter 4.4.6). They may also offer good examples or points of contact with other disciplines.

Even younger pupils can explore the path of the Sun independently using the plastic hemisphere if they have got sufficient instructions. Collecting data sets in long-term measurements will educate them into responsibility and persistency.

Exploring elliptical orbits of the planets suits for pupils already in lower secondary school, especially drawing the orbit with thread and two sticks is considered inspiring. This subject can be integrated with mathematics when teaching the coordinates of the point or the equation of the orbit.

The radiation power and temperature effects of the Sun can be measured with simple tools outside of the classroom in the sunlight. Results are drawn in graphic representation and desired values can be calculated in them. This kind of research is convenient also in the lower secondary school, if you reduce calculatory aims.

Intensity of the light as function of the distance from the source can be explored in the classroom with an exposure meter. From this it is easy to start the discussion about the light received from a celestial object, its intensity and colour, and its relation to the distance.

Project works are convenient when teaching a larger subject area including many parts. For example, the planets in the solar system are excellent and most common subjects for teamwork. Each group acquaints themselves with one representative of the solar system, and prepares a presentation of that for the common session. Project work can also be a painting made by the group on the wall of the school (see chapter 9.3.3) or a performance on the stage. The group may also prepare a computer-based presentation using Internet. Some groups may photograph stars as their teamwork, learn to recognise constellations and use photographing equipment or materials and study photographing techniques.

Photographing studies require both teacher and pupils to commit themselves in this action. Star photography is not easy at least in the beginning, but one will be trained in that soon. Through trial and error many people learn to plan the photographing event properly: appropriate equipments, films with correct sensitivity, useful tools such as a lamp with red-coloured light, considering weather conditions, exposure times, source materials etc. It is worth to study photographing at first with a common mechanical camera. New digital cameras are not appropriate in all kinds of star photography. In addition, photographing through the telescope can be studied. Use of new technological applications increases substantially the possibilities for star photography. For example a star image in the telescope can be seen on the computer screen with help of the camera connected to the telescope, it can be saved on the disc, photographed by the digital camera or recorded by the video camera. The saved image can be edited with different computer programs if needed.

Mathematical exercises are not essential in astronomy teaching based on practical methods. Mathematical examples are special cases or deepening part of the subject, but not in general the main contents of the subject - not to speak about mechanical formula calculation. Problems to be solved should be based on empirical explorations. Mathematical treatment of observational data may still be necessary; particularly when the data are based on one’s own measurements. Simple calculatory tasks are often involved in modelling. For instance, when preparing a mini-model of the solar system to fit in the school interior one has to calculate sizes and distances for the planets of the model. Also when teaching motions of the planets, it is useful to verify the validity of Kepler's third law on the basis planetary data. If you wish to determine the diameter of a distant galaxy on a slide or to compare properties of the planets you will need proportionality calculation. It may also be interesting to calculate radii of the event horizons of fictional black holes born in the collapse of stars. According to my experience, this may initiate long discussions, showing that such a calculation may act as a motivating agent. However, theoretical deductive calculation, such as prediction of motion of bodies on the basis of Newtonian mechanics and the law of gravitation, can come into the picture only later, at the earliest in the upper level of the secondary school.

IV Conclusion

11 Conclusive discussion

I have examined in this research work (1) the need and (2) the possibilities of astronomy teaching in the Finnish comprehensive school. As a result I have made in chapter 10 a proposition (3) for the guidelines of the contents and methods of astronomy teaching, which is based on the clarified need and possibilities, and takes at the same time into account the conceptual structure of astronomy and demands of the development of pupil's astronomical worldview.

For this I made five mapping examinations. The bases for estimation of the need of astronomy teaching are in the first place (i) *the significance of astronomy* (chapter 4), which consists of all such factors through which teaching of astronomy can promote the educational aims of school. For planning contents and methods that fulfil significances I mapped (ii) *the conceptual structure of astronomy* (chapter 5) particularly as for the birth and development of the construction of astronomical knowledge and meanings of concepts, and (iii) *the development of pupil's astronomical worldview* (chapter 6) particularly as for the viewpoint of astronomy teaching. For clarifying possibilities to realise the teaching, I examined preconditions for teaching astronomy by mapping (iv) *existing starting points and practices for astronomy teaching in sch*ool (chapter 7) and (v) *teachers' attitudes to astronomy teaching* (chapter 8). Besides the mappings, my research is based on my own experiences of different kinds of experimentations in astronomy teaching, which I have had in the comprehensive school for over twenty years, and also on teacher education during the last years of this research, including my work in the international association for preparing a recommendation concerning astronomy teaching (chapter 9).

Significances are mapped by analysing literature concerning astronomy and astronomy teaching, by projecting facts and explained takings of an attitude in them in the classification of the educational aims presented in the school laws and curricula. The historical viewpoint was emphasised in this analysis for two principal reasons. At first, the significance of astronomy teaching relates closely to the significance of astronomy to the mankind in different fields of culture, which can be seen in the historical development. Secondly, the learning, and in this context more generally the development of pupil's astronomical worldview, is on the personal level the same kind of process as the progression of science in the mankind's cultural community. That is why the examination of the historical development forms at the same time also the basis for the planning of contents and methods of astronomy teaching in the way, which takes into account the proceeding of the construction of worldview and its conceptual knowledge.

Studying the stages of the history of astronomy aids to *construct the worldview*, acts as *constructor of concepts* and builds up pupil's *own entire conception about the universe*. Various *emotional experiences* are also important in the development of individual's personality; astronomy gives a lot of such kinds of feelings. *Observation* and *discussion about observations* include at the same time learning of science's development and scientific research work, which educates pupils both in *doing science* and *in social life*. When teaching astronomy pupils will get *the astronomical basic knowledge,* which is *important for an individual in society* when all the time present and in action necessary processes come true. A person grows up to the science doing, by acquainting himself with scientific method. *Searching mutual agreement* by discussing of observations and discrepancies will educate him in social life, *broaden conceptions* and construct individual's worldview. When *doing science* and *own examinations,* a person acquaints himself at the same time with *technological deci-*

sions and *applications*, his *individual abilities* both in *utilising technology* and *promoting* its possibilities increase. So the subject content knowledge and skills, contents and methods arisen in the mappings of history and school world, help in their part to achieve ordinary educational aims. In the light of these research results, astronomy teaching is significant in all the educational fields, so teaching of it is needed for to reach the educational aims.

As result of the mapping, the fulfilment of the significances of astronomy teaching will take its form in five themes, which guide the planning of astronomy teaching.

The main theme and the whole planning process controlling longitudinal factor rises (i) *the worldview*, whose development follows the direction of pupil's natural development, and which is constructed during all the individual's life. Expanding of the worldview from the immediate surroundings to the large and distant objects forms the structural base of astronomy teaching. Grouping of the contents in the gradually expanding entities within each other in the hierarchical chain of the structures follow this natural course of the development of astronomy and mankind's history and individual's personality.

The other four themes remain this structure permeating subject matters or subjects, which guide the planning of teaching in various phases of this construction. (ii) *Observing*, its possibilities and impossibility, influences especially in the methodological planning of teaching and approaches.

At the same time it is a question about the resources of the school and especially of the pupil. (iii) Pondering, in the classroom or on personal level, over *the existence of life* is always actual and interesting. This includes a strong social thought – we alone in the whole universe or where are the others?! This problem acts also as motivating and inspiring factor towards the scientific research and universal perceptions, and trains at the same time pupil up to doing science. Teaching planning of each subject matter includes pondering of exploration equipments and tools. This concerns both observations and examinations in school and scientific research work round the world. Through these activities pupil will acquaint himself (iv) with potentials of *technology* and available tools and equipments. Various (v) *culture environments* come up in the review of history and brought up globally by modern technology will enrich pupils' worldview and join them as a part of mankind's great development process. This includes also a strong factor bringing up in social life and approval of pluralism, which fulfil aims of the development of personality. This theme gives a reason to emphasise teaching methods, which are based on social interaction, as teamwork and discussions in which astronomy teaching offers many kinds of possibilities. They suit well also the fulfilment of school's social educational aims, because the aim to gain the mutual understanding in the school community is emphasised especially clear in them.

The essential significance of astronomy is, besides in the construction of pupil's worldview, also in *the mental image* of the entire universe being structured in *the perceiving of concept formation and conceptual structure of astronomy*, starting from microcosm and extending in unbelievable large macrocosm. Because *the structured picture of the world* is important *as for the human's well-balanced development*, it places astronomy in a special position among the other disciplines, and brings out a sample of principles presented before, to be taken in account in planning astronomy teaching. In addition to that, it brings out a significant methodological factor in astronomy teaching, the principle of *the perceptual approach*. The sensible, meanings-constructing learning provides that astronomy teaching proceeds, according to the generalisation and integration development, from single concepts to still more general and extended concept fields. It also proceeds, according to the conceptual hierarchy, from the qualitative level of entities, phenomena and properties through the quantification to the quantitative level of the conceptual structure, at first to quantities and from them through laws to theories. This development of the sample of concepts means at the same time *the development of language*, which is a significant fundamental factor of perceiving learning. The change to understand the use of physical concepts in astronomy depends on teaching according to the generalisation process of concepts.

In accordance to the perceptual approach, the basis of understanding learning is in *concepts' empirical meanings* – 'meanings comes first', and in *the significance of experimentalism* in teaching – 'by exploring one finds out'. The teaching also in astronomy has to follow the direction of natural, experimental proceeding from observations to concepts and from experiments to theory. Proceeding to the theory level as a learning aim provides always a conscientious consideration. MacIntyre (2002), Lucas (1999) and Taylor (2003) have investigated conceptual understanding in astronomy and effective teaching strategies.

The experimental work in school means in the first place *an experimental approach*, where the experimentalism is considered as the basis of all knowledge and understanding. There the own functional experimental work has a significant role. One has to learn to observe, measure, plan experiments, make different kinds of explorations, discuss about observations and interpret them for to understand the experimental basis of the knowledge. The own experimentalism in teaching situation requires anyway always additionally *a narrated empiry*, connecting own experiments to more exact and broaden, continuously specifying and extending experimentalism of science, and being acquainted in researches and experiments, which have been done and will be done in laboratories and observatories. This is necessary for to understand the empirical basis of existing knowledge. The role of the teacher is emphasised in this. *The theoretical approach*, the use of the existing theoretical knowledge, concept structures and models, as the starting point when teaching new thing has to be taken in use consciously by taking in account both the subject matter and the level of pupils' conceptual abilities. In every case, care has to be taken that the empirical basis of the theoretical ponderings becomes understood. Otherwise often very exotic evidences and ponderings of the modern astronomy may easily give an impression of mystic imagination games.

The aim also in all astronomy teaching is to *perceive entities* and teach pupils *scientific thinking*. It is important in consideration of the most essential education aim, the development of personality, that contents and methods of astronomy teaching will be planned according to principles described before and in the light of the themes arisen in the examination of history. In this case the teaching promotes best the development of pupil's worldview into the hierarchical system in accordance with the construction chain of the universe. In the same time it promotes the development of scientific work together with the development of pupil's own self-image.

The teacher has *an essential significance* when fulfilling these aims, although the contribution of other adults, close to the pupil, to the development of the harmonious picture of the world is not insignificant. The most important task of the school is to create such kind of *learning environment*, where the pupil may construct his own worldview according to the aims of teaching. Bennett (1999) has examined strategies for teaching astronomy and the learning environment, and states that it takes hard work to bring the science alive and to make it meaningful in the classroom (*cf.* Asbell-Clarke 2001). This construction process requires work from the pupil, because he has to think and ponder in the mind things being covered. In the same time the process requires special skills from the pupil, *process skills*, so he would learn to criticise the found information and to build his worldview construction according to that. On the other hand, it requires special skill from the teacher, so that pupil's working motivation would last and he would become inspired to explore scientific phenomena also individually. According to the research, pupils are interested in astronomical things, so teaching of them will increase motivation in scientific studies. The teacher has to help pupils to perceive connections between various concepts, to test the learning of the physical language and to guide the planning and realising of the scientific research considering pupil's age and abilities. Surely the teacher has to plan his own teaching, its contents and use of time. The more detailed planning of contents is based however *on the curriculum of the school*, the formulation of which all the teachers may participate in, on the basis of the national framework curriculum. The existing curriculum is quite cursory as for astronomy, so the teacher has had to plan astronomy teaching in his own school according to his own view and interests considering the use of time.

According to the research, examined possibilities of astronomy teaching, the teacher interested in astronomy makes generally his own individual curriculum. It includes often a sample of separate subjects, in which case there exists a possibility that pupil's worldview may remain a sample of separate information. In the astronomy division of *the national curriculum*, it should be mentioned, besides the topic, at least *the names of the components of the construction chain*, so that teachers would perceive the subject matter as an undivided entity. It should be mentioned also in curriculum the five themes arisen in this research as teaching guiding subject matters. In the school practices the teachers may then plan themselves the more detailed contents of the subject matters in the construction chain according to their own abilities and pupils' level of development. The most important is to teach astronomy starting from *the beginning of pupils' scientific studies*, to *collect up contents based on the construction chain and permeating themes* and *to proceed in teaching according to the conceptual structure of astronomy and the development of pupil's astronomical worldview*.

When mapping possibilities to teach astronomy, the problem of time seemed to emerge as threshold problem in many ways. Scientific studies should be started in all the school levels by exploring phenomena and events in the immediate environment and space according to proceeding strategy presented before. In planning the contents this means that astronomical contents are done at first. Another problem of time is an amount and extent of subjects to be learned. As basic thought I consider that the structure related to the worldview is covered as a whole, making eliminations and selections of subjects only inside of each subject matter. The decision how long time each subject matter is going to be covered remains with the teacher and it depends in its part also on the school's resources. According to this research, that did not seem to be a problem or an obstacle.

The development of teacher's own worldview puts a challenge to *the teacher training*. One of the priorities in teacher training, in addition to subject content and pedagogical knowledge and skills, is to *develop teaching abilities*, to help teacher to find his own *teaching strategy* (*cf.* Bennett 1999). Also matters concerning teachers' *attitudes* are included in the development of teaching abilities. The strong self-confidence, the sufficient, but thorough contentual and methodological knowledge in discipline to be taught, and the harmonious, clarified worldview will give the best basis for successful teaching.

Education training to teach astronomy has not been organised before this research work got started, of course the departments of astronomy have organised astronomy education. *The didactical astronomy*, research and planning of teaching based on the structure and significance of astronomy, is quite an unknown term yet, but this kind of education is now beginning in the university, at least in Helsinki. According to the research, teachers have participated in different kind of courses and made self-studies, but the number of passing ordinary university grades in astronomy has been low. This seems to be a great threshold problem for many people, for beginning astronomy teaching. According to the research, teachers experienced as a great limitation the lack of teaching abilities in astronomy. On the other hand, clearly seen in the study was the willingness of educating oneself, even if some preconditions – for example short distances – were easily set. Teachers were willing to participate in courses, as long as they got there teaching ideas, practical instructions and plenty of materials to apply in school right away.

For this research work I have organised courses of didactical astronomy in the department of physical sciences in the University of Helsinki for many academic terms. The courses are designed for pre-service subject teachers and class teachers, and also for in-service teachers. The teaching is based on exploring phenomena either in nature or using models. The aim of the education is to give course participants abilities to teach structured worldview to pupils, to train up knowledge of appropriate subject matters and teaching methods according to the perceptional approach and modern learning conception. The teaching in practical workshops follows progressive strategy based on the construction chain presented in chapter 10, using methods presented in the same chapter. Participants' feedback has been positive in general, they have experienced the course observational, systematic and educational just because of the own examinations and practical approach. The lack of elementary knowledge has indeed caused anxiety in some, especially in-service participants. I have comforted them by saying that astronomical information is easily found in literature and Internet, but in this course they have in addition got training to realise structural astronomy teaching, as such kind of the whole that suits best for themselves and their school.

At the end of the astronomy workshop courses in the university, I have asked course participants if they wanted to send me feedback of the course by email or in writing. In follows there are comments from some participants after the course:

> Thanks to you for astronomy teaching, I got many good hints to my own work in it.
>
> I want to thank you for the course. It has been very interesting!
>
> We thank you for the interesting and educational course. Especially preparing the illustrative booklet of micro- and macrocosm stuck in our minds and we are going to use it in our own teaching as well as other ideas in the workshops.
>
> Besides I went ... to buy the set of scale models of planets. Very nice, they are luminous in the darkness. Thanks for the good lessons.
>
> When the nights get darker I realised recently how a little time ago I participated in your course. And I promised, when seeing lately, to write something to you. There has not been time enough to write, because I got a real desire for knowledge in physics and its phenomena thanks to your course. And there is no more time to study besides working than earlier. I decided to become acquainted with astronomy, because it seemed to be a good key to physical sciences, thanks to its workshop-type teaching method. The large natural laboratory is always there to wonder, and it was really exciting to construct insights of it under your guiding. This kind of course increases versatility and attraction of physical sciences.
>
> This astronomy workshop course has taken care of that the thing (astronomy) will at least in some amount mark the rest of my life. Thank you very much for the inspiring teaching in the astronomy course!
>
> Thanks once again for the good astronomy course.

In my own experience, the practical arrangement of astronomy teaching is quite easy to fulfil despite of school's small material facilities. According to the research, many respondents agreed to this. Basic studies can be done using simple and cheap tools. One can prepare a great part of these tools.

One may observe by naked eye, at least in the beginning. The binocular is an excellent tool in observations; every school has them. One can consider buying a telescope later, according to interest and possibilities. There exist few written teaching materials, not ordinary textbook at all. There are available some good resource books. In Internet there are a lot of materials, although the quality of them is variable. According to this research, teachers desire teaching packages and audiovisual materials, teacher books, exercise materials and instructions for preparing models (see chapter 7).

All in all, the research proves that astronomy teaching in the comprehensive school is needed. Also in present situation there is a possibility to increase the amount of it, and according to the research teachers' attitudes towards it are positive (*cf*. Beal 2000). A more permanent arrangement requires however that the position of astronomy in curriculum has to be confirmed so that structural and methodological principles presented in this research can be realised (*cf*. Lucas 1999). At the same time, this also absolutely requires an organisation of teacher education and training courses for training this kind of astronomy teaching.

The problem field of this work leads automatically to the question about the role of astronomy in teacher education, which would be an obvious problem for further research. Another related problem to be clarified is proper organisation of pre-service and in-service training of teachers so that the ideas of astronomy teaching concluded in this research could be implemented.

References

Abrams, E. 1998. Talking and Doing Science: Important Elements in a Teaching-for-Understanding Approach. In Mintzes, J. J., Wandersee, J. H., Novak, J. D. (eds.) Teaching Science for Understanding. A Human Constructivist View. San Diego: Academis Press.

Aebli, H. 1991. Opetuksen perusmuodot. Helsinki: WSOY

Aho, L. 1982. Luontokuvan muodostuminen lapsuusiässä. Teoksessa Takala, A., Vepsäläinen, K. (toim.) 1982. Maailmankuvan muodostumisesta. Raportti Mekrijärven seminaarista huhtikuussa 1981. Joensuun korkeakoulu. Kasvatustieteiden osaston julkaisuja 22. Joensuu: Joensuun korkeakoulun offsetpaino. .

Ahtee, M. 1990. Työtavat ja luonnontieteiden opetus. Teoksessa Sahlberg, P. (toim.) Luonnontieteiden opetuksen työtapoja. Helsinki: Kirjayhtymä.

Ahtee, M. 1991. Luokanopettajaksi opiskelevien käsityksiä fysiikan ja kemian ilmiöistä. Helsingin yliopisto, Opettajankoulutuslaitos, tutkimuksia 97. Helsinki: Yliopistopaino, 65-67.

Ahtee, M. 1992. Oppilaiden käsityksiä valo-opin ilmiöistä. Helsingin Yliopiston Opettajankoulutuslaitos. Tutkimuksia 102. Helsinki: Yliopistopaino.

Ahtee, M. 1998. Luonnontieteiden opettaminen ja konstruktivismi. Teoksessa Lavonen, J., Erätuuli, M. (toim.) Tuulta purjeisiin. Matemaattisten aineiden opetus 2000 -luvulle. Jyväskylä: Atena Kustannus, WSOY-Kirjapainoyksikkö, Juva.

Ahtee, M. 2003. Fysiikan ainetiedon muutaminen pedagogiseksi sisältätiedoksi luokanopettajien koulutuksessa. Teoksessa Virta, A., Marttila, O. (toim.). Opettaja, asiantuntijuus ja yhteiskunta. Ainedidaktiikan symposium 7.2. 2003. Turun yliopiston kasvatustieteellisen tiedekunnan julkaisuja B:72. Turku: Painosaloma Oy, 92-100.

Ahtee, M., Pehkonen, E. (toim.) 1994. Constructivist Viewpoints for School Teaching and Learning in Mathematics and Science. University of Helsinki. Department on Teacher Education. Research Report 131. Helsinki: Yliopistopaino.

Ahtee, M., Rikkinen, H. 1995. Luokanopettajaksi opiskelevien mielikuvia fysiikasta, kemiasta, biologiasta ja maantieteestä. *Dimensio* 59 (2), 54-58.

Anon. 1970a. Peruskoulukomitean opetussuunnitelmakomitean mietintö I. Komiteamietintö 1970:4. Opetussuunnitelman perusteet. Helsinki: Valtion Painatuskeskus.

Anon. 1970b. Peruskoulukomitean opetussuunnitelmakomitean mietintö II - oppiaineiden opetussuunnitelmat. Komiteamietintö A 5. Helsinki: Valtion Painatuskeskus.

Anon. 1974a. Report of the seminar concerning the astronomy teaching in school.

Anon. 1974b. The notes to the Ministry of Education concerning the significance of astronomy in physics.

Anon. 1983. Peruskoululaki 476/83.

Anon. 1985. Peruskoulun opetussuunnitelman perusteet. Kouluhallitus. Helsinki: Valtion painatuskeskus.

Anon. 1988. Matemaattis-luonnontieteellisen perussivistyksen komitean välimietintö 1988:30. Helsinki: Valtion painatuskeskus.

Anon. 1989a. Opettajankoulutuksen kehittämistoimikunnan mietintö 1989:26. Helsinki: Valtion painatuskeskus.

Anon. 1989b. Matemaattis-luonnontieteellisen perussivistyksen komitean loppumietintö 1989:45. Helsinki: Valtion painatuskeskus.

Anon. 1993. Komiteamietintö 1993: 31. Humanismin paluu tulevaisuuteen. Humanistis-yhteiskuntatieteellisen komitean mietintö. Opetusministeriö. Helsinki: Valtion painatuskeskus.

Anon. 1994. Peruskoulun opetussuunnitelman perusteet (*The framework curriculum for the comprehensive school 1994*) Opetushallitus. Helsinki: Valtion painatuskeskus.

Anon. 1996. Koulutuksen lainsäädännön kokonaisuudistus. Komiteanmietintö 1996:4. Opetusministeriö.

Anon. 1998. Perusopetuslaki 21.8. 1998/628.

Anon 2004. Peruskoulun opetussuunnitelma (*National Core Curriculum for Basic Education 2004*) Opetushallitus. Helsinki: Valtion painatuskeskus.

Arons, A. B. 1990. Difficulties in Physics Teaching. Teoksessa Ahtee, M., Meisalo, V., Saarikko, H. (eds.) 1991. Proceedings of the International Symposium on the Evaluation of Physics Education. Criteria, Methods and Implications. Department of Teacher Education. University of Helsinki. Research Report 96. Helsinki: Yliopistopaino.

Asbell-Clarke, J. 2001. On-line Astronomy Education. *Mercury* 30(6), 12.

Ausubel, D. P. 1968. Educational Psychology. A Cognitive View. New York: Holt, Rinehart and Winston, Inc.

v. Bagh, P. 2000. Valokuvauksellista tähtitieteen opetusta. *Dimensio* 4, 18-19.

Bailey, J. M. 2003. A Review of Astronomy Education Research. *The Astronomy Education Review* 2(2).

Baxter, J. 1989. Children's understanding of familiar astronomical events. *International Journal of Science Education* 11, special issue, 502-513.

Beal, G. 2000. A Partner-Approach to Astronomy Education: Project ASTRO the Tucson Way. *Mercury* 29(1), 16-24.

Bennett, J. O. 1999. Strategies for Teaching Astronomy. *Mercury* 28(6), 25-32.

Blais, R. N. 1993. History in the Sky. *The Physics Teacher* 31(Oct), 422-425.

Bressan, B. 2004. A Study of the Research and Development Benefits to Society Resulting from an International Research Centre CERN. Helsinki: Yliopistopaino.

Brown, D. E. 1992. Using Examples and Analogies to Remediate Misconceptions in Physics: Factors Influencing Conceptual Change. *Journal of Research in Science Teaching* 29 (1), 17-34.

Brunila, M. 1996. Tieteen ensiaskeleet. *Tähdet ja avaruus* 26(6), 14-16.

Burris, H. 1993. Everyone Deserves a Speeding Ticket. *The Physics Teacher* 31(1), 30-31.

Chiodo, J. J. 1993. Mental Maps: Preservice Teachers' Awareness of the World. *Journal of Geography* 92(3), 110-116

Cohen, L., Manion L., Morrison, K. 2000. Research Methods in Education (Fifth Edition). Routledge, Falmer. Great Britain: TJ International Ltd, Padstow, Cornwall.

Crowe, M.J. 1994. Modern Theories of the Universe from Herschel to Hubble. New York: Dover Publications, Inc.

Davis, N. T., McCarty, B. J., Shaw, K. L., Sidani-Tabbaa, A. 1993. Transitions from objectivism to constructivism in science education. *International Journal of Science Education* 15(6), 627-636.

Driver, R., Asoko, H., Leach, J., Mortimer, E., Scott, P. 1994. Constructing Scientific Knowledge in the Classroom. *Educational Researcher* 23(7), 5-12.

Driver, R., Guesne, E., Tiberghien, A. 1985. Children's Ideas in Science. Milton Keynes: Open University Press.

Eckroth, C. A. 1993. The Earth’s Seasons in 3-D – Part I. *The Physics Teacher* 31(Oct), 419-420.

Eckroth, C. A. 1995. Model of a Negatively Curved Two-Dimensional Space. *The Physics Teacher* 33(5), 286-287.

Erätuuli, M. 1988. Fysiikka ja kemia yläasteen turhien ja tärkeiden, yleisien ja mieluisien sekä vaikeiden ja helppojen oppiaineiden joukossa. *Dimensio* 52 (8), 42-43.

Farrell, C. 1996. The Ninth-Century Renaissance in Astronomy. *The Physics Teacher* 34(5), 268-272.

Finegold, M., Pundak, D. 1991. A Study of Change in Students’ Conceptual Frameworks in Astronomy. *Studies in Educational Evaluation* 17, 51-161.

Fraknoi, A. (ed.) 1995. The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook. A Publication of PROJECT ASTRO at the Astronomical Society of the Pasific, USA.

Francis, P. J. 1999. Using Role-playing Exercises to Teach Astronomy. *The Physics Teacher* 37(7), 436-437.

Fullan, M. 1991. The New Meaning of Educational Change. 2nd ed. London: Cassell.

Gabel, D. L. (ed.) 1994. Handbook of Research on Science Teaching and Learning Contents

Gilbert, J. K., Boulter, C., Rutherford, M. 1998. Models in explanations. Part 1: Horses for courses? *International Journal of Science Education* 20(1), 83-97.

Gil-Perez, D., Carrascosa, J. 1990. What to Do About Science ”Misconceptions”. *Science Education* 74(5), 531-540.

Gott, R., Duggan, S. 1996. Practical work: its role in the understanding of evidence in science. *International Journal of Science Education* 18(7), 791-805.

Gribbin, J. & M. 1996. Companion to the Cosmos. London: Weidenfeld & Nicolsen.

Grindahl, T. 2000. Astronomy in compulsory school in Sweden. Personal report. Stockholm.

Gunstone, R. F., Mitchell, I. J. 1998. Metacognition and conceptual change. In Mintzes, J. J., Wandersee, J. H., Novak, J. D. (eds.) Teaching Science for Understanding. A Human Constructivist View. San Diego: Academic Press. 1*34-164*

Haapasalo, L. 1993. Miksi opetuksen uudistaminen ei onnistu? *Kasvatus* 24(3), 266-275.

Hansgen, R. 1995. Watching the Earth Spin: A Determination of Midday. *The Physics Teacher* 33(2), 116-117.

Harlen, W. 1988. Teaching and Learning Primary Science. London: Harper & Row, Publishers, 175-183.

Harlen, W. (ed.) 1988. Primary science. Taking the plunge. How to teach primary science more effectively. Oxford: Heinemann Educational Books.

Hashweh, M. 1996. Effects of Science Teachers' Epistemological Beliefs in Teaching. *Journal of Research in Science Teaching* 33 (1), 47-63.

Hickman, J. (ed.) 1993. Moon Dance: A ”Handy” Way to Teach Moon Phases. *The Physics Teacher* 31(3), 178-179.

Hodson, C. 1998. Teaching and Learning Science. Towards a personalized approach. Guilford and King’s Lynn: Biddles Ltd.

Hodson, D., Bencze, L. 1998. Becoming critical about practical work: changing views and changing practice through action research. *International Journal of Science Education* 20 (6), 683-694.

Hodson, D., Hodson, J. 1998. Science education as enculturation: some implications for practice. *School Science Review* 80(290), 17-24.

Jones, M. G., Carter, G. 1998. Small Groups and Shared Constructions. In Mintzes, J. J., Wandersee, J. H., Novak, J. D. (eds.) Teaching Science for Understanding. A Human Constructivist View. San Diego: Academic Press, 261-279.

Joyce, B. & Weil, M. 1996. Models of Teaching. 5th edition. Boston: Allyn and Bacon.

Kaila, K. 1979. Tähtitaivaan opas. Ursan julkaisuja XII. Helsinki: Tähtitieteellinen yhdistys Ursa ry.

Karjalainen, M. 1996. Hyvästä opettajankoulutuksesta vieläkin parempaan. *Opettaja* 44-45, 18-20.

Karma, K., Komulainen, E. 1992. Käyttäytymistieteiden tilastomenetelmien jatkokurssi. Helsinki: Yliopistopaino.

Karttunen, H. 1982. Tähtitiede koulussa – perusteita, ei yksityiskohtia. *Tähdet ja Avaruus* 12(4), 141.

Karttunen, H. 1996. Vanhin tiede. Helsinki: Tähtitieteellinen yhdistys Ursa ry.

Karttunen, H. 2000. Tähtitieteen perusteet. Tähtitieteellinen yhdistys Ursa ry, Helsinki. Vaasa: Ykkös-offset Oy.

Keeves, J.P. 1992. Learning Science in a Changing World. Cross-national Studies of Science Achievement: 1970 to 1984. The International Association for the Evaluation of Educational Achievement (IEA).

Ketolainen, P. 2000. TIE - Telescope in Education. Järvenpään tähtilukio! *Dimensio* 4, 15-17.

Kipnis, N. 1998. A History of Science Approach to the Nature of Science: Learning Science by Rediscovering It. In McComas, W. F. 1998. The Nature of Science in Science Education. Netherlands: Kluwer Academic Publishers.

Klaassen, C. W. J. M., Lijnse, P. L. 1996. Interpreting Students' and Teachers' Discourse in Science Classes: An Underestimated Problem? *Journal of Research in Science Teaching* 33(2), 115-134.

Komiteamietintö 1989: 45. Matemaattis-luonnontieteellisen perussivistyksen komitean loppumietintö. Helsinki: Valtion painatuskeskus.

Koulutuksen lainsäädännön kokonaisuudistus. Komiteanmietintö 1996:4. Opetusministeriö.

Krapp, A., Hidi, S. & Renninger, K. A. 1992. Interest, learning and development. In Renninger, K. A., Hidi, S. & Krapp, A. (eds.) The role of interest in learning and development (pg. 3-25). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.

Kuhn, K.F. 1996. Basic Physics: A Self-Teaching Guide. USA: John Wiley & Sons, Inc.

Kuhn, T. S. 1970. The Structure of Scientific Revolutions. The University of Chicago. Translation in Finnish: Kimmo Pietiläinen 1994. Tieteellisten vallankumousten rakenne. Juva: WSOY.

Kurki-Suonio, K. 2000a. Modernin fysiikan perushahmojen synty. *Dimensio* 2, 32-36.

Kurki-Suonio, K. 2000b. Modernin fysiikan perushahmojen synty. *Dimensio* 3, 36-41.

Kurki-Suonio, K. 2000c. Hahmottava lähestymistapa tähtitieteessä. Private discussion in network.

Kurki-Suonio, K., Kervinen, M., Korpela, R. 1985. Kvantti. Fysiikan laaja oppimäärä 3b. Tampere: Weilin + Göös.

Kurki-Suonio, K. & R. 1987a. Kokeellisen ja teoreettisen lähestymistavan tuntomerkit fysiikan opetuksessa. Report Series in Physics, University of Helsinki, HU-P-A68.

Kurki-Suonio, K. & R. 1987b. Käsiteluokkien sekoittuminen fysiikan kielenkäytössä. *Dimensio* 51(9), 24-26.

Kurki-Suonio, K. & R. 1988. Kokeellisen ja teoreettisen lähestymistavan tuntomerkit fysiikan opetuksessa. *Dimensio* 52(1), 14-18.

Kurki-Suonio, K. & R. 1991. Tutkimuksen ja oppimisen perusprosessit. *Dimensio* 55 (5), 18-24.

Kurki-Suonio, K. & R. 1994. Fysiikan merkitykset ja rakenteet. Helsinki: Limes ry.

Kurki-Suonio, K. & R. 1995. Vuorovaikuttavat kappaleet – mekaniikan perusteet. Helsinki: Limes ry:n graafiset laitokset.

Kurki-Suonio, K. & R. 1998. Ajatuksia Didaktisesta fysiikasta. Teoksessa Lavonen, J., Erätuuli, M. (toim.) Tuulta purjeisiin. Matemaattisten aineiden opetus 2000-luvulle. Jyväskylä: Atena Kustannus, WSOY -Kirjapainoyksikkö, Juva.

Kustaanheimo, P. E. 1985. Läheinen ja kaukainen avaruus. Keuruu: Otava.
Laurikainen, K. V. 1967. Nykyfysiikan ongelmia. Porvoo: WSOY.

Lavonen, J., Jauhiainen, J., Koponen, I. & Kurki-Suonio, K. 2004. Effect of a long-term in-service training program on teachers' beliefs about the role of experiments in physics education. *International Journal of Science Education*, 26(3), 309 - 328.

Lavonen, J. Kurki-Suonio, K., Hakulinen, H. 1996. Galilei. Porvoo: WSOY-yhtymä Weilin+Göös.

Lavonen, J., Meisalo, V. 1997. Arvioinnin monipuolistaminen fysiikassa ja kemiassa. Osa 1. *Dimensio* 61 (6), 4-10.

Lavonen, J., Meisalo, V. 1998. Arvioinnin monipuolistaminen fysiikassa ja kemiassa. Osa 2. *Dimensio* 62 (1), 16-25.

Lavonen et al. 2005. Tutkimustuloksia muorten näkemyksistä teknologia-alasta ja luonnontieteiden opetuksesta. Mirror, project nro 6. Teknologiateollisuus Oy. Helsinki: Askonpaino Oy.

Leach, J., Scott, P. 1999. Teaching and learning science: Linking individual and sociocultural perspectives. Paper at the meeting of the European Association for Research in Learning and Instruction. Göteborg, Sweden.

Lehti, R. 1989. Tanssi Auringon ympäri. Kopernikus, Kepler ja aurinkokeskisen tähtitieteen synty. Oulu, Pohjoinen. Jyväskylä: Gummeruksen Kirjapaino Oy.

Lehti, R. 1992. Astronomian merkitys tieteelle ja kulttuurille. Teoksessa Airola, A. et al. (toim.) Tieteen teitä. Helsinki: Yliopistopaino. Luonnonfilosofian seuran julkaisuja 2, 93-109.

Lehti, R. 1996. Tähtiä ja ihmisiä. Ursan julkaisuja 58. Helsinki: Tähtitieteellinen yhdistys Ursa ry.

Lehti, R. 1998. Lumihiutaleet ja maailmankuvat. Tähtitieteellinen yhdistys URSA ry. Helsinki: Gummeruksen Kirjapaino Oy.

Lemke, J.L. 1993. Talking Science: Language, Learning, and Values. USA: Ablex Publishing Corporation.

Levy, D. H., Lebofsky, L. & N. 1997. Sharing the Sky. A Parent's and Teacher's Guide to Astronomy. Plenum Publishing Corporation, New York.

Lightman, A., Sadler, P. 1993. Teacher Predictions Versus Actual Student Gains. *The Physics Teacher* 31(3), 162-167.

Lovi, G., Tirion, W. 1973. Men, monsters and the modern universe. USA: Willmann-Bell, Inc.

Lucas, K. B. 1999. The changing seasons: Teaching for understanding. *Australian Science Teachers Journal* 45(4), 9-18.

Luova, P. 1994. Fysiikan opetuksen kieli. *Dimensio* 58(5), 54-55.

MacIntyre, B. 2002. Teaching for conceptual understanding in astronomy: using an investigating with models approach. *Australian Primary & Junior Science Journal* 18(1), 6-9.

Mancuso, R. V., Long, K. R. 1995. The Astro-Blaster. *The Physics Teacher* 33(9), 358.

Markkanen, T. 1982. Mitä tähtitieteestä olisi koulussa opetettava? *Tähdet ja avaruus* 12(1), 18-22.

Martins, F. 2001. Astronomy teaching in compulsory school in Portugal. Report for Socrates-Comenius Working Group. Bad Honnef, Germany.

Marton, F. 1981. Phenomenography - Describing Conceptions of the World Around Us. *Instructional Science* 10, 177-200.

Meichtry, Y. 1998. Elementary Science Teaching Methods Developing and Measuring Student Views the Nature of Science. In McComas, W. F. 1998. The Nature of Science in Science Education. Netherlands: Kluwer Academic Publishers.

Meidav, M., Netzer, H. 1995. Planted Errors in a Scientific Article. *The Physics Teacher* 33(11), 512-513.

Meisalo, V. 1991. Aims and Goals of Physics Teaching on Personal Level. In Ahtee, M., Meisalo, V., Saarikko, H. (eds.) Proceedings of the International Symposium on the Evaluation of Physics Education. Criteria, Methods and Implications. Department of Teacher Education. University of Helsinki. Research Report 96, 37-47.

Mintzes, J.J., Wandersee, J.H. 1998a. Reform and Innovation in Science Teaching: A Human Constructivist View. In Mintzes, J. J., Wandersee, J. H., Novak, J. D. (eds.) Teaching Science for Understanding. A Human Constructivist View. San Diego: Academis Press.

Mintzes, J. J., Wandersee, J. H., Novak, J. D. 1998b. Epilogue: Meaningful learning, knowledge restructuring, and conceptual change: on ways of teaching science for understanding. In Mintzes, J. J., Wandersee, J. H., Novak, J. D. (eds.) Teaching Science for Understanding. A Human Constructivist View. San Diego: Academis Press, 328-350

Mustelin, N. 1980. Elämää maailmankaikkeudessa. Porvoo: WSOY.

Mäkinen, J. 1986. Koululaiset ja tähtitiede. Tampereella pidettyjen 14. Tähtipäivien ohjelmassa oli mm. keskustelutilaisuus ”Tähtitieteen ja sen maailmankuvan opetus kouluissa”. *Tähdet ja avaruus* 16(1), 28-30.

Neal, Ph., Palmer, J. 1990. Environmental Education in the Primary School. Blackwell Education. Great Britain: Dotesios (Printers) Ltd. Trowbridge.

Neittaanmäki, P. 1991. Luonnontieteellisen koulutuksen kehittäminen. *Dimensio* 55(8), 15-17.

Nersessian, N. 1984. Faraday to Einstein: Constructing Meaning in Scientific Theory. Dordrecht: Kluwer. Martinus Nijhoff Publishers.

Nielsen, H. 2000. Astronomy Olympiads in the Caucasus. *Sky & Telescope* March, 86-89.

Nieminen, R. 1995. Tähtitieteen kouluopetus heikossa jamassa. *Tähdet ja avaruus* 25(5), 14-17.

Niiniluoto, I. 1984. Tiede, filosofia ja maailmankatsomus. Filosofisia esseitä tiedosta ja sen arvosta. Helsinki: Otava.

Noll, E. D. 1996. Kepler’s Third Law for Elliptical Orbits. *The Physics Teacher* 34(1), 42-43.

Norusis, M. J. 1985. SPSS x. Advanced Statistics Guide. SPSS Inc.McGraw-Hill Book Company, USA.

Nurmi, J.-E. 1997. Maailmankuvan vaikutus oman elämän muotoutumiseen. Teoksessa Rydman, J. (toim.) Maailmankuvaa etsimässä. Tieteen päivät 1997. Porvoo: WSOY.

Nussbaum, J. 1979. Children’s Conceptions of the Earth as a Cosmic Body: A Cross-Age Study. *Science Education* 63(1), 83-93.

Ogborn, J., Martins, I. 1996. Metaphorical understandings and scientific ideas. *International Journal of Science Education* 18(6), 631-652.

Osborne, J. 1997. Practical alternatives. *School Science Review* 78(285), 61-66.

Osborne, R., Freyberg, R. 1989. Learning in Science. Hong Kong: Heinemann.

Pajares, M. F. 1992. Teachers' Beliefs and Educational Research: Cleaning Up a Messy Construct. *Review of Educational Research* 62 (3), 307-332.

Pannekoek, A. 1989. A History of Astronomy. New York: Dover Publications, Inc.

Parker, J., Heywood, D. 1998. The Earth and Beyond: Developing Primary Teachers' Understanding of Basic Astronomical Events. *International Journal of Science Education* 20(5), 503-520.

Percy, J. R. 1996. Those Who Can, Teach. *Mercury* 25(1), 34-36.

Perkkilä, P. 2002. Opettajien matematiikkauskomukset ja matematiikan oppikirjan merkitys alkuopetuksessa. Jyväskylä: Jyväskylän yliopisto.

Perko, T. 1980. Kosmologiset mallit. Teoksessa Gefwert**,** C. Kosmologian maailmankuva. Juva: WSOY

Piaget, J. 1988. Lapsi maailmansa rakentajana: Kuusi esseetä lapsen kehityksestä. Helsinki: WSOY

Pietilä, A. 1996. Maailmankaikkeuden tuntemus heikkoa peruskoulussa ja lukiossa. *Opettaja* 44-45, 36-39.

Pinto, F. 1995. CCDs in the Mechanics Lab – A Competitive Alternative? (Part II) *The Physics Teacher* 33(11), 520-524.

Pomeroy, D. 1993. Implications of Teachers' Beliefs about the Nature of Science: Comparison of the Beliefs of Scientists, Secondary Science Teachers, and Elementary Teachers. *Science Education* 77(3), 261-278.

Poole, M. 1995. Beliefs and Values in Science Education. Buckingham: Open University Press.

Postlethwaite, K. 1993. Differentiated Science Teaching. Open University Press, Buckingham, Philadelphia. Great Britain: St Edmundsbury Press Ltd.

Pyykkönen, M. 1995. Tähtitieteen opetus lyöty laimin. *Opettaja* 51-52, 16-17

Ranta, H. 1998. Opetustoimen lainsäädäntö 1999. Juva: WSOY.

Rauste-von Wright, M. 1982. Minään liittyvistä käsitysjärjestelmistä ja niiden osuudesta maailmankuvan rakentumiseen. Teoksessa Takala, A., Vepsäläinen, K. (toim.) 1982. Maailmankuvan muodostumisesta. Raportti Mekrijärven seminaarista huhtikuussa 1981. Joensuun korkeakoulu. Kasvatustieteiden osaston julkaisuja 22. Joensuu: Joensuun korkeakoulun offsetpaino.

Rauste- von Wright, M. 1997a. Opettaja tienhaarassa - konstruktivismia käytännössä.Juva: WSOY-Kirjapainoyksikkö.

Rauste-von Wright, M. 1997b. Oppiminen ja maailmankuva. Teoksessa Rydman, J. (toim.) Maailmankuvaa etsimässä. Tieteen päivät 1997. Porvoo: WSOY.

Rikkinen, H. 1989. Maantiede koulussa. Helsinki: Yliopistopaino.

Rikkinen, H. 1994**.** Spatiaalisuus maantieteessä. Teoksessa S. Tella (toim.) Näytön paikka. Opetuksen kulttuurin arviointi. Ainedidaktiikan symposiumi Helsingissä 4.2. 1994. Osa 2. Helsingin yliopiston opettajankoulutuslaitos. Tutkimuksia 130. Helsinki: Yliopistopaino, 10-18

Rikkinen, H. 1998. Maantiede peruskoulun ala-asteella. Helsinki: Hakapaino.

Ros, Rosa M. 1997-2004. Proceedings of International Summer Schools of Astronomy Education. Spain: Technical University of Catalonia.

Ros, Rosa M. 1999-2002. “We share the ‘European’ sky – why not teach the same Astronomy subject? Socrates-Comenius project. Spain: Technical University of Catalonia.

Ros, R. M. 2000. Astronomy in secondary education in Spain. Report for Socrates-Comenius Working Group. Bad Honnef, Germany.

Saarikko, H. 1998. Fysiikan ja luonnonfilosofian historia osana inhimillistä kulttuuria, erityisesti opetuksen näkökulmasta. Teoksessa Lavonen, J., Erätuuli, M. (toim.) Tuulta purjeisiin. Matemaattisten aineiden opetus 2000-luvulle. Jyväskylä: Atena Kustannus, WSOY - Kirjapainoyksikkö, Juva

Sahlberg, P. (toim.) 1990. Luonnontieteiden opetuksen työtapoja. Kouluhallitus, Finiste. Helsinki: Valtion painatuskeskus.

Sahlberg, P., Ahtee, M. 1990. Oppilaiden ennakkokäsitykset opetuksen lähtökohtana – konstruktivismi luonnontieteissä. *Dimensio* 54(5), 20-25.

Sarjala, J. 1996. Matematiikan ja luonnontieteiden opetuksen kehittämistalkoot. *Dimensio* 60 (4), 22-23.

Sawicki, M. 1996. Using the Solar Eclipse to Estimate Earth’s Distance from the Moon. *The Physics Teacher* 34(4), 232-233.

Seinelä, K. 1988. Fysiikan didaktiikan tutkimuksesta ja sovellutuksista. *Dimensio* 52(1), 20-24.

Shulman, L. S. 1987. Knowledge and teaching: Foundations of the new reform. *Harvard Education Review*, 57 (1), 1-22.

Singer, Ch. 1996. A History of Scientific Ideas. New York: Barnes & Noble Books, Oxford University Press.

Schmidt, H.-J. 1996. Students' misconceptions-looking for a pattern. Teoksessa Ahtee, M., Lavonen, J., Meisalo, V. (toim.) 1996. Opettajankoulutuksen uudet haasteet. XIII Matematiikan ja luonnontieteiden opetuksen tutkimuksen päivät Helsingissä 21.-23.9. 1995. Helsinki: Yliopistopaino.

Solomon, J. 1993. Teaching Science, Technology and Society. Open University Press, Buckingham, Philadelphia. Great Britain: St Edmundsbury Press Ltd.

Spector, B., Strong, P., La Porta, Th. 1998. Teaching the Nature of Science as an Element of Science, technology and Society. In McComas, W. F. 1998. The Nature of Science in Science Education. Netherlands: Kluwer Academic Publishers.
Star navigation 1992. A booklet for astronomical studies. The Naval Academy of the Finnish Defence Forces.

Sutton, C. 1992. Words, Science and learning. Open University Press, Buckingham, Philadelphia. Great Britain: St Edmundsbury Press Ltd.

Takala, A. 1982a. Maailmankuvan metakognitiosta sekä maantieteellisen maailmankuvan muodostumisesta. Teoksessa Takala, A., Vepsäläinen, K. (toim.) 1982. Maailmankuvan muodostumisesta. Raportti Mekrijärven seminaarista huhtikuussa 1981. Joensuun korkeakoulu. Kasvatustieteiden osaston julkaisuja 22. Joensuu: Joensuun korkeakoulun offsetpaino.

Takala, A. 1982b. Maantieteellisen maailmankuvan kehittymisestä. Joensuun korkeakoulu. Kasvatustieteiden osaston julkaisuja 24.

Takala, M. 1982. Ihmiskuvan muodostumisesta. Teoksessa Takala, A., Vepsäläinen, K. (toim.) 1982. Maailmankuvan muodostumisesta. Raportti Mekrijärven seminaarista huhtikuussa 1981. Joensuun korkeakoulu. Kasvatustieteiden osaston julkaisuja 22. Joensuu: Joensuun korkeakoulun offsetpaino.
114-155.

Taylor, I. 2003. Promoting mental model building in astronomy education. *International Journal of Science Education* 25(10), 1205-1226.

Tebbutt, M. 1994. Ideas for Teaching Earth and Space in 'School Time'. *School Science Review* 75(272), 51-60.

Teerikorpi, P., Valtonen, M. 1990 (1988). Kosmos: maailmamme muuttuva kuva. Helsinki: Tähtitieteellinen yhdistys Ursa ry.

Tobin, K., Tippins, D.J. and Gallard, A. J. 1994. Research on instructional strategies for teaching science. In D. L. Gabel (ed.). Handbook of Research on Science Teaching and Learning. New York: Macmillan, 45-93.

Trumper, R. 2000. University Students' Conceptions of Basic Astronomy Concepts. *Physics Education* 35(1), 9-14.

Tuomi, K. 1999. Miksi opettaa tähtitiedettä? *Opettaja* 94(15), 44-45.

Tähtimerenkulku (Star Navigation) 1992. Tähtitaivaan mytologia –koonnoksen ovat toteuttaneet 61. Merikadettikurssin kadetit kadettiylikersantti Jukka Anteroisen johdolla. Puolustusvoimat, Merisotakoulu.

Valtaoja, E. 2004. "School teaching should be educational and worldview constructive". Private discussion in network.

Valtaoja, L., Engeström, J. 1995. Maailmankaikkeuden tutkija valloittaa koulun ja koululainen maailmankaikkeuden. Tähtitieteilijä kouluvierailulla ja koululaiset maailmankaikkeuden valloituskursseilla. *Dimensio* 59(4), 26-29.

Valtonen, M. 1981. Maailmankaikkeutta tutkimassa. Tähtitieteellinen yhdistys Ursan julkaisuja 15. Helsinki: Gummerus.

Vilks, I. 2000. State of astronomy education in Latvia. Report for Socrates-Comenius Working Group. Bad Honnef, Germany.

Virrankoski, M. 1986. Peruskoulun oppilaan fysikaalinen maailmankuva. Joensuun yliopisto. Kasvatustieteiden tiedekunnan tutkimuksia 10. Joensuu: Joensuun Yliopiston keskusmonistamo.

Virrankoski, M. 1996. Kosmologinen maailmankuva. Antiikista nykyiseen ja lapsuudesta aikuisuuteen. Turun Yliopisto, Turku

Virtasola, T., Kuusela, A. 1985. ”Olen osa avaruutta”: monipuolinen tähtikerho Kinnulassa. *Opettaja* 80(11), 12-15.

Vosniadou, S. 1991. Designing curricula for conceptual restructuring: lessons from the study of knowledge acquisition in astronomy. *Journal of Curriculum Studies* 23, 219-237.

Vosniadou, S. 1994. Capturing and modelling the process of conceptual change. *Learning and Instruction* 4, 45-69.

Vosniadou, S., Ioannides, C. 1998. From conceptual development to science education: a psychological point of view. *International Journal of Science Education* 20(10), 1213-1230.

Warland, W. 2000. Astronomy in German school education. Report for Socrates-Comenius Working Group. Bad Honnef, Germany.

West, M. L. 1996. Sunrise Surprise. *The Physics Teacher* 34(1), 58-60.

Wheatley, G. H. 1991. Constructivist Perspectives on Science and Mathematics Learning. *Science Education* 75 (1), 9-21.

White, R. T. 1988. Learning Science. Great Britain: Athenaeum Press Ltd., Newcastle upon Tyne.

von Wright, G. H. 1997. Maailmankuvan käsitteestä. Teoksessa Rydman, J. (toim.) Maailmankuvaa etsimässä. Helsinki: WSOY.

von Wright, J. 1982. Maailmankuvan muodostumisen problematiikkaa. Teoksessa Takala, A., Vepsäläinen, K. (toim.) 1982. Maailmankuvan muodostumisesta. Raportti Mekrijärven seminaarista huhtikuussa 1981. Joensuun korkeakoulu. Kasvatustieteiden osaston julkaisuja 22. Joensuu: Joensuun korkeakoulun offsetpaino

von Wright, J. 1996. Oppimisen tutkimuksen opetukselle asettamia haasteita. *Kasvatus* 27(1), 9-21.

Woolnough, B. E. 1994. Effective Science Teaching. Buckingham: Philadelphia, Open University Press, 10-25.

Woolnough, Br. E. 1991. Setting the scene. In Woolnough, Br. E. (ed.) Practical Science. Open University Press, Milton Keynes, Philadelphia. Great Britain: Biddles Ltd, Guilford and King's Lynn.

Encyclopaedias:

Otavan iso tietosanakirja 1963. Helsinki: Otava.
Facta 2001 1984. Porvoo: WSOY.
Nykysuomen tietosanakirja 3 1993. Porvoo: WSOY.
Nykysuomen sanakirja 2 1988. Porvoo: WSOY.
WSOY Iso tietosanakirja 1996. Porvoo: WSOY.
Otavan suuri ensyklopedia 1978. Keuruu: Otava.

Web pages:

Web 1.1	http://per.physics.helsinki.fi/uudet_sivut/index.htm Department of didactical physics, University of Helsinki
Web 1.2	www.eaae-astro.org/ EAAE – European Association for Astronomy Education
Web 4.1	http://per.physics.helsinki.fi/ihannula/astronomy.html List of aims and laws (in Finnish)
Web 4.2	http://per.physics.helsinki.fi/ihannula/astronomy.html Categorised text material with codes of categories (in Finnish)
Web 4.3	http://per.physics.helsinki.fi/ihannula/astronomy.html One example of the analysis of one category (in Finnish)
Web 4.4	www.maol.fi/ MAOL The Finnish Association of Teachers of Mathematics, Physics, Chemistry and Informatics MAOL ry
Web 4.5	www.minedu.fi/julkaisut/pdf/102_2LUMAeng/103annexes.pdf Annex 5
Web 5.1	www.cern.ch/lhc CERN LHC The Large Hadron Collider
Web 7.1	http://learn.arc.nasa.gov/products/k12/jpl_tie.html and www.pisa.oecd.org/pages/
Web 7.2	www.iea.nl/ IEA homepage
Web 7.3	http://per.physics.helsinki.fi/ihannula/astronomy.html List of themes in the textbooks (in Finnish)
Web 9.1	http://tie.jpl.nasa.gov/tie/schools.html TIE – Telescope in Education, Pasadena, Mount Wilson observatory
Web 9.2	http://msowww.anu.edu.au/~pfrancis/roleplay.html Francis, role-play games
Web 9.3	http://per.physics.helsinki.fi/ihannula/astronomy.html Interview of pupils (in Finnish)
Web 10.1	http://per.physics.helsinki.fi/ihannula/astronomy.html EAAE – The basis of Curriculum

References of figures:

Fig. 4.1 Gravitation controls the motion of the heavenly body and keeps the galaxy together. Lavonen *et al.* 1996, p. 64
Fig. 4.2 Mythological features on the background of the constellations – imaginational inspiration. Karttunen 1996, p. 350. Lovi *et al.* 1973.
Fig. 4.3 The physical world of Ptolemy. Lehti 1996.
Fig. 4.4 The epicycle theory of Ptolemy. Karttunen 1996, p. 153.
Fig. 4.5 Portray of Copernicus. Valtonen 1981.
Fig. 4.6 The Copernican world system. Lehti 1996.
Fig. 4.7 Tycho's quadrant. Karttunen 1996, p. 241.
Fig. 4.8 Parallax with planet. Karttunen 1996, p. 160.
Fig. 4.9 Curvature of space. Lavonen *et al.* 1996, p. 64.

Fig. 5.1 Cycle of perceptual concept formation. Kurki-Suonios 1994, p. 149 and 1995, p. 2.
Fig. 5.2 Processes of empirical science. Kurki-Suonios 1994, p. 145.
Fig. 5.3 Hierarchy of physical concepts. Kurki-Suonios 1994, p. 159.
Fig. 5.4 The basic elements of understanding of physics. Kurki-Suonios 1994, p. 287.
Fig. 5.5 Proceeding of teaching in the conceptual hierarchy. Kurki-Suonios 1994, p. 253.

Fig. 6.1 Process skills, Harlen 1985, p. 25.

Fig. 7.1. Distribution of teaching methods used by the respondents. Hannula 2001.
Fig. 7.2 Supplementary materials in the schools of the respondents. Hannula 2001.
Fig. 7.3 Actions realised in recent years in the schools of the respondents. Hannula 2001.

APPENDICES

Appendix 4.1

<u>The extracts from the set of books, writings and articles for the text material to be analysed.</u>

Viewpoint 1 Astronomy in social life and culture

Crowe 1994, pf-1
Farrell (1996), article
Pannekoek (1989), the large part of the book
Singer (1996), p. 1-5

Viewpoint 2 Astronomy in school life

MAOL, web 4.4
Naval Academy (1992), a booklet
Noll 1996), article
Tuomi (1999), article
West 1996), article

Viewpoint 3 A philosophical scientific viewpoint

Lehti (1992), article
Lehti (1996), the large part of the book

Viewpoint 4 Astronomical worldview in history

Encyclopaedias:
Otavan iso tietosanakirja (OTAVA 1963), chapter
Facta 2001 (WSOY 1984), chapter
Nykysuomen tietosanakirja 3 (WSOY 1993), chapter
Iso tietosanakirja (WSOY 1996), chapter
Nykysuomen sanakirja 2 (WSOY 1988), chapter
Otavan suuri ensyklopedia (OTAVA 1978), 2 chapters

Crowe (1994), p. 42-46
Gribbin (1996), the large part of the book
Karttunen (1996), 80-94
Karttunen (2000), p. 14-16, 533, 582
Kuhn (1970), p. 34 ; (1994)
Kurki-Suonio, K. (2000 a and b), 2 articles
Kurki-Suonio et al. (1985), p. 22-49, 124-137
Kustaanheimo (1985), the large part of the book
Lehti (1989), p. 7,13, 253, 261
Lehti (1996), the large part of the book
Lehti (1998), the large part of the book

Mustelin (1980), p. 10-19
Niiniluoto (1994), p. 141-152
Pannekoek (1989), the large part of the book
Rikkinen (1994), article
Singer (1996), the large part of the book
Takala (1982 a), article
Takala (1982 b), article
Valtonen (1981), the large part of the book
Valtonen (1991), article
Virrankoski (1996), p. 130
von Wright, G. H. (1997), article
von Wright, J. (1982), article

Appendix 7.1

Questionnaire Part I

Query about astronomy teaching to teachers of physics/geography/environment and natural science in the Finnish comprehensive school **Part I**
Irma Hannula

BACKGROUNDS
Cross the right choice (in some questions there might be several choices to be crossed). More space can be found on the other side of paper if needed.

1. Name of the school: ________________________________ **School level: ______ Upper level**

______ Lower level ____ class

2. Gender: ____ male ____ female

3. Age: between

____ 20-29 y ____ 30-39 y ____ 40-49 y ____ over 50 y

4. Qualification:

____ vacant ____ temporary ____ part-time teacher

____ supply teacher ____ other, what?

5. Teaching experience:

____ under 2 y ____ 2-5 y ____ 6-15 y ____ 16-25 y ____ over 25

6. Competency: ____ competent ____ formally incompetent

7. Main subject/special subject in studies: ____

8. My studies in astronomy:

____ advanced studies / laudatur

____ entity of subject studies / cum laude approbatur

____ entity of basic studies / approbatur

____ separate courses

____ self-studies, hobbyism

____ no studies

9. I have studied astronomy

____ in my ordinary studies

____ besides my teaching work

____ in other time, when? ____

10. I have passed following separate courses (name of the course, organiser, length, place, year, target group):

11. In my self-studies I have used

___ textbooks ___ science books ___ videos ___ slides etc. ___ magazines__ TV-programs ____ observation

___ observation tools, what? ______________________ other, what? ____________________________

TEACHING

12. I have taught astronomy

____ in ordinary courses of physics

____ in environment and science courses

____ in geography

____ in optional course in ______________________ (discipline)

____ in club

____ in other situation, where?____

____ I have not taught it at all

13. Number of lessons in astronomy per teaching group in one school year:

____ under 4 hours ____ 4-8 hours ____ 9-12 hours ____ over 12 hours

14. Period of astronomy teaching:

____ 9. grade in order of textbook

____ teaching period in the beginning of 9.grade

____ always when appropriate

____ in the beginning of physics or geography teaching (7./8. level)

____ in primary school ______________ levels

____ in other situation, where? ____

15. What are the main aims in your astronomy teaching? ____

____

16. Which subjects are included in your teaching content? ______________________________________

____

____

17. What is the main principle in formation of teaching content?

____ according to textbook used

____ according to curriculum

____ self-made systematic teaching program

____ unconnected subjects, no systematic way

____ other, what? ____

18. Which teaching methods have you used?

____ table ____ discussion ____ teamwork

____ project work ____ computer ____ observation

____ individual research ____ self-studying ____ role-play

____ argumentation ____ concept map ____ integrating teaching

____ mental image teaching ____ Internet ____ other, what? _____________________

19. Mark in previous question also by numbers 1, 2 and 3 the three most used methods (1 = most used etc.).

20. How pupils have experienced astronomical things? Have those things increased motivation to explore nature more? ____

21. Do pupils ask questions about actual things of astronomy/space exploration, e.g. on the basis of TV-programs or of writings in papers? (Do you have had difficulties in answering in them?) ______________________________

____

22. How do you map the initial grade? ____

____

23. How do you test the realisation of aims? ____

____

24. What is your evaluation method? ____

____

TEACHING MATERIALS

25. Name of the textbook I have used in physics/geography/environmental and natural science

____

26. Which additional teaching material you have in your school? An example if possible. Have you used it (Y/N)?

	Y/N
____ series of slides:	____
____ videos:	____
____ TV-programs:	____
____ literacy:	____
____ computer programs:	____
____ papers:	____
____ movies:	____
____ Internet	____

____ other, what? ____

27. Which additional teaching materials have been acquired/borrowed temporarily for astronomy teaching?

____

28. Which materials have you developed yourself? ____

____

TEACHING TOOLS

29. Which of the following tools exist in your school?

____ telescope ____ binocular ____ rotating globe ____ sun clock ____ sextant

____ Earth-Moon-Sun - model ____ other, what? ____

30. Which of them have you used in your teaching? ____

31. Which other tools have you used in your astronomy teaching? ____________________________________

____

32. Which of the following activities have been realised in recent years in your school?

____ Ursa's planetarium in school

____ other planetarium in school, what? ____

____ visit planetarium, where? ____

____ visit observatory, where? ____

____ lecturer in school, subject? ____

____ other expert in school (e.g. technical aid), subject? ____________________________________

____ astronomy project as teamwork, what? ____

____ some other: ____

33. Which astronomical tools have you prepared yourself? ____________________________________

____

34. Which tools are under construction? ____

35. Where did you get the model/idea for your tools?

____ self-made ____ in media ____ in literacy

____in other schools ____ in Internet ____ somewhere else, where? ______________________________

EDUCATION

36. Which abilities do you think you have for astronomy teaching? __________________________________

____

37. Which astronomical studies have you planned to take in the immediate future? _________________________

____

38. What kind of training courses would you like to have in astronomy? ____________________________

____

39. What kind of training courses you prefer most? Number 1, 2 and 3 (1 = best possibility etc.).

____ course e.g. in Heinola ____ local course

____ distance education + contact period ____ self-studies freely

____ self-studies using ready-made teaching packages

____ other, what? ____

40. What kind of support and materials would you like to have for your astronomy teaching? _______________

____

____

41. Open question: What else would you like to tell about astronomy teaching in your school and in general about attitudes of teachers in it? (more space on the other side)

Appendix 7.2

Questionnaire Part II

Circle your choice: 5= strongly agree, 4= agree, 3= undecided, 2= disagree, 1= strongly disagree

	strongly agree	agree	un-decided	dis-agree	strongly disagree
1. It is important for teacher to study astronomy in addition to physics/geography/ environmental and natural science.	5	4	3	2	1
2. Astronomical education inspires teacher to teach astronomy in school	5	4	3	2	1
3. If you have not studied astronomy in the university, you are not able to teach universal subjects in school.	5	4	3	2	1
4. There are enough astronomical subjects in different disciplines in studies.	5	4	3	2	1
5. It is enough for teacher to know everyday phenomena (like seasons and periods of day and night).	5	4	3	2	1
6. One can get ability to teach astronomy with self-studies.	5	4	3	2	1
7. It is necessary to teach the structural picture of world to pupils (e.g. the solar system, galaxy systems etc.).	5	4	3	2	1
8. Studying constellations will enliven pupil's astronomical studies.	5	4	3	2	1
9. It is important for pupil to know the use of astronomical tables (e.g. comparison of planets' orbital data and masses, calendar).	5	4	3	2	1
10. Clear figures and schemes give the right conception for pupil about perception the astronomical phenomena.	5	4	3	2	1
11. It is necessary for pupil to know the calculation methods of astronomical problems (like distances of planets, proceeding of light etc.).	5	4	3	2	1
12. Optional course in astronomy or own subject matter instead of separate subjects are most essential for pupil to form an unique worldview.	5	4	3	2	1
13. It has to be taught for pupils the use of observation tools (like telescope and sextant).	5	4	3	2	1
14. Observing sky phenomena by naked eye is a sufficient research method for pupil.	5	4	3	2	1
15. Preparing own observation tools improve the understanding phenomena observed.	5	4	3	2	1
16. It always cost a lot of money to buy astronomical teaching tools	5	4	3	2	1
17. Using simple illustrative tools (like mini models) improve understanding of phenomena.	5	4	3	2	1
18. Astronomical phenomena may be perceived just with observation tools.	5	4	3	2	1

	strongly agree	agree	un-decided	dis-agree	strongly disagree
19. Perceiving astronomical dimensions will help people to understand their position in the universe.	5	4	3	2	1
20. People have an inadequate perception of the surrounding world and universe if they have no astronomical basic knowledge.	5	4	3	2	1
21. It is necessary to follow news in media about the development of astronomical knowledge, for constructing the worldview	5	4	3	2	1
22. Astronomical knowledge gives people a basis for to construct their worldview.	5	4	3	2	1
23. The significance of astronomy for other disciplines is obvious.	5	4	3	2	1
24. Astronomy influences in people in their emotional-aesthetic feelings.	5	4	3	2	1
25. There are enough various basic and in-service courses in astronomy on offer.	5	4	3	2	1
26. All-round education of astronomy is significant in society.	5	4	3	2	1
27. It has to be provided in national curricula to organise astronomical education to all pupils.	5	4	3	2	1
28. Basic studies in astronomy should be obligatory for all those who teach it.	5	4	3	2	1
29. In the syllabus of physics/geography/environmental and natural science in the universities astronomy should be an obligatory course.	5	4	3	2	1
30. In-service training in astronomy is necessary because of all the time developing astronomical knowledge.	5	4	3	2	1
31. One has needed astronomy for ”conquest of space”.	5	4	3	2	1
32. Astronomical knowledge is not needful in political solutions concerning the future of the Earth.	5	4	3	2	1
33. Technological development has an essential significance in seeking for astronomical information.	5	4	3	2	1
34. Threat of war in the world is not dependent on astronomy.	5	4	3	2	1
35. Knowing astronomical phenomena will help in making social decisions (e.g. satellites, space flights, problems with tides etc.)	5	4	3	2	1
36. Astronomical information has also a political meaning. .	5	4	3	2	1

Thank you for your responds and effort!
Comments:

Appendix 7.3

Some examples of the cross tabulations in chapter 7.1.6.

<u>School level-astronomy teaching- age</u>

k01aste * k12topet * k03ika Crosstabulation

level – astronomy teaching – age

k03ika				k12topet FK	YL	GE	LyK	kerho	muu	ei	Total
20-29 v (6)	k01aste	ylaaste	Count		0				1	3	4
			Expected Count		1.3				.7	2.0	4.0
		ala-aste	Count		2				0	0	2
			Expected Count		.7				.3	1.0	2.0
	Total		Count		2				1	3	6
			Expected Count		2.0				1.0	3.0	6.0
30-39 v (18)	k01aste	yläaste	Count	7	0	1	1	0	1	2	12
			Expected Count	5.3	2.7	.7	.7	.7	.7	1.3	12.0
		ala-aste	Count	1	4	0	0	1	0	0	6
			Expected Count	2.7	1.3	.3	.3	.3	.3	.7	6.0
	Total		Count	8	4	1	1	1	1	2	18
			Expected Count	8.0	4.0	1.0	1.0	1.0	1.0	2.0	18.0
40-49 v (44)	k01aste	yläaste	Count	18	0		3		4	3	28
			Expected Count	11.5	8.3		1.9		2.5	3.8	28.0
		ala-aste	Count	0	13		0		0	3	16
			Expected Count	6.5	4.7		1.1		1.5	2.2	16.0
	Total		Count	18	13		3		4	6	44
			Expected Count	18.0	13.0		3.0		4.0	6.0	44.0
yli 50 v (25)	k01aste	yläaste	Count	11	0	2	3		1	0	17
			Expected Count	7.5	4.8	1.4	2.0		.7	.7	17.0
		ala-aste	Count	0	7	0	0		0	1	8
			Expected Count	3.5	2.2	.6	1.0		.3	.3	8.0
	Total		Count	11	7	2	3		1	1	25
			Expected Count	11.0	7.0	2.0	3.0		1.0	1.0	25.0

<u>School level-motivation-age</u>

k01aste * k20motiv * k03ika Crosstabulation

level – motivation – age

k03ika				k20motiv pos	neg	motiv	Total
20-29 v (6)	k01aste	ylaaste	Count	1	1	1	3
			Expected Count	.6	.6	1.8	3.0
		ala-aste	Count	0	0	2	2
			Expected Count	.4	.4	1.2	2.0
	Total		Count	1	1	3	5
			Expected Count	1.0	1.0	3.0	5.0
30-39 v (18)	k01aste	yläaste	Count	3	0	7	10
			Expected Count	1.9	.6	7.5	10.0
		ala-aste	Count	0	1	5	6
			Expected Count	1.1	.4	4.5	6.0
	Total		Count	3	1	12	16
			Expected Count	3.0	1.0	12.0	16.0
40-49 v (44)	k01aste	yläaste	Count	6	2	14	22
			Expected Count	5.5	1.8	14.7	22.0
		ala-aste	Count	3	1	10	14
			Expected Count	3.5	1.2	9.3	14.0
	Total		Count	9	3	24	36
			Expected Count	9.0	3.0	24.0	36.0
yli 50 v (25)	k01aste	yläaste	Count	6	2	8	16
			Expected Count	5.3	2.0	8.7	16.0
		ala-aste	Count	2	1	5	8
			Expected Count	2.7	1.0	4.3	8.0
	Total		Count	8	3	13	24
			Expected Count	8.0	3.0	13.0	24.0

Gender-method-age

k02sukup * k191tapa * k03ika Crosstabulation

gender – method – age

k03ika				k191tapa ta	prt	ytu	ke	iop	web	ryt	hav
20-29 v	k02sukup	nainen	Count	1			1	1			
			Expected Count	1.0			1.0	1.0			
	Total		Count	1			1	1			
			Expected Count	1.0			1.0	1.0			
30-39 v	k02sukup	mies	Count	3		1	2	0		1	1
			Expected Count	3.4		1.1	1.7	.6		1.1	.6
		nainen	Count	3		1	1	1		1	0
			Expected Count	2.6		.9	1.3	.4		.9	.4
	Total		Count	6		2	3	1		2	1
			Expected Count	6.0		2.0	3.0	1.0		2.0	1.0
40-49 v	k02sukup	mies	Count	5	0	1	5		1	5	0
			Expected Count	3.2	2.3	.5	6.0		.5	3.7	.5
		nainen	Count	2	5	0	8		0	3	1
			Expected Count	3.8	2.7	.5	7.0		.5	4.3	.5
	Total		Count	7	5	1	13		1	8	1
			Expected Count	7.0	5.0	1.0	13.0		1.0	8.0	1.0
yli 50 v	k02sukup	mies	Count	3	1		1	0		3	2
			Expected Count	2.9	1.0		1.4	.5		2.9	1.0
		nainen	Count	3	1		2	1		3	0
			Expected Count	3.1	1.0		1.6	.5		3.1	1.0
	Total		Count	6	2		3	1		6	2
			Expected Count	6.0	2.0		3.0	1.0		6.0	2.0

Gender-teaching ability-age

k02sukup * k36ovalm * k03ika Crosstabulation

gender – teaching ability – age

k03ika				k36ovalm ei ole	hyvät	tyyd.	heikot	Total
20-29 v	k02sukup	mies	Count	0	0	0	1	1
			Expected Count	.2	.2	.2	.5	1.0
		nainen	Count	1	1	1	2	5
			Expected Count	.8	.8	.8	2.5	5.0
	Total		Count	1	1	1	3	6
			Expected Count	1.0	1.0	1.0	3.0	6.0
30-39 v	k02sukup	mies	Count		5	0	6	11
			Expected Count		3.1	2.4	5.5	11.0
		nainen	Count		0	4	3	7
			Expected Count		1.9	1.6	3.5	7.0
	Total		Count		5	4	9	18
			Expected Count		5.0	4.0	9.0	18.0
40-49 v	k02sukup	mies	Count	2	3	5	11	21
			Expected Count	4.3	2.4	5.3	9.1	21.0
		nainen	Count	7	2	6	8	23
			Expected Count	4.7	2.6	5.8	9.9	23.0
	Total		Count	9	5	11	19	44
			Expected Count	9.0	5.0	11.0	19.0	44.0
yli 50 v	k02sukup	mies	Count	2	3	3	3	11
			Expected Count	2.3	2.3	3.7	2.8	11.0
		nainen	Count	3	2	5	3	13
			Expected Count	2.7	2.7	4.3	3.3	13.0
	Total		Count	5	5	8	6	24
			Expected Count	5.0	5.0	8.0	6.0	24.0

Appendix 7.4

Respondents' list of textbooks

Textbooks on physics:	
Aine ja energia (Substance and Energy), WG x	17
Ydin 9 (Nucleus 9), WSOY	15
Impulssi 3 (Impulse 3), Otava x	6
Koulun Fysiikka 7 ja 9 (School Physics 7 and 9), Arvonen et al.	6
Fysiikan kirjani (My Textbook on Physics), Otava	5
Pisara 9 (Drop 9), Otava	3
Text books on geography	
Koulun maantieto 7-9 (School geography 7-9), Mattila et al.	3
Värikäs luonto (Coloured nature)	1
Värikäs maailma (Coloured world)	1
Text books on environment and natural sciences	
Koulun ympäristötieto (School environment science), Otava x	12
Luonnontutkija 5-6 (Nature explorer), WG x	6
Verne 3 and 5-6, WSOY x	5
Luontokirja 1-2 (Textbook of nature), Otava	2
Other sources:	
Lumo, WSOY x	3
Polaris, H. Oja, Ursa	3
Aineiden maailma (World of matters), Kiiveri et al. WG x	1
Yleismaantiedon käsikirja (Handbook of general geography)	1
Books in Swedish:	
Puls- fysik (Pulse – physics)	2
Atomos (Atom)	4

Appendix 7.5

Textbooks used in analysing of astronomical teaching contents

Aho, L., Enqvist, S., Kytömäki, P., Nurmi, J., Saarivuori, M. 1996. Verne 5. Porvoo: WSOY. **(V5)**

Aho, L., Enqvist, S., Kytömäki, P., Nurmi, J., Saarivuori, M. 1998. Verne 5. Tutkimusvihko. Porvoo: WSOY.

Holste, M., Kröger, P., Raekunnas, M., Riikonen, J., Vaajakallio, U, 1996. Luonnontutkija 5-6. Porvoo: Weilin+Göös. **(LT)**

Holste, M., Kröger, P., Raekunnas, M., Riikonen, J. 1997. Luonnontutkija 5-6. Porvoo: Weilin+Göös.

Kiiveri, K., Nuutinen, A., Tolvanen, P., Raitanen, M. 1997. Luonnontutkija. Aineiden Maailma. Porvoo: Weilin+Göös. **(LTA)**

Nyberg, T., Vestelin, O., Arjanne, S., Kenno, P., Leinonen, M., Palosaari, M., Vehmas, P. 1998. Koulun ympäristötieto 6. Keuruu: Otava. **(KY)**

Viinikka, T., Ahtee, M., Krokfors, L., Pokki, S. 1997. Mars matkaan. Esiopetuksen ympäristö- ja luonnontieto. Rauma: Kirjayhtymä (Kirjapaino Oy West Point). Myös opettajan materiaali saatavilla**.** **(MM)**

Kärnä, P., Leskinen, M., Montonen, M., Repo, K. 1997. Lumo. Porvoo: WSOY. **(L)**

Kärnä, P., Leskinen, M., Montonen, M., Repo, K. 1998. Lumo 3. Porvoo: WSOY.

Hirvonen, H., Hongisto, J., Lavonen, J., Saari, H., Viiri, J., Aspholm, S., Bjurström, L. 1996. Aine ja energia. Porvoo: WSOY. **(AE)**

Vuola, R., Kuosa, O. 1997. Fysiikan impulssi. Keuruu: Otava. **(FI)**

Vuola, R., Kuosa, O. 1998. Impulssi - Fysiikan lisäkurssi. Keuruu: Otava. **(I LK)**

Lehto, H., Luoma, T. 1998. Fysiikka. Fysiikka luonnontieteenä. Jyväskylä: Kirjayhtymä (Gummeruksen Kirjapaino OY) **(FLT)**

Arohonka, J., Jutila, H., Kankaanrinta, I-K., Kytömäki, J. 1996. Värikäs Amerikka. Porvoo: WSOY. **(VA)**

Leinonen, M., Nyberg, T., Kenno, P., Vestelin, O. 1995. Koulun maantieto. Maailmamme. Keuruu: Otava. **(KM)**

Leinonen, M., Nyberg, T., Kenno, P. 1998. Koulun maantieto. Maailmamme. Keuruu: Otava.

Appendix 7.6

Astronomical concepts and subject matters in textbooks
See abbreviations in the previous page, in appendix 7.4.

Subject	**V5**	**LT**	**KY**	**LTA**	**MM**	**L**	**AE**	**FI**	**I LK**	**FLT**	**VA**	**KM**
Earth, globe	x	x	x	x	x	x	x	x	x	x	x	x
Moon	x	x	x	x	x	x	x			x		x
Sun	x	x	x	x	x	x	x	x		x		x
Solar system		x	x		x	x	x		x	x		x
Star, constellation	x	x	x	x	x	x	x		x	x		x
Planets	x	x	x	x	x	x	x			x		x
Motion of the Earth		x	x	x	x	x	x			x		x
Phenomena in atmosphere	x		x			x	x	x				
Space			x	x		x	x		x	x		x
Universe and its structure	x					x	x		x	x		
Artificial satellites, probes	x		x	x		x			x		x	x
Space exploration, space flights	x			x	x		x		x		x	
Observation and observation tools						x	x					
Map, co-ordinates, circles, zones, time	x	x	x		x					x	x	x
Man in the universe						x						
Theories of the universe						x	x	x	x	x		
Development of the worldview						x			x			
Life on the Earth, division of radiation											x	x
Galaxy, Milky Way	x	x	x			x	x		x	x		x

Appendix 8.1

The original rotated factor matrix is presented here as one example of matrixes of various types explained in the text in chapter 8. The most significant values in each factor column are underlined.

Rotated Factor Matrix[a]

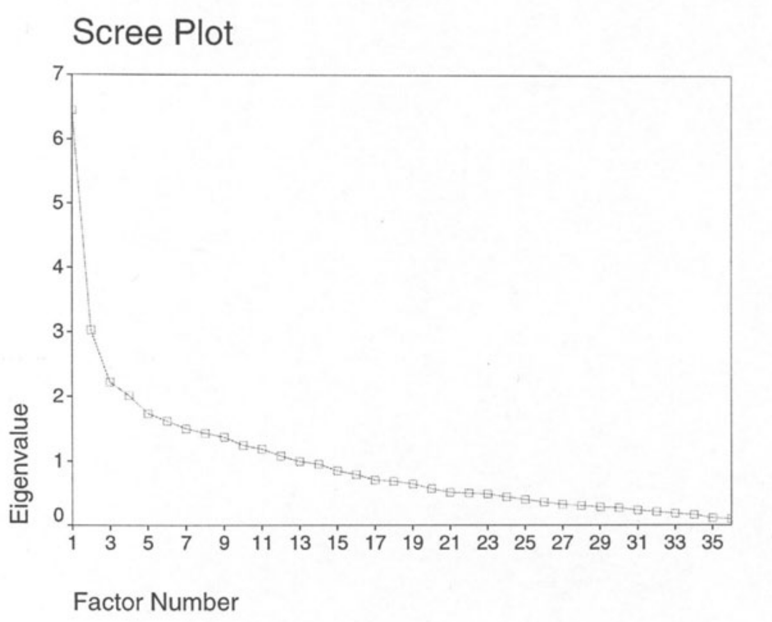
	Factor				
	1	2	3	4	5
K411	.457	.446	-.024	.011	.127
K412	.473	.229	.012	-.017	-.101
K413	.068	-.037	-.446	.057	-.068
K414	-.369	.024	.045	.024	-.060
K415	-.337	-.340	-.264	.042	.041
K416	.010	-.193	.690	.055	-.101
K421	.137	.387	.251	.088	.150
K422	.363	.105	.084	.103	-.022
K423	.282	.195	-.264	.023	.070
K424	.172	.136	.378	.070	.098
K425	.394	-.047	.002	.149	-.207
K426	.298	.335	-.173	.191	-.016
K431	.430	.098	-.360	.230	-.152
K432	-.261	-.035	.312	-.212	-.015
K433	.257	.042	-.071	.176	-.377
K434	-.006	-.482	-.010	.077	.163
K435	.323	.051	.172	.158	.041
K436	.115	.043	-.166	.047	-.147
K441	.486	.315	.138	.084	.096
K442	.666	.261	.364	.142	.069
K443	.656	.260	-.062	.085	.098
K444	.534	.333	.001	.323	.015
K445	.142	.366	-.043	.144	.002
K446	.027	.498	.106	.099	.051
K451	-.405	-.067	-.024	.026	-.247
K452	.226	.574	.020	.117	.246
K453	-.055	.332	.389	.145	.539
K454	.244	-.010	-.116	.044	.700
K455	.298	.129	.010	.281	.643
K456	.500	-.039	-.156	.109	.330
K461	.248	.254	.538	-.064	.015
K462	-.094	-.046	-.031	-.580	-.176
K463	.108	.246	.406	.006	-.160
K464	.049	.010	.221	-.617	.148
K465	.286	.101	.119	.563	.011
K466	.084	.198	-.028	.744	.070

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 10 iterations.

Appendix 8.2

Eigenvalues of factors are presented in the diagram as function of factor numbers.



Correlations of factors F1-F5

Correlations

Correlations

		faktori1	faktori2	faktori3	faktori4	faktori5
faktori1	Pearson Correlation	1.000	.132	.007	.050	.028
	Sig. (2-tailed)	.	.205	.947	.630	.789
	N	94	94	94	94	94
faktori2	Pearson Correlation	.132	1.000	.057	.053	.039
	Sig. (2-tailed)	.205	.	.588	.612	.709
	N	94	94	94	94	94
faktori3	Pearson Correlation	.007	.057	1.000	-.028	.013
	Sig. (2-tailed)	.947	.588	.	.792	.900
	N	94	94	94	94	94
faktori4	Pearson Correlation	.050	.053	-.028	1.000	.023
	Sig. (2-tailed)	.630	.612	.792	.	.827
	N	94	94	94	94	94
faktori5	Pearson Correlation	.028	.039	.013	.023	1.000
	Sig. (2-tailed)	.789	.709	.900	.827	.
	N	94	94	94	94	94

Appendix 8.3

Questions for teachers' interview

1. What kind of position astronomy should have in your school teaching? How it could be improved?
   Physics teaching time importance appreciation in general
2. Which status astronomy should have in science teaching and how it could be made better?
   Separate discipline together with others integrations
3. What is the significance of astronomy for people when constructing one's worldview?
4. Which kind of astronomical knowledge is important when constructing one's worldview?
5. How could you improve your own astronomical worldview?
   Is there any need for that?
6. How could you improve your abilities to teach astronomy?
   Teaching possibilities astronomical knowledge
7. Do you think astronomy teaching has an influence when pupil is building his worldview?
8. What are, in your opinion, the most essential subjects to be handled in the upper/lower comprehensive school?
   What and why? What kind of perception you have?
9. What kind of teaching you think is needed for to change pupils' incorrect conceptions?
   Some hints about those misconceptions? Some example. Do you think it is important to change these?
10. What kinds of significance correct concepts and conceptions have in astronomy?
    See changing conception in previous question
11. What kinds of methods are important when teaching astronomical concepts and phenomena?
    Observations outside planets empiry stories slide show videos
12. What kind of astronomical education, you think, should be organised?
    More education do you have enough training in astronomy? What kind of education you would prefer?
13. Do you think it should be set some requires in astronomy section in teacher education?
    What? Astronomy in university studies didactical astronomy in teacher training
14. What is the significance of astronomy in people's life?
    Way of life smallness astrology

Appendix 10.1

List of additional themes for astronomical projects

Experimental study
Determination of time
Determination of location and orientation
Determination of locations of celestial bodies and calculation of coordinates
Use of observation tools: astrolabe, metallic protractor, guidebook, map with longitudes and latitudes, clock, compass, telescope
Determination of longitude with time difference of zero-meridian
Calculation of astronomical quantities from observations, development of calculation methods
Transformations of co-ordinates
Spectral analysis: angular velocity of rotation of planet, physical exploration of fixed stars
Planets: physical properties, geometrical determination of size, space probe explorations
Observation of stars and measurements
Exploration of eclipses
Astronomical catalogues: fixed stars, comets, cluster of stars, galaxies
Translation of scientific literature
Parallax method in determination of Earth's circular motion and distance of star
Universe: matter, structure, distribution of stars, laws of motion, objects of deep sky, cosmology
Special findings: nova, Cepheid-type variable star, pulsar, neutron star, Black hole
Distance of star: parallax method, inverse-square law of brightness, periods of luminosity relation, and spectrum
Testing of theory of relativity: phenomena in solar system, double pulsars
Study of theory of gravity
Phenomena in atmosphere
Phenomena in magnetosphere
Moon survey
Sun survey

Theories
Mathematical presentation of physical world
Mathematical analysis of astronomical phenomena
Birth of spectroscopy --- physical exploration of fixed stars, spectral analysis
Theory of dynamics of planets, mathematical theory of planets
Pondering of birth and future of universe and searching for solutions
Theory of relativity: mass related to energy, time retardation with fast moving object near to light speed, ray of light --- curving near the Sun, red shift of light --- photons in gravitation field, retardation of light speed in gravitation field near the Sun
Cosmology: theory of physics and astronomical observations
Astronomical phenomena as examples in physics teaching