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EXPLANATIONS FOR PHYSICS PHENOMENA GIVEN BY PRIMARY SCHOOL WOULD-BE TEACHERS

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Abstract. *A naturalistic case study on the way primary school would-be teachers explain physics was conducted in Science and Technology Education. The study dealt with explaining physics phenomena (mechanics, thermodynamics, optics and electricity) at the beginning and at the end of the course on physics. Although the students used everyday and scientific knowledge their explanations also offered mixed information that comprised both types. When using scientific knowledge the most advanced justifications were found in the issues concerning mechanics and electricity related phenomena. The students mainly used everyday expressions discussing the cases of light and heat.*

Keywords: explanations, reasoning, arguments, teacher education, physics education.

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Introduction

Science instruction depends on the development of the hypothetico-deductive reasoning ability (Kwon & Lawson, 2000). Even children begin to make logical connections, establishing links between their actions and the reactions of the objects (Carvalho, 2004). However, most arguments in everyday life are non-deductive in nature (Voss, 1989, p. 220). These everyday ideas, strongly held, may interfere with learning, and need to be replaced with correct conceptions (Warren et al., 2001, p. 530). The validity of a non-deductive argument is considered in terms of it being sound and based on three criteria: *Is the reason relevant to the conclusion? Does it support the conclusion? Are all the reasons taken into account that could support the contradiction of the conclusion?* Such arguments are not valid or invalid; they are regarded as being relatively sound or unsound. Informal reasoning may be regarded as the process of reasoning that occurs when individuals generate a non-deductive argument and/or evaluate its soundness. (see Voss, 1989, p. 220.)

Reasoning, arguments, or explanations are often considered in terms of everyday and scientific knowledge. Everyday knowledge means common knowledge about natural phenomena acquired by most people in their daily life and early schooling before coming to a more systemic study of science (Reif & Larkin, 1991, p. 736). It also means everyday, colloquial language or common sense ways of talking and thinking (Leach & Scott, 2000, p. 43) developed, learned and reinforced through everyday communication. Scientific knowledge is developed and proved valid by scientific communities and means a more formalized way of talking and thinking than everyday knowledge (Leach & Scott, 2000, p. 43). Science is "artificial" and is in several respects distinctly different from the "natural" knowledge of everyday life (Reif & Larkin, 1991, p. 736). The most central notions of scientific explanations are causal coherence and evidentiary support (Sandoval, 2003). Causal coherence embodies scientific explanations articulating causal mechanisms in order to explain phenomena and demands that chains of causes and their effects cohere sensibly. The criterion for evidentiary support reflects the idea that explanations are constructed to explain patterns of data, and so it should be clear how the data relates to the claims. The difference between high and low coherence explanations is the use of language that explicitly marks causal claims: because, caused, thus, due to (Sandoval, 2003). Along everyday and scientific knowledge, school science knowledge has also been discussed in literature. School science is different from real-life problem solving on the grounds of the criterion used for judging the value or correctness of an idea: the approval of an authority in the shape and form of the teacher and the textbook (Claxton, 1991, 55).

A great deal of international research has been carried out on the typical ways that students explain natural phenomena (see Duit, 2004) and how these so-called alternative conceptions develop over time (Driver, Asoko, Leach, Mortimer, & Scott, 1994). The students at different levels have been studied in several contexts: Sandoval (2003) has studied high school students" explanations for an event of natural selection, and has examined the causal coherence in the explanations; Gómez Crespo and Pozo (2004) have studied the relationship between students" everyday knowledge and scientific knowledge of the students in the case of understanding how matter changes; and Carvalho (2004) has considered how children build up explanations in physics. In any particular content area, the students may have alternative conceptions as well as other ideas that are more scientifically acceptable (Palmer, 1999). The knowledge type the students used may also depend upon the question asked (Solomon et al., 1996).

The significance of instruction in relation to the explanations has also been highlighted in literature. Greenwood and Schribner-MacLean (1997) have studied elementary school teachers and the effect of instruction on their explanations in the context of physics and in particular optics. Wiser and Amin (2001) have found that the scientific concept became compatible with the everyday concept through metaconceptual teaching in which explicit reference was made to the fact that laypersons and scientists use the same words for different referents, and that both conceptualizations can be integrated into one conceptual system with the latter explaining the former. Hogan and Maglienti (2001) have extended the research to link cognitive perspectives on the nature of reasoning processes, further to sociocultural perspectives on the origin of reasoning practices, in other words, the cultural practices of various groups. According to them, people seem to possess both informal heuristics for thinking and more formal rules of logic, and they use whichever one suits a particular purpose.

The aim of Finnish school science is that school leavers will be able to apply their science knowledge to everyday situations, to take a justified stand on different issues and to convey their conclusions to other citizens. These abilities can be regarded as being especially important for primary school teachers who hold discussions with their pupils on versatile questions concerning unexpected everyday situations, at the same time maintaining pupils" positive attitudes to science (attitudes, see Simon, 2000). The teachers" explanations on versatile science phenomena have to be both comprehensible for children and in accordance with scientific knowledge. The explanations are constructed through the knowledge which is acquired in everyday communication and education. According to the constructivist point of view, pre-knowledge has a significant role. Sometimes the students may learn the right way of thinking and understanding but not the right scientific concepts (Aho et al., 1993). Therefore everyday explanations may also be acceptable in some circumstances, they may also show understanding. The aim of this study is to clarify firstly, how primary school would-be teachers explain everyday physics phenomena, secondly, how the explanations differ in different physics topics, and thirdly, how these explanations differ from those given in other circumstances.

Methodology of Research

This study is a descriptive case study in which the physics explanations given by the students are regarded as discourses. Discourse analysis is based on constructive, everyday use of language (Roth & McGinn, 1998) and involves the ways of thinking about discourse (theoretical and metatheoretical elements) and treating discourse as data (methodological elements) (Wood & Kroger, 2000, p. 3). The focus is not on language as an abstract entity, but as the medium for interaction; analysis of discourse then becomes an analysis of how students explain. Discourse analysis also involves interpretative work with categorization. While reading, it should be considered how the discourse is being read. The obvious could be the starting point, considering what is missing or included and asking whether a particular word of the text relies on some assumption. Besides discourse analysis there is a need for content analysis too, in the context of which the concepts the students use in connection with the phenomena.

This study has a different viewpoint compared to earlier research. Firstly, several physics sub areas are considered in the same study. Secondly, the explanations are considered in an everyday, but, not however in a simple context. Generally the studies in literature, report explanations made in a more academic science education context. The focus is on the way to explain, but also compared is the ability to explain, and the students" use of explanations in other tasks.

Participants and data collection

The participants in this study were seventeen primary school would-be teachers participating in Science and Technology Education. All the students were in their third year of teacher education. Science and Technology Education is a voluntary minor study, and the students who had chosen the education as a part of their Master"s Degree, made up about 22% of all the third year students.

At the beginning and at the end of the physics course in Science and Technology Education, the students filled in a questionnaire which included physics questions on mechanics, thermodynamics, optics and electricity. Before the students filled in the questionnaire, the researcher discussed the aims of the study with them and reminded that the study did not influence their marks. The students were also reminded that it was important to be able to discuss everyday science phenomena with pupils. At first, the students chose one of the four given answers, which they thought was the most correct one. After, they were asked to justify their choice. The method was tested in the pilot study in a similar context. The questions were chosen from a book written for the public (Mäkelä & Suvanto, 1984) instead of the course book, in order to avoid direct explanations learned by heart. Most of the questions were unfamiliar to the students, the purpose of which was to model situations where pupils ask versatile, difficult and complex questions not directly included in the curriculum. Due to the findings of the pilot study, the questions on four different topics were chosen. Nine questions were chosen as most of the concepts in them were those also discussed in primary school, however, in a different context and in a simpler form. It is the language (concepts) and the way of explaining, more than giving the correct answers, which is in focus in this study. The questions and alternative answers for choices are shown in Table 1.

Table 1. The multiple questions to be explained and the choice of alternatives (in Finnish, Mäkelä & Suvanto, 1984; in English, Keinonen, 2005).

Why is the astronaut in the satellite flying round the Earth weightless?	a) The gravitation does not influence him anymore, b) The gravitations of the Earth and the Moon cancel out each other, c) The gravitations of the Earth and the Sun cancel out each other, d) The astronaut is not weightless.

If one wanted the weight to be at its lowest where would it be more advantageous to weigh oneself, on the shore or in the mountain?	a) on the shore b) in the mountain c) there is no difference.
The car is driving the one hundred-kilometer-drive from Helsinki to Hämeenlinna. During the first 50 kilometres the velocity is 40 km/h because of the traffic jams. What should the velocity be during the last part of the drive in order to have the mean velocity of 80 km/h?	a) 120 km/h b) 160 km/h c) 200 km/h d) is not possible.
What happens to the room temperature, when the door of the refrigerator is opened?	a) the room temperature does not change b) the room gets warmer the whole time c) the room cools off the whole time d) at first the room cools off, then it gets warmer.
When one brews a pot of tea, the quickest way to boil the water is to immediately use the highest possible power. But what is the most economical way to do it?	a) to use the lowest power so that water just starts to boil b) to use the highest power c) the way used has no influence on the total consumption of electricity.
The landscape reflected on the calm water surface is a little bit darker and upside down, compared to the original landscape. Is it otherwise the same?	a) yes b) no.
What is the colour of the shadow that the Sun makes on the snow?	a) black b) grey c) red d) blue.
On the top of the antenna of the car radio there is a knob, because	a) it improves the audibility b) a sharp top could be dangerous c) it prevents the antenna from vibrations when the wind blows.
Orienteers know that they can not trust the compass under power lines. If the power line is in the east-west direction (as shown in the figure), then under the lines the needle of the compass shows	a) north b) south c) east d) west e) anywhere.

Data analysis

Discourse analysis requires a particular orientation to texts and a particular frame of mind. In this study, it came from physics education and the context of the study. The frame was thus connected to the causal connections, present or absent, and to the concepts used or not used in physics. The analysis was started by carefully reading the texts which itself involved interpretation, and then guided to further analysis. In the following, according to qualitative research methodology, interpretation and analysis are tightly connected to each other. The examples are aimed at showing the versatile ways of interpreting explanations by looking at them from different viewpoints (causality, concepts, language) but based on the data. Finally, data-based analysis has lead to choosing two ways of categorizing the explanations: *Did the answer explain the phenomena or not? Was it an everyday or scientific explanation?* As an example of the interpretation and analysis process, below we present the first of the nine questions and the explanations given to it by the students.

An example of the data and its interpretation and analysis

The first question on the weightless astronaut is the farthest from the students“ daily life. The subject however, is familiar from news and books. The correct answer is item d) and its physics explanation is the following: Neither the astronaut nor the satellite is weightless. The influence of the gravitation is not noticeable, because both are in the falling motion due to gravitation. The motion is difficult to understand as a falling motion, because the distance to the Earth is the same the whole time. This is due to the fact that the satellite moves with the same velocity in the direction of the Earths" surface, and the Earths" surface moves away in the same velocity, as the satellite falls towards the Earth.

The students mostly connected the astronaut"s weightlessness to gravitation, as seen in the following discourse. (B refers to the explanations at the beginning of the physics course and P8 refers to the student.)

> The astronaut always weighs something. When he is floating in Space, he still weighs something, but gravitation is not strong enough for him to stay in place. BP8

The astronaut always weighs something can be interpreted as expressing the concrete weight people have and measure. It is not seen to contain the existence of gravitation. According to the student"s interpretation, the astronaut is "floating" in Space. In the question, the issue is about the flight of the satellite. Floating indicates the visual image people have about motion in Space. Does the student think that floating and flying are synonyms? The student speaks about the astronaut"s floating, not that the satellite floats or that the astronaut is inside the satellite. She has not considered the problem in the present context, but has spoken generally about floating in Space. The student states that the gravitation is not strong enough. She refers to the change of gravitation in Space, but she does not mention which gravitation she means. Probably the student only means the gravitation of the Earth. "Enough" seems to mean the distance being long enough to decrease the gravitation. The student sees the opposite of flying to be "should stay in place". She says that when gravitation is strong enough, the astronaut should stay in place. The student thinks that only the gravitation of the Earth is essential in Space. She does not understand or at least realize that gravitation can generally be due to other objects in Space too.

Explanations for the "weightless astronaut" problem connect gravitation to weightlessness, but the language which is used cannot as a whole (connecting floating to weightlessness) be seen as adhering to the physics explanation. There are some attempts at logical reasoning by using the word "because".

> The astronaut still has the same weight, but the pressure in Space is different, because of that the astronaut is floating in the shuttle. There is no gravitation. BP11
>
> Gravitations of the Earth also influence the astronaut, because otherwise the satellite would float. EP17

(E refers to the explanation at the end of the course on physics.) Even though physics concepts on gravitation, floating and pressure were used, these explanations are in forms that do not exactly fit into the physics explanation. The concepts were not used precisely enough in order to make them physics explanations. They rather resemble daily life reasoning. Here also the emphasis is not on the right concept, however some attempts have been made to explain the phenomenon.

Most of the explanations concerning the weight of the astronaut, lay somewhere between daily life reasoning and the physics (scientific) explanation.

> The astronaut is so far from the Earth, that the gravitation of the Earth does not influence anymore. BP7

The gravitation of the Earth does not extend outside our atmosphere. EP6

These explanations include the fact that gravitation is dependent on distance, but the students have not understood the phenomenon correctly. They also stated that the Earth"s gravitation has no influence in Space or outside the atmosphere; there is no gravitation in space; in Space it is a weightless place; the attraction force of the Moon is weak; g is no longer the Earth"s attraction force, but there is another attraction force.

Another type of weightlessness-phenomenon described by the students, was one that sounded like a physics explanation, but was expressed by using sentences that sounded like daily talk.

> The astronaut always weighs something. When he is floating in Space he also weighs something, but the gravitation is not so strong that he "could stay in place". BP14
>
> Weight is a different thing from mass. Even if the gravitation of the Earth doesn"t influence so much anymore, there are other forces in Space which influence – the astronaut is not weightless. EP11

The statement about weightlessness is right, but the other sentences are not precise enough to be taken quite as statements relating to physics.

Two of the students used the physics concepts in the quite right way, but did not explain the phenomenon correctly. Although the statements are right, they do not explain the question asked.

> The gravitation law is also valid in Space. BP15
>
> In Space, the satellite is just under the influence of the Earth"s gravitation, because it orbits the Earth, then small gravitation influences the astronaut. EP14

These students have probably understood the influence of gravitation in general but could not reason the question asked. It may also be that they have learned to memorize this fact and therefore it was the first idea which came in this connection.

Every explanation (21 in total) included gravitation. The argument that gravitation does not exist outside the atmosphere is a misconception. None of the students tried to explain the influence of the two motions, which are essential in the situation. Some students had misunderstanding that gravitation would not influence in Space. All students had limited understanding of the phenomena. The concepts which students used were scientific concepts but the explanations were mostly incorrect and weak in logic. It must be noticed that the explanation that sounds like physics does not mean that the explanation, or even the answer, is correct. On the other hand, an everyday explanation could be accepted as a correct one. At this stage of the research, the knowledge level of the students was not under consideration. Both correct and incorrect answers were analysed in the same way to find out the type of language or knowledge used by the students.

Results of Research

Twelve of the seventeen students answered the questions in both cases before and after the instruction period. In addition, three students answered only once and two of the respondents didn't answer the questionnaire at all. In the following, the explanations are presented from the three different viewpoints found in the analysis: the causality, the degree of explanation, and everyday vs. scientific knowledge.

Causal coherence

When paying attention to absences it was noticed that there were few causal connections in the explanations. This kind of language was only used in some explanations.

> In Space, the satellite is just under the influence of the Earth"s gravitation, *because* it orbits the Earth, *then* small gravitation influences the astronaut. EP14
>
> The weight g is smaller in the mountains *because* the Earth"s gravitation there…less further away from the Earth"s core, the mass does not change. EP17
>
> Sunlight has all wavelengths. *Because* the snow reflects white light, the counter colour of white is black? Black colour. BP8

Following the statements "under the influence of the Earth"s gravitation" and "*because* it orbits the Earth" the student should state that both are in the falling motion *due to* gravitation. In the second explanation the student correctly thinks that all wavelengths (white light) reflect from the snow, but does not take into account that due to scattering from the atmosphere, the light is more blue than red.

Categorization of explanations and their justification

The primary school would-be teachers justified their choices of alternatives by using words, phrases or concepts which did not noticeably differ from the concepts introduced in the school books or expressions used in everyday life and based on experiences. In some explanations, students tried to *explain* (Earth"s gravitation is smaller on the mountain) the phenomenon, but some explanations were purely *tautological phrases* repeating the question or its alternative answers in some other form (the temperature difference between the room and the refrigerator normalizes; cf. the last alternative in the question). In some explanations *correct concepts were used, but the phenomenon was not explained* (when entering the water, the light beam refracts towards the normal to the surface; the sentence is right, but on its own it does not explain the phenomena). There were also rather *irrational explanations* (inessential facts from the viewpoint of the phenomenon; There is more mass in the knob, thus waves can reach it easier). The frequencies of the explanations in this categorization are shown in Table 2. The tautological phrases here do not answer the question 'why', thus they do not explain the phenomenon.

Table 2. Categorization of the explanations ranging from real to irrational explanations.

subject of the question	explained	tautological phrases	correct concepts used, but not explained	irrational explanations	quantity
astronaut/gravity	21	3	1	1	26
mountain/gravity	15	1	6	0	22
car/velocity	4	5	0	8	17
refrigerator/heat transfer	5	7	1	8	21
boiling/heat transfer	3	16	1	1	21
mirror/refraction	0	18	3	0	21
snow/scatter	2	8	4	3	17
antenna/charge density	0	1	0	12	13
compass/electric field, magnetic field	5	10	0	1	16
quantity	55	69	16	34	174

Most of the explanations were tautological phrases (69). Less than half (55) were true explanations and most of them were associated with the questions on gravity.

Categorization of explanations in terms of everyday or scientific explanations

Reasoning has often been studied in literature in the framework of *everyday-scientific knowledge*. In this study the students used some kind of colloquial language in their descriptions. They also reasoned in the way of physics and mixed different ways to explain. These notions finally led to the categorization of the students" explanations by using definitions of both everyday and scientific knowledge (see Reif & Larkin, 1991; Leach & Scott, 2000; Author, 2005).

Explanations such as,

> The faster the water boils, the less electricity is consumed. BP14
> The surface of the water is like a mirror. BP1,

serve as good examples of knowledge based on everyday communication. In everyday knowledge it is important to pursue the sub goal of predicting and sometimes of explaining as in the explanation.

> The air pressure is higher (in the mountains) rather than down in the valley. BP11

Scientific knowledge predominantly means knowledge that is encompassed by the present-day physical sciences (Reif & Larkin, 1991, p. 787) which is evident in the following student“s description.

> The gravitation law is also valid in Space. BP4

In this study, the students“ explanations do not exactly correspond with the definition of scientific knowledge in the way that Reif and Larkin (1991) have defined it, as being the knowledge predominantly encompassed by the present-day-physical sciences. In addition, the explanations do not correspond with the scientific knowledge of Leach and Scott (2000) as a more formalized way of talking and thinking. The explanations in this study represent some knowledge between scientific and everyday knowledge which could be seen to be school science knowledge (see Claxton, 1991). In the student“s explanation,

> The light beam refracts when it hits the water, in the direction of the normal to the surface. EP16

Correct scientific concepts are used, the statement is quite right, but it does not answer the question. This corresponds better with school rather than scientific knowledge.

In reading the explanations it became evident that the everyday and scientific /school knowledge were insufficient to account for the variations in students“ discourses. Some of the explanations resembled everyday knowledge even though they had been expressed by using scientific knowledge. Some of the explanations sounded like scientific knowledge, but the knowledge, which was used, was, however, everyday knowledge. The framework of the explanations was thus expanded to four different categories according to the arguments: physical argument; physical sounding arguments constructed with everyday concepts; everyday arguments with physical concepts and everyday arguments. For example, when “fall motion‘ and “velocity‘ are the concepts which are needed to explain the phenomena, instead, the students used “pressure‘ and “floating‘ in their everyday explanations. When the students used the concept “force‘, the explanation sounded like a physical argument, but the concept more resembled everyday thinking. In the compass question, the students used several correct concepts in their scientific explanations. In the everyday explanations they used only the magnetic field, and it was not connected to the electric field. In the heat questions the students used more different concepts than in the other questions and most of them were everyday words or concepts such as “comes colder air”, “more warm air”, “flows cold air”, or energy and power in different meanings. The four categories of the explanations are then named to be: scientific knowledge; scientific sounding knowledge expressed by using everyday knowledge; everyday knowledge expressed by using scientific concepts; and everyday knowledge.

Types of knowledge in different topics of physics

This study also investigated whether the students“ explanations differed in variation of physics topics. The first three physics questions concerned mechanics, the next two thermodynamics. These were followed by two questions which dealt with light or waves, and finally there were two questions about electricity. The frequencies of different types of explanations are shown in table 3.

Table 3. Numbers of explanations in different kinds of knowledge (at the beginning/end of the course).

Subject	Everyday knowledge	Everyday knowledge expressed by using scientific concepts	Scientific sounding knowledge expressed by using everyday knowledge	Scientific knowledge	Quantity
astronaut/gravity	2 (1/1)	16 (8/8)	2 (1/1)	2 (1/1)	22
mountain/gravity	12 (5/7)	0	0	12 (7/5)	24
car/velocity	13 (5/8)	0	1 (1/0)	4 (2/2)	18
refrigerator/heat transfer	18 (11/7)	2 (0/2)	2 (1/1)	1 (1/0)	23

Subject	Everyday knowledge	Everyday knowledge expressed by using scientific concepts	Scientific sounding knowledge expressed by using everyday knowledge	Scientific knowledge	Quantity
boiling/heat transfer	18 (11/7)	2 (0/2)	0	0	20
mirror/refraction	16 (8/8)	1 (1/0)	0	2 (0/2)	19
snow/scatter	9 (4/5)	5 (4/1)	0	3 (0/3)	17
antenna/charge density	13 (5/8)	0	0	0	13
compass/electric field, magnetic field	4 (3/1)	2 (2/0)	0	11 (4/7)	17
quantity	105	28	5	35	173

By comparing the explanations of the phenomena, it is noticed that the questions concerning mechanics (astronaut and mountain) were explained by using more scientific or scientific sounding rather than everyday knowledge, and the questions concerning thermodynamics (refrigerator and boiling) were explained by using more everyday rather than scientific knowledge.

Connections between the categories

By comparing two categorizations, the everyday-scientific knowledge categories (Table 3) and the explained- irrational categories (table 2) it was noticed that when the largest group of answers in the astronaut questions was everyday knowledge expressed by using scientific concepts, on the other side it was the explained category in the other categorization. Though the question about the mountain was explained mostly using everyday or scientific knowledge it was however, explained. Both everyday knowledge and irrational explanations were used in the question about velocity, as was also the case in one of the questions about heat transfer. The other question about heat transfer was answered using everyday knowledge and tautological explanations. The questions concerning light connected everyday knowledge with tautological explanations. Irrational questions and everyday knowledge are connected in the question about antenna and tautological explanations with scientific knowledge in the question about compass. The relations between the two categories are shown in Table 4. Not all of the everyday-scientific explanations could be analyzed as belonging to the explained/irrational categories, and vice versa.

Table 4. Numbers of the explanations in two categorizations in comparison with each other.

Categories	Everyday knowledge	Everyday knowledge expressed by using scientific concepts	Scientific sounding knowledge expressed by using everyday knowledge	Scientific knowledge	Quantity
tautological phrases	49	7	0	7	63
explained	8	14	5	20	47
irrational	27	1	0	1	29
real concepts	6	3	0	2	11
quantity	90	25	5	30	150

When the explanations were categorized as being scientific ones, thus using scientific concepts, they mainly (20 cases) explained the phenomena. When the explanations were everyday knowledge, they were mainly tautological (49 cases) or irrational statements (27 cases). Thus, by using everyday knowledge, the students could seldom explain the phenomena. It was done only in eight cases. Knowledge about scientific concepts and their use was necessary to explain the phenomena. Also in some cases a mixed knowledge (14 and 5 cases) has lead to explanations.

Knowledge in other tasks

In addition to the questionnaire discussed above, the students had an exam and homework in which they had to explain everyday physics phenomena. These explanations showed how they used scientific concepts and could make causal connections, thus constructing explanations suitable for everyday use and fitting in with the physical explanation. They also got good marks in the exam.

Discussion

The explanations, typically one sentence, were maybe too short to show any causal claims. According to Sandoval (2003), longer explanations are not necessarily more or less coherent than shorter ones. Thus, the demands for longer explanations could not guarantee the causality. The students" answers also did not necessarily explain the phenomena and this was especially the case in more familiar subjects in daily life. Even though everyday knowledge is sometimes enough to explain physics phenomena, the students could more often explain the phenomena through scientific knowledge. Thus, acquiring scientific knowledge seems to be necessary for primary school would-be teachers to manage with their science explanations.

According to the exam, subject knowledge of primary school would-be teachers was good enough. However, the above discussed explanations gave another impression of their understanding as also Greenwood and Scribner (1997) have found. The explanations made at home more comparable with the study of Sandoval (2003) also showed causal coherence which was not found in the explanations of the questionnaire.

Gravitation belongs to the subjects that have already been discussed in grades 5 and 6 of comprehensive school and also appears in the school course books. Gravitation seems to be understood during school instruction because the explanations at the beginning of the course on physics were at the same level as at the end of the course. Primary school would-be teachers' everyday ideas in general seem to be strongly held, agreeing with previous science education research (Warren et al., 2001). The students" explanations were not valid or invalid but rather regarded (cf. Voss, 1989, p. 220) as relatively sound (scientific and scientific sounding knowledge expressed by using everyday knowledge) or unsound (everyday knowledge and everyday knowledge expressed by using scientific concepts). The criterion for the validity (Voss, 1989, p. 220), as to whether the reason is relevant to the conclusion, is not fulfilled by the students" explanations in this study. Irrelevant reasons leading to the conclusion were also presented. The second criterion, whether or not the reason supports the conclusion, became somewhat clear but the third criterion, whether all reasons are taken into account that could support the contradiction of the conclusion, remained unclear.

The students could not specify the concepts explicitly and thus were unable to identify them properly in this situation, which is in accordance with the observations of Reif and Larkin (1991, p. 747.) The students used concepts very broadly. Everyday concepts were used in scientific explanations, and scientific concepts were used in everyday explanations. In the categories between them, the concepts were used more like everyday concepts even though, as words, they were scientific concepts. In everyday life, the connections between concepts and their references are not usually specified with great precision and concepts need not necessarily be related to observable phenomena. The concepts used by the students in everyday explanations were mainly related to the phenomenon, but they were not always the most essential ones. The students have partly learned the right way of thinking and understanding (cf. exam and home work), but haven"t learnt how to use the correct scientific concepts in new situations, which Aho et al. (1993) have noticed with younger students.

The answers differed according to the physics topics. The phenomena of water boiling represents a topic where past experiences and local knowledge in specific contexts are generally quite adequate for commonly required predictions and explanations. During Science and Technology Education, formulas are not used. Mainly the subjects which are significant for the primary school level are discussed. The topics in mechanics, present in this study, have been discussed more thoroughly during the course on physics than the topics of thermodynamics. Thus, the students have adopted more precise knowledge of mechanics. This may be one of the reasons for the better conceptual knowledge in mechanics. The topics of thermodynamics and discussion about them are closer to people in everyday life. These phenomena have been explained through experience. Mechanics is not discussed to the same extent in everyday life and the topic is also not as concrete as thermodynamics. Because the pre-existing conceptions are not so strong in mechanics, those concepts which have been learnt in the course on physics are used in the explanations. However, the students have not learnt to connect these concepts correctly. In the optics domain (mirror and shadow) the students used everyday knowledge, but in the electricity domain (antenna and compass) both everyday and scientific knowledge. Light is normally very close to everyday life and is therefore easily explained by commonsense knowledge. The students answered the question about electricity (compass) discussed quite well during the course on physics using scientific concepts. Scientific knowledge was used even though this question concerned everyday phenomena familiar to the students. The second question about electricity (antenna), not included in the course, was answered using everyday knowledge. These findings support the findings of Gómez Crespo and Pozo (2004) concerning matter, and extend the knowledge about explanations to other physics topics.

The students" understanding can be seen to be fragmented, because causal coherence is absent. Palmer (1999) names the fragments as p-prims (phenomenological primitives, in accordance with DiSessa), and says that they can be understood as simple abstractions from common experiences. A particular problem context activates a particular p-prim and that determines the type of explanation the student gives. The context of the task influences the inference pattern one employs. Wiser and Amin (2001) agree on the view that learning physics involves reorganizing p-prims in a manner consistent with the scientific view. According to Palmer (1999), the knowledge system is weakly organized so that the students" justifications typically lack depth and their responses can often appear to be ad hoc in nature. Students possess pieces of knowledge, facets, which are closely related to a particular context of a problem. In this study, the students could not consider the phenomena as a whole. The students developed their reasoning by using superficial knowledge. For the most part, the students did not notice the most essential aspect related to the task. They liked to reason the tasks by means of words, which were almost correct, but not precisely. It may also be that the formulation of the questions activated fragmented rather than coherent knowledge (cf. Solomon et al., 1996).

The students typically draw upon more than one form of reasoning when responding to questions (Leach et al. 2000). This might be predicted from the situated perspectives on learning. The students also select at least some of the fixed response statements at random, with almost no critical judgement (cf. Leach et al., 2000), which has also been stated by some students in the explanations of this study. The students" explanations, before and after the instruction period did not differ. They used scientific and everyday knowledge in both cases. Sometimes the student constructed the answer for the same phenomena through scientific knowledge in the pre-questionnaire and everyday knowledge in the post-questionnaire. Changes between the four categories occurred in the explanations.

Conclusions

This study gives detailed information about primary school would-be teachers' ways of explaining physics phenomena. The would-be teachers explained physics phenomena using different types of knowledge including everyday knowledge, everyday knowledge with scientific concepts, scientific sounding knowledge with everyday concepts and scientific knowledge. Scientific knowledge seems to be necessary in order the would-be teacher succeed in explaining everyday phenomena. The explanations in everyday topics also gave a different picture of the students" knowledge, from what the exam had given. The analysis of the explanations can thus give other information on the results of learning. No difference was observed in the nature of the explanations given by different students. If a primary school would-be teacher did explain one question well, s/he did not necessarily do well in other questions. No specific coherence between the students and their responses was found. The would-be teachers possibly have different experiences of everyday life and also due to school science and different mental images of different topics.

This study has lead to some thoughts about the ratio between pedagogical knowledge and subject knowledge in education. For establishing the learning environment the students" multidimensional development in which is promoted, the purposes and starting points of teaching need to be clarified. Based on these two aspects of teaching, the teacher needs to use pedagogical and scientific knowledge. In addition, both of these knowledge areas must be in harmony with knowledge of students" understanding. The primary school teacher's achievements in scientific knowledge and its adaptation for pedagogical situations have an essential role in primary science as well as at higher education levels. Thus, depending on how well the "language" about scientific phenomena is understood between the teacher and students, the students" science understanding process can be supported and guided. This kind of awareness should be a core issue in teacher training. Rice (2005) suggests that we should take a closer look at pre-service elementary school teachers" knowledge of the science content they will be expected to teach. Even though the need to essentially increase the subject knowledge courses in Science and Technology Education has not been supported, there still seems to be a need to focus subject instruction more towards the feature of explanation. In focusing on explanations, care must be taken to ensure that scientific knowledge is used to support the ways the students explain the phenomena scientifically. Because science instruction depends on the development of hypothetico-deductive reasoning ability (Kwon and Lawson 2000) possessed even by children (Carvalho, 2004) thinking about explanations should be more effectively practiced in teacher education.

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Резюме

ОБЪЯСНЕНИЯ ФИЗИЧЕСКИХ ЯВЛЕНИЙ БУДУЩИМИ УЧИТЕЛЯМИ НАЧАЛЬНОЙ ШКОЛЫ

Туула Кейнонен

Проведено исследование в области подготовки учителей, которые изучили естествознание в аспекте отношений технологий и общества. Изучалось разнообразие объяснений физических явлений студентами – будущими учителями основной школы. Объяснения обсуждались на основе сообранных данных. Был выяснен язык студентов на котором велись эти объяснения. Перед и после рассмотрения вопросов физики, на качественном уровне обсуждались соответствушщие виды мышления, проходящие на базе полученных экспериментальных данных и предидущих исследований. Несмотря на ряд случаев, когда объяснения были весьма ограниченными, были выяснены виды знаний, которыми пользовались студенты для соответствующих объяснений.

Исследование дало детальную информацию о путях объяснения студентами физических явлений на основе разных видов знания: повседневное знание, повседневное знание с научными понятиями, псевдонаучное или научноподобное знание с повседневным знанием, научные знания. Для объяснения повседневных явлений для студентов необходимы научные знания, которыми они владели в различной степени. Анализ объяснений предоставляет ценную информацию о результатах обучения студентов. Необнаружена разница в характере объяснений разными студентами. Каждый студент одни явления объясняет лучше, другие хуже. Студенты имеют разный опит поседневной жизни и, благодаря их шкоьной науке, разные представления о разных явлениях.

Ключевые слова: образование учителей, обучение физики, объяснения, аргументы.

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