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THE COMPARATIVE STUDY OF PROSPECTIVE SCIENCE TEACHERS' SKILLS OF WRITTEN EXPLANATION

Oleg Popov

Umeå University, Sweden

Sergey Bogdanov

Karelian State Pedagogical University, Russia

Abstract. *A comparative study of prospective teachers' pedagogical skills of written communication in science is presented. Russian and Swedish students were asked to give detailed explanations of two simple physical phenomena (how and why the shadow from a tree appears and why the bulb lights in a torch) to a hypothetical Grade 7 pupil. The results of the questionnaire revealed the evident gap between the students' knowledge per se and their abilities to express didactically their knowledge in written form and in pictures. Undoubtedly this is one of the challenges to teacher educators. The study also revealed the differences between forms and qualities of explanations given by Russian and Swedish students as the result of different pedagogical traditions and communication cultures.*

Key words: *science teacher education, comparative study, communication skills, sociocultural context.*

Introduction

During the last three decades research in science education has been dominated by two trends: emphasis on direct learning through practical activity (hands-on) and the constructivist approach to learning (personal construction of knowledge). Teachers were considered to have only an indirect possibility of influencing learners' minds through organising *leaning situations*. Currently, a new tradition is emerging in the field emphasising the importance of communication in science education (Lemke, 1993; Ogborn et al, 1996; Strömdahl, 2002; Laptev, 2002). We agree with Ogborn et al (1996, p. 141) that 'communication is action' and 'to teach is to act on other minds, which act in response'.

Teachers use in their professional practice a range of modes of communication, e.g. speech, drawing on the blackboard, demonstrations, and gestures. Monk and Dillon (1995, p. 96) point out that 'science teachers have a professional responsibility to monitor their own communication skills and to improve them consciously and deliberately.'

An important professional skill that prospective science teachers need to develop during their university studies is how to explain things to pupils. We assume that most teacher educators would share our concern about the development of students' skills in communicating science, including training in the production of text-based resources and written accounts.

This paper presents a research project that was designed to study student teachers' pedagogical skills in giving written explanations in science in two different pedagogical cultures: Swedish and Russian. Background information on some aspects of the corresponding socio-cultural contexts was also collected.

A sociocultural perspective on human activities (Säljö, 2000, Leach and Scott, 2003) was adopted in order to compare and discuss development of communication skills in science teacher education in the two countries.

A sociocultural perspective

The main reason for adopting a sociocultural perspective as a theoretical framework of analysis, was our search for understanding the relationship between communication, learning and the sociocultural context.

A central assumption of a sociocultural perspective is that mind and culture co-constitute each other and develop in close interrelationship (Vygotsky, 1987). Accordingly, student teachers' minds are formed by their education and also within and by a broader sociocultural context.

According to Vygotsky (1987), personal development is conditioned by learning. To learn and develop means to appropriate and master artefacts within meaningful social activities. The nature of cultural artefacts and their appropriation is not uniform across cultures and societies. Sociocultural context influences why, what kind of and how cultural artefacts are developed, selected and used. Communication tools are probably the most important cultural artefacts that mediate our perceptions of, and actions in, the world.

In different contexts humans learn in different ways. When studying nature, health, or social phenomena, people tend to learn through communication rather than discovery. Think only about looking for answers to such questions as how to cure a sick child, what mushrooms are eatable, or how to make a good investment in the stock exchange. "Try and error" ways of answering these questions may not be the best. A better way would be to consult an expert in the field.

Communication is the teacher's main pedagogical tool, used for mediating his/her relations with pupils. Leach and Scott (2003) argue that 'the ability to guide the classroom discourse as ideas are explored and explanations are introduced, is *central* to the science teacher's skill and is critical in influencing students' learning'. During initial teacher education, students need to acquire basic skills in using a variety of mediation artefacts, such as oral, written and graphical communication tools. Nowadays, they also need to master different kind of multimedia equipment.

For this study, we chose to examine prospective teachers' skills in pedagogical communication, by looking at the mediating instruments of their communication - written texts and drawings presented to a hypothetical pupil. Following Ogborn et al (1996) we call them 'explanatory entities' that are used to transform 'scientific knowledge' into 'school knowledge' appropriate to the pupil.

Research methodology

Research instrument

The questionnaire focused on the skills of written communication. As a starting point we used the idea that school culture is based mainly on written language; it is a text-based culture. According to Säljö (2000), mastery and practice of written forms of communication emerge as significant activities per se within the school. In the school context, pupils learn to *read the world* through and with a text. They acquire new knowledge as it is presented in print. Therefore, we found it appropriate to explore prospective teachers' skills of communication by means of paper and pencil.

The following problem situation was presented to student teachers: a hypothetical Grade 7 pupil was not able attend a school because of illness and the pupil has asked for an explanation by letter, of two physical phenomena: how and why the shadow from a tree appears (a sketch of a tree and a street lamp is presented) and why the bulb lights up in a torch (see Appendix). Students were encouraged to use a variety of ways and communication tools in making the presentation.

We tried to formulate simple questions that could allow future teachers' to show their skills of didactical reasoning and written communication, rather than test their own conceptual understanding. However, there were so many misconceptions "communicated to a hypothetical pupil" that we could not avoid including them in our analysis.

Description of the sample

The questionnaire was completed by students specialising in science in the Faculty of Teacher Education in Umeå and students from the Faculty of Physics and Mathematics at Karelian State Pedagogical University. The students were all trained to teach science/physics in Grade 7. About 200 students in Sweden and Russia completed the questionnaire. 185 responses were selected as valid for analysis: 110 in Russia and 75 in Sweden.

Concerning gender representation, numbers of female and male students in the sample reflect general gender trends in the corresponding institutions in the two countries. In Russia, there were 70% female and 30% male students, while in Sweden the corresponding figures were 55% and 45%.

The mean age of Russian students was 19 years and the Swedish, 30 years, i.e. Swedish students were in average ten years older than Russians. This can be explained by the following: in Russia, people usually enter to university at age 17, directly after finishing secondary school (after 10 years and recently 11 years of compulsory schooling), while in Sweden, students finish gymnasium at age 19 and often work a couple of years before going to university. The Swedish part of the sample also included 16 distance education students, some of whom were over 40 years old.

Findings and discussions

Written explanations provided by student teachers to a hypothetical Grade 7 pupil reflected, on the one hand, their own (mis)understandings of the phenomena, and on the other hand traditions of teaching/learning in the two countries. As Ambrose *et al* (1999) point out 'it is often difficult to distinguish difficulties with concepts from difficulties with representations. The two are intertwined.' In the following text, we try to shed light on typical use of representations (explanatory entities) by student teachers that, we assume reflect their scientific and pedagogical knowledge. In the analysis, we have divided each response into two parts: *picture* (symbols and illustrations) and *text* (concepts, analogies and suggested experiments and activities). Therefore, our discussion concentrates on both visual images and written explanations.

Explanations about shadow

Russian students explained shadow construction in a more formalised way, using a geometrical optics approach. More than half of them (53%) drew light rays only in the direction of the tree (so called construction rays) and marked shadow as a place on the ground (64%) as it is shown in Figure 1 below:

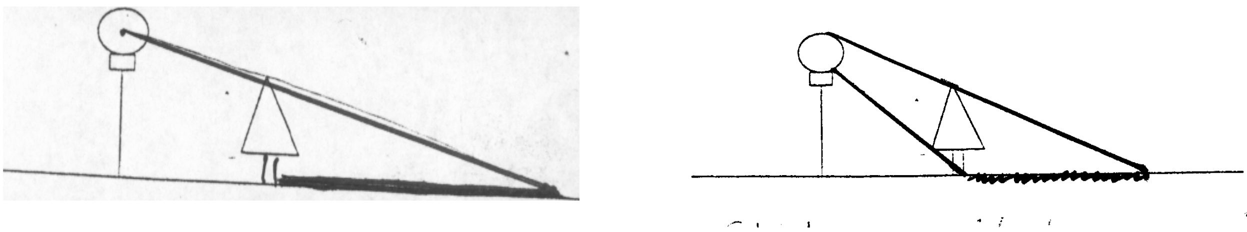

Figure 1. Typical rays construction made by the Russian students.

In Sweden, most of the students used a more common sense approach that, in our opinion, aided their pedagogical method in thinking about age of the target group of pupils. The majority of them drew rays in all directions from the lamp (57%) (Figure 2). However, they made less articulated illustrations (drawing) of the shadow: 34% drew the shadow as flat, 24% as volume and almost 40% did not draw it at all.

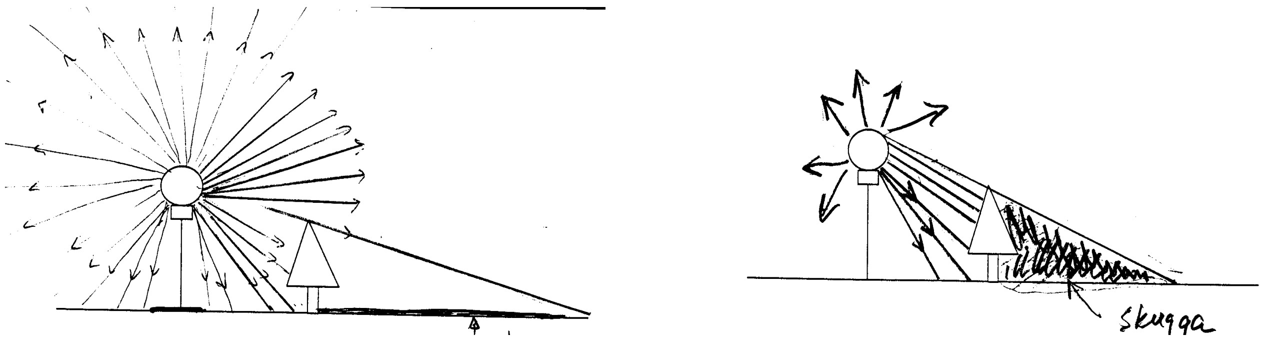

Figure 2. Typical rays construction made by the Swedish students.

Nevertheless, 85% Swedish students presented the description of the shadow in words (as compared to 75% of Russian students).

We could also distinguish between scientific and everyday understandings of shadow. Those students who presented a volume/space form of shadow either in a drawing (Figure 3) or in a text were considered to be students who could communicate scientific understanding of shadow. This was attributable to 27% of Swedish and 18% of Russian students.

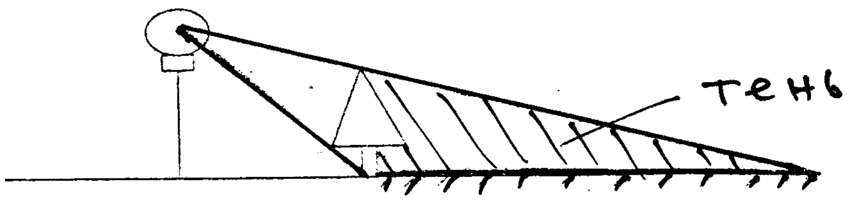

Figure 3. Example of drawing a volume/space form of shadow by a Russian student.

As was mentioned earlier, 64% of Russians and 34% of Swedes drew a flat shadow on the ground, according to their everyday perception of shadow. There were also several students in both countries who drew a shadow without indicating light rays. This could be interpreted as an observable phenomenon at the everyday level of understanding – what we can see. We do not see light rays, we see just shadows. However, these students did not use the scientific tools of explanation (light rays model) to explain how shadows that we see, appear.

Many students in both countries revealed having problems in making presentations of meaning in clear language. As a consequence, their pupils are likely to construct only vague ideas about the essence of physical phenomenon. For example, 31% Swedes and 43% Russians described shadow as darkness behind the tree, without pointing out whether this darkness is located on the ground or in a space where direct lamplight does not reach. Such presentations may lead pupils to different interpretations of the teacher's words.

Providing the learner with additional information about the context of the problem can facilitate understanding, and some students presented the ideas relevant for preventing learners' misunderstandings. In particular two Swedish student teachers pointed out that it had to be dark in the street to see a shadow of the tree created by the street lamp. Six Swedish respondents also explained that shadow does not mean complete darkness but rather less light.

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Only 25% of Swedish and 17% of Russian students clearly presented in the text an important idea that light travels in a straight line.

Explanations about a flashlight

Russian students explained flashlight functioning also in a more formalized academic way. For example, 33% of Russians drew a conventional schema of an electric circuit while only 15% of Swedish students did so. Russian students were also more likely to use schematic presentation of batteries (⊣⊢) and a lamp (⊗) as it is practised in physics classes (Figure 4a below)

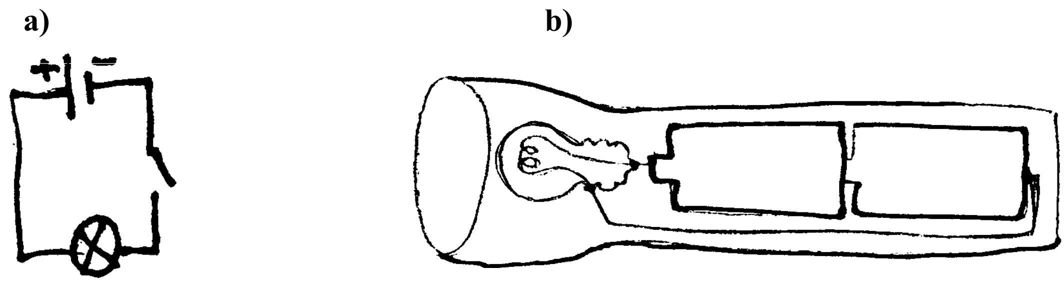

Figure 4. a) Schematic presentation of an electric circuit and b) flashlight construction with the electric circuit clearly marked.

Swedish students relied more in their responses on pupils' everyday experience. About a quarter drew a picture of flashlight construction with the electric circuit clearly marked (Figure 4b), and 18% drew such a picture but without a marked circuit.

Among Russian students 12 % drew flashlight construction with a circuit and 23% without a circuit. Students who did not draw a circuit in the pictogram of the torch were likely to be unaware about pupils' difficulties with understanding of this concept.

Instead of or in addition to the flashlight construction, 42% of Swedish and 13% of Russian students drew the bulb and battery forming the circuit (Figure 5 below) and used it as a didactical tool (explanatory entity) for explaining a circuit.

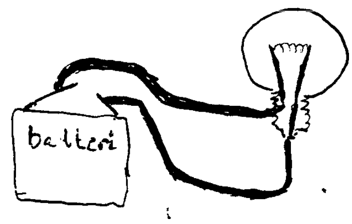

Figure 5. Separate drawing of the bulb and battery forming the circuit.

Totally, 72% of Swedish students showed the bulb with its inner structure and 12% drew the bulb without its inner structure. Russian students drew the bulb with an inner structure in 32% of cases, and in 23%, without inner structure.

How the bulb emits light was explained by 58% of Swedish students as compared with 32% of the Russians.

Use of analogies and suggestion of activities

An obvious way to facilitate communication of meaning in science is through use of analogies. Another classical way of giving scientific explanations is using demonstrations and other activities. Swedish student teachers provided more examples of different analogies and activities in order to facilitate understanding of the phenomena than did the Russians.

Table 1 below presents the percentage of Swedish and Russian respondents' suggestions for illustrating their explanations with analogies and practical activities (pupils' experiments and teachers' demonstrations).

Table 1. Suggestions of analogies and activities in the students' texts.

	Shadow (%)		**Flashlight (%)**	
	analogy	*activity*	*analogy*	*activity*
Sweden	24.2	22.4	30.3	7.6
Russia	2.7	5.5	14.5	0

There were mainly two kind of analogies used for the flashlight case:

Analogies related to qualities of human/living beings:

- Active electrons *(piga elekroner*[1])
- People in a queue rash through an open door into a dance hall,
- Electrons *forcing themselves* to go through the lamp

Analogies related to different everyday phenomena/objects:

- Sport: ”start (-) and finish (+)”, a running race (*löparbana*)
- Battery as equivalent to a pump
- Electrons as equivalent to domino pieces (*elektroner agerar som brickor i domino när batteri puttar på de*)

Analogies and activities are important meaning-making tools in science education. It was obvious for us that most of the students are familiar with these tools, but few could use them in responding to the questionnaire.

Contradictions between different forms of explanations

Students had problems connecting visual images with written explanations. In some cases, text and illustrations enhanced and confirmed each other; in other cases, students presented description in the text that did not correspond to their drawing.

A picture is usually easier for children to remember than a text message. Therefore, what is not reflected in a drawing can be more easily forgotten, or even pass unnoticed within the text. For example, some Swedish students drew rays only in the direction of the tree but wrote that the light from a lamp spreads in all directions.

In several cases, the meaning derived from pictures was opposite to the meanings of sentences and concepts used in the text. For example, the following erroneous text was presented alongside correct drawings of the shadow:

> We can explain the appearance of shadow by the property of light which bends the objects. Light rays meet the tree, bend round it and then spread in different directions. (*Зная такое свойство света огибать препятствия, можно объяснить появление тени. Лучи света, доходя до дерева, огибают его, распространяясь в разные стороны.)*

Here we can see a contradiction between the straight propagation of light and its bending!

In our opinion, student teachers need more training in producing and deciphering descriptions and presentation of images, as it is not an easy task to use visualisation as a mediating tool for communicating ideas.

Some examples of misconceptions presented in the explanations of students

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[1] We provide in brackets *in italic* examples of original sentences/expressions in Swedish or Russian.

Below we present some examples of 'wrong' physics ideas from the student teachers' explanations that we organise around specific categories.

- Relativism/egocentrism

The shadow is an image of the tree. The form of the shadow depends on the observer's position. *(Skuggan är bilden av trädet. Beroende på var du står faller skuggan olika.)*

- Electrons and current

Electrons move from the battery's minus pole towards the plus pole. They move against the current and therefore, the electric tension is built up and this tension warms up metal wire (wolfram) in the bulb so it lights up. *(Elektroner vandrar från batteriets minus till dess plus sida, de går i motsats riktning mot strömmen, & då bildas en spänning, & spänningen värmer upp metalltråden (wolfram) in glödlampan & den lyser.)*

- Current as a wave

The electric current is like a wave of small particles. These particles are charged and it is this charge that makes the bulb light up. When the bulb receives the charge wave, the bulb also becomes charged and can therefore emit light. *(Ordet elektricitet kan man förstå som "en våg av små partiklar". Dessa partiklar är laddade och det är denna speciella laddningen som gör att lampan lyser. När lampan tar emot vågen blir den också laddad och kan därför lysa.)*

- Battery and electric current

Battery contains current (*batterier innehåller ström = elektroner som rör sig. Batteri kan alstra elektrisk ström.*)

- Ideas about electrons

Electrons are minus charged atoms *(elektorner är minus laddade atomer)*.
Electrons move at such a high speed that they emit light (*elektroner rör sig så fort att det blir ljus).*
Electrons are small charged "things" that leave their charges in the bulb (*elektroner är små laddade "saker" som "lämnar" av sina laddningar till glödlampan)*

- A bulb filament and gas in the bulb

Low resistance in the bulb filament. (*motståndet är liten i glödtråden*)
Copper wire in the bulb (*Koppar tråd i lampan*)
Because of the gas, the bulb emits more light (*gas i lampan är för att åstadkomma mer glöden – ljus*)
Gas lights (*Gas "antänds"*)
Light comes from the gas in a bulb (*Det blir ljus eftersom det är gas i lampan*).
There is a vacuum in the lamp.

- Light interference

Branches of the tree are not transparent for light quanta thus interference takes place. Light decomposes and, as a result, only a black color of light can go through the branches to form a shadow. (*Ветви дерева становятся препятствием на пути квантов света, в результате происходит интерференция света и свет разлагается, в результате чего сквозь ветви дерева проходит только чёрный цвет света, он и образует тень*)

- Hot charges

Charges get hot and emit heat so the bulb gives off light. (*Заряды нагреваюстя, выделяют тепло и лампочка загорается.)*

- Antimatter?

The filament inside the bulb get warmer because incompatible substances meet there. (*Нить накаливания нагревается, так как вспречаются несовместимые вещества.)*

- Charge interaction

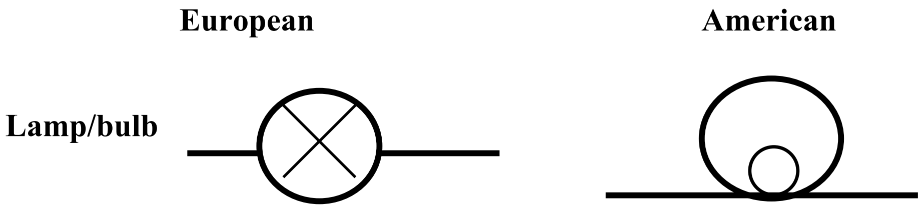
The bulb receives both positive and negatives charges; because of this it gives off light. (*Лампочка получает и положительные и отрицательные заряды, за счёт них она и горит.*)

Common communication problems for Swedish and Russian prospective teachers

The tradition of communicating ideas in pictorial and diagrammatic form is very strong in physics and has proper rules and conventions. Drawings are not always self-explanatory. 'One has to learn to 'read', as well as learn how to 'write' (make), drawings and graphs' (Monk and Dillon, 1995, p. 95). Student teachers in both countries appear unaware of pupils' difficulties with simple illustrations and not appear to possess clear knowledge about visualisation conventions neither do they value them. For example, quite a few students indicated light rays by wavy lines and not by straight lines with arrows. Some students used lines of dashes for this purpose. Perhaps we need in science teacher education clearer presentations of idiosyncratic conventions used in physics concerning, for example, how a light ray should be indicated.

When students drew shadows, many had problems with stereometric/3-dimentional representation of shadow (how and where shadow is placed, how to draw it).

An important idea in the explanation of how a flashlight works is that the current should go through the bulb – but this was often (too often) missing. The role of the bulb in students' drawings (of a circuit) seemed unclear, i.e. how a current goes through the bulb. We suggest that this could be also caused by misleading symbolic presentation of the bulb in European textbooks (indicated by circuit with a cross inside). In our opinion, the American way of symbolically presenting a bulb in a circuit is more helpful pedagogically than European. In the American pictogram of a bulb, there is clear indication of a current's way through the bulb.



Presenting knowledge at the level appropriate for a grade 7 pupil was not an easy task. A number of students openly admitted that they lacked a vocabulary to express their ideas. ("I know but cannot express my knowledge"). A few were self-critical and wrote that their presentation would not be appropriate for grade 7 pupils. They felt a lack of skills in terms of reworking their knowledge to make it accessible for pupils.

Conclusions

According to Vygotsky (1987), learning is impossible to describe as a general phenomenon but is a phenomenon in a context, related to *what* one is expected to learn. Future teachers have to learn to use different communicative tools for transmitting meaning to their pupils. Evidence as found in this project shows that many students have problems in expressing didactically their knowledge in written form and in pictures. To create a simple illustration was not an easy task for many Swedish and Russian students. Their minds and hands have somehow forgotten how to draw because this skill has been neglected since childhood. It seems that teacher educators likewise underestimate the importance of students' practice in explaining and communicating knowledge. We suggest that the development of communicative skills should be a central focus of teacher education. As language grows through function, so do communication skills in general.

Future teachers during their training need to change their perspective on science and science education; to shift from the student's view towards the teacher's view. In practice, this means acquiring awareness not only about personal understanding of natural phenomena and possession of scientific skills, but also about the ability to introduce scientific knowledge and skills to children. Prospective teachers have to learn the skills of 'didactical transposition', i.e. of transforming 'scientific knowledge' to 'school knowledge' adapted to teaching at a given level (Ogborn et al, 1996).

The analysis of the findings from this study shows that the Russian prospective teachers had more problems with seeing themselves in the role of teacher than did the Swedish students. Russian participants of the study tended to answer the questions just as if they were students on a science course. Their explanations tended to be more academic and formalised than is appropriate for a Grade 7 pupil. In our opinion, this reflects the strict and formal style of teaching / learning which still dominates in Russian teacher education. For Russian students and teacher trainers, a correct answer is valued more highly than a good pedagogical form of presentation. Apparently, the skills of reworking knowledge and communication at the appropriate for children level are not systematically practiced in Russian teacher education.

In contrast, in Swedish teacher education, students frequently work in small groups, often practising presentations at the children's level. They generally feel quite comfortable in acting out different social roles and responsibilities. This reflects the conviction of Swedish teacher educators that learning about science should reflect a participatory and collaborative knowledge generating process. Thus, science education in Sweden is seen as a participatory activity in which teachers and learners share responsibility for learning.

The dominant form of communication in teacher education also varies between the two countries. In Sweden, there is a richer multi-way communication based on group work. This differs from Russia where the one-way – lecturing form is still dominant. Progressive Russian teacher educators, however, are working actively to change the situation (Laptev, 2002).

The pedagogical traditions and communication cultures which exist in the corresponding teacher training institutions are probably the main factors explaining the different forms and qualities of explanations presented by the prospective science teachers involved in this study.

According to a well-known pedagogical saying "people teach as they were taught"; thus future teachers build on their own experience, which included good and bad examples of 'teacher communication' in responding to the questionnaire. In that sense, their answers reflect the teaching culture that students are exposed to. As we can judge by our experience, both institutions involved in the comparative study are rather typical representatives of Swedish and Russian teacher education cultures. In that case, the results indicate more or less typical national pedagogical features.

The science questionnaire used in this project was viewed as a tool for learning about pedagogical traditions and communication cultures in teacher education in two countries. This served also as a 'didactical mirror' reflecting differences between students' perspective and teachers' perspective on explaining a science topic. Skills of 'didactical transposition' were missing in many students. We hope through this paper to bring this issue to attention of science teacher educators.

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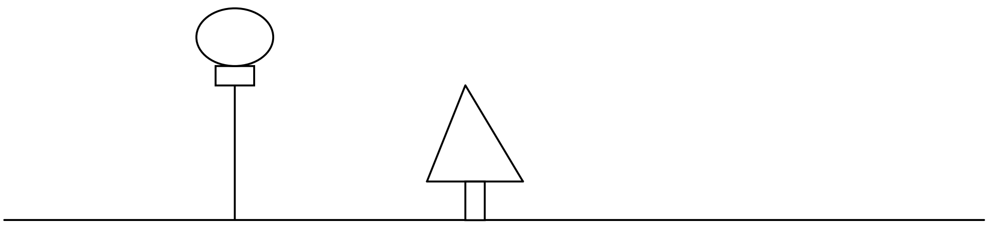
Appendix

Questionnaire

Sex: F ☐ M ☐

Age: ______

1) In grade 7, pupils start to work with light phenomena. A pupil has drawn a sketch of a tree and a street lamp and asked you to explain how and why the tree's shadow appears as it does.



2) Pupils often have difficulty in understanding the physics behind simple technical things, for example, how a flashlight works. Using words, pictures, models and/or analogies, explain for a grade 7 pupil, why a bulb lights in a flashlight.

Резюме

НАВЫКИ ПИСЬМЕННЫХ РАЗЪЯСНЕНИЙ У БУДУЩИХ УЧИТЕЛЕЙ-ЕСТЕСТВЕННИКОВ: СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ

Олег Попов, Сергей Богданов

В статье представлены результаты сравнительного исследования коммуникативных навыков будущих учителей – естественников в Швеции и России. В проекте участвовали около 200 студентов университа Умео (Швеция) и Карельского государственного педагогического университета (Россия). Предложенный им тест был ориентирован на выявление их умений в использовании широкого спектра педагогических технологий: от использования письменных объяснений и графических иллюстраций до применения в учебной практике доступных аналогий и стимулирования собственной активности учащихся.

У большинства студентов не возникло трудностей с пониманием содержательной части материала теста, однако значительные проблемы возникли при выполнении основного задания: попытаться объяснить и интерпретировать этот материал гипотетическому ученику 7 класса. В этой связи как минимум приходится констатировать очевидный разрыв между знаниями как таковыми и главным профессинальным качеством будущего учителя – умением передавать, транслировать их в разном контексте.

Сравнительный анализ результатов тестирования выявил существенное влияние педагогических традиций и культурных особенностей двух стран на характер и структуру ответов студентов. Работа в малых группах, практика дискуссий по заданной теме, характерные для шведской школы, в ходе тестирования проявились, например, в том, что в ответах чаще использовались аналогии, примеры из повседневной жизни. Ответы российских студентов были гораздо более академичны. Создавалось впечатление, что многие студенты не готовы или не хотят изменять привычный статус учащегося на учительский.

Подобные тесты могут играть роль «дидактического зеркала», отражающего педагогические навыки студентов и могут служить хорошим инструментом совершенствования профессионализма будущего учителя..

Ключевые слова: естественнонаучное образование, сравнительные исследования, коммуникативные навыки, социокультурный контекст**.**

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Oleg Popov

Deputy Head of the Department,
Department of Mathematics, Technology and Science Education (MaTNv inst.), Faculty of Teacher Education
Umee University
901 87 Umee, Sweden

Phone: +46-90-786 6463 (work).

E-mail: oleg.popov@educ.umu.se
Home page: www.educ.umu.se/~popov

Sergey Bogdanov

Dean, Faculty of Physics and Mathematics,
Karelian State Pedagogical University
Pushkinskaya 17, Petrozavodsk
185680 Karelian State Pedagogical University, Russia

Phone: +7 (8142) 765295 (work)
E-mail: sbogdanov@onego.ru