The Quality of Physics Teaching – Cases of Teaching over Time and in Space by Three Teachers

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Abstract: The strategic goal of the research, including this empirical study, is to contribute to the search for connections between the teaching quality and other factors, and to deepen the understanding of the context of the teaching quality. The research questions are posed as follows: Have the parameters of the quality of physics teaching changed after eight years? In what way do the teachers perceive these parameters, their (un)successful implementation in their teaching, and their possible changes over time? To answer these questions, a mixed method research design was used. A case study was chosen as the basic research plan. An ex-post facto research was chosen as the design of the quantitative part of the research, and the data was collected using the method of pedagogical observation. Regarding the qualitative part, the data were collected using semi-structured interviews. The research sample consisted of three physics teachers, teaching in Czech grammar schools, who are considered experts with an extended level of reflective competence. The research focused on a longitudinal comparison of the parameters of the quality of physics teaching (in the school years 2004/2005 and 2012/2013), and so this contribution describes cases of teaching, more precisely cases of the teaching quality of the particular teachers. The research revealed that the parameters of the quality of physics teaching of these selected teachers changed very little over the period of eight years. Also, the curricular reform taking place in the Czech Republic in this period has probably not influenced teaching quality changes. It seems that teachers are aware of the influence of various stakeholders of the teaching process, including those who are not directly present in lessons (e.g. school management, parents). This research shows that it is reasonable to look at the teaching quality from a wider perspective.

Keywords: quality of teaching, quality of physics teaching, pedagogical observation, case study, longitudinal study, context of education, curricular reform

The quality of teaching, teachers, and schools (generally quality in education) have for some time been one of the main topics of pedagogical discussions. The evidence for this are, especially, conceptual works from abroad (e.g. Reynolds, 1995; Terhart, 2000), as well as works from the Czech environment, to which context this study is connected (e.g. Janík & Chvál, 2012; Janík et al., 2013). *The strategic goal* of the research, including this presented study, is to contribute to the search for connections between the teaching quality and other factors, and to deepen the understanding of the teaching quality context. As the title of this study indicates, we limit our concerns only to the teaching quality of a concrete subject – physics. In the sense of the strategic goal, we will deal with the teaching quality in a broader context. To a certain extent, it is a connection of a subject methodology (here physics) with a broader context (general methodological, pedagogical, social etc.).[1]

[1] This corresponds with the word "space" in the title, which is understood as an abbreviation taken from the field of physics and mathematics.

Regarding the context, we consider also the time dimension as important. This means that the text presented below has a longitudinal character. We think that the time aspect is, to the detriment of many research studies, rather overlooked; a considerable number of research studies in the field of pedagogy (and not only in this field) are orientated to a description of a certain state which is connected to a relatively narrow time interval.[2] The motivation for the consideration of the time was the fact that there was a possibility comparing the present quality of teaching of physics, and the state from the school year 2004/05, i.e. before the implementation of the curricular reform in the Czech Republic.

The curricular reform can be an important factor influencing the quality of teaching, so we discuss this matter shortly.[3] Reforms implemented in different countries have, of course, different characteristics. They may be based on different starting points, aims, and impacts on the process of education and its results, etc. Research findings and considerations of different aspects of curricular reforms may be found, for example, in works by Künzli (1998), Fullan (2001), Flores (2005), Rollf (2009), and many others. It would not be possible, in this paper, to deal with all particular findings if we focused only on, for instance, the aims of the particular reforms. This area is very wide, and as claimed by Altrichter (2009, p. 247), the resulting shape of the reform is influenced more by its implementation than its original plans and the intentions connected to it. This brings us to the idea that the key role is played by the particular actors participating in the reform, then also on the teachers, and in which way they approach it. It is, therefore, difficult to generalise particular findings about the influence of reforms on the teaching process. On the other hand, we consider the finding by Künzli (1998, p. 8) as potentially beneficial, that any curriculum change may be an opportunity for considerations about the concept and sense of school and its structure, etc. An indication, how teachers participating in the research approached the curricular reform is also presented in this study.

Research findings connected closely to the context of this research (Czech curricular reform at upper secondary /academically oriented/ school level) are presented by Janík et al. (2011). However, we do not know about any research focusing on the teaching processes in the class before and after the reform, and their comparison. This may be a partial benefit of this research. If we talk about the academic achievement of pupils and its comparison before and after the reform, we may use, to a certain extent, the international comparative research studies, such as PISA and TIMSS (in the context of the Czech Republic, see Potužníková, Lokajíčková, & Janík, 2014). However, also here it is true that the teaching process and its changes take place in a wider context than only in the context of the curricular reform, so the

[2] On the other hand, it is possible to observe the time development of some phenomena in international comparative research studies of school education, such as PISA, TIMSS, etc. The newest overview of those taking place in the Czech Republic is provided by Potužníková, Lokajíčková and Janík (2014).

[3] We are also fully aware of other factors and actors participating in the teaching process and its changes (see primarily Section 3).

impact of the reform cannot be determined exactly. The aim of this study is to focus on this wider context.

To uncover, to a broader extent, the context of the teaching quality, we decided to interview physics teachers whose teaching was analysed in this study. We consider the selected teachers to be reflective practitioners who observe and evaluate their own teaching practice in order to understand it well and improve it. This comes out from the previous research conducted among teachers (Žák, 2014, p. 77). The reflective practice model (or its elements) has been considered relevant for a long time in works by many authors (e.g. Goodman, 1984; Korthagen et al., 2001; Pollard, 1998; Schön, 1983). The findings that the selected teachers have a relatively developed level of the reflective competence were identified in previous research (Žák, 2014, p. 77).

We could look at the selected teachers and their role in obtaining relevant pieces of information about the teaching quality, in the sense of Korthagen et al. (2001), in a simplified way as follows: During their practice, teachers become more and more aware that the original implicit professional intuition (gestalt) becomes a structured scheme which can culminate to a development to a certain theory shared by other teachers. We can assume that the selected teachers managed to transform the original gestalt (the unconscious professional intuition) into a scheme (a certain better organised overview), and to proceed to a theory which can be shared with other professionals. Taking into account this fact, we can consider the obtained information from the teachers as relevant data for solving the below stated research problems.

In connection with the strategic goal, the concrete aim of this text is to present research findings describing parameters of the teaching quality of physics, and their changes in time (regarding selected teachers), and evaluation of these parameters and their changes by the teachers themselves. As *research problems* connected with the stated goals, we formulated the following research questions:

- Did the parameters of the teaching quality of physics of the selected teachers change over the period of eight years?
- In what way do the teachers perceive these parameters, their (un)successful implementation in their teaching, and their possible changes over time?[4]

Considering the fact that this study has a methodological overlap, relatively significant space is devoted to research methodology (Section 1). Results (section 2) are organised around the research problems – a longitudinal comparison is presented in Sections 2.1 and 2.2, and readers are introduced to teachers' reflections, which is integrated into the previous research findings (Section 2.3). In the conclusion (Section 3), we summarise our findings, and compare them with findings of other research pieces.

[4] Considering the overall approach, which was mixed method design of a qualitative type (see the next section of the paper), we do not formulate hypotheses in connection with the research problems.

1 Methodology

From the methodological point of view, the mixed method design, combining both the qualitative and quantitative approach, was used to solve the research problems. The basic research plan was a case study. This is typical of qualitative research, and so we can say that this qualitative approach was dominantly used (see Creswell & Plano Clark, 2006). In accordance with the requirements placed on a case study (see Yin, 2003, p. 13–14), there was a quest:

- to see the case (the teaching led by a particular teacher, more precisely the teaching quality) as an integrated system[5];
- to investigate the quality of teaching of a given teacher in as natural an environment as possible;
- to use more sources and methods for the collection of relevant data.

The rate of respecting the stated principles will be obvious from the following. The quest to investigate in as natural an environment as possible went to the fact that for the design of the quantitative part (solving primarily the first research problem), basically, ex-post-facto research where data are collected using the method of pedagogical observation, was chosen. Regarding the qualitative part (solving primarily the second research problem), data were collected using a semi-structured interview.

From the time sequence view, the process was managed in the sense of Creswell and Plano Clark (2006) rather sequentially; quantitative data collection (observation) was followed by interviews (qualitative data collection). While in the case of the first research question the process was basically only quantitative, the approach to the second question depended on the first one (the questions posed in the interview were formulated according to the quantitative findings of the first question). The linkage of the data was done when making a description of particular cases (Section 2.3). In accordance with Tashakkori and Teddlie (1998), it resulted in a combination of quantitative and qualitative approaches at various levels.

Considering the research plan, we would like to explain (or at least to contribute to the explanation) the basics of the case, or cases, which are the quality of teaching (conducted by given teachers). The case study design was chosen in order to focus on several cases of many – more precisely, three grammar school teachers of physics whose teaching (its quality) we decided to investigate more closely. It is obvious that conclusions of the research can only be generalised to a certain extent. However, they can bring important impulses for further research and for further education of (future) teachers (of physics) and their teaching practice.

[5] It is a question of what to consider, in this research, as particular *cases*. To make it simple, we can relate particular cases in this study mainly to teachers, and so we talk briefly about *cases of teachers*. However, as a particular *case* we should denote, rather than a teacher, directly what we investigate, so *the teaching led by a particular teacher*, or more precisely *the quality of teaching led by a particular teacher*. Particular cases are created not only by teachers, pupils, and other actors, but also by their interactions, mainly during the teaching process.

The research sample were available physics teachers (and their teaching), who can be considered, according to the previous research, to be experts with a relatively developed level of reflective competence (Žák, 2014, p. 77). The selected teachers can be considered experienced, with relatively long teaching practice.[6] These teachers teach physics in several grammar schools in Prague (upper secondary level). The basic information about them is as follows:

- Teacher 1 – teacher of Mathematics and Physics (Faculty of Education), teaches Mathematics, Physics, and relevant seminars, 15 years of practice.
- Teacher 2 – teacher of Mathematics and Physics (Faculty of Mathematics and Physics), teaches Mathematics and Physics, 25 years of practice.
- Teacher 3 – teacher of Mathematics and Physics (Faculty of Mathematics and Physics), teaches Mathematics and Physics, 17 years of practice.

The essential parts of the research were conducted as follows:

- Trained observers (hereinafter: researchers) observed, in the school year 2004/05, seven to eight lessons by each of the teachers.
- In the school year 2012/13, each researcher again observed seven to eight lessons by the same teachers (in the same schools, in comparable classes, regarding the study year).[7]
- Comparison of the teaching process (from the quality parameters set beforehand point of view) in the school years 2004/05 and 2012/13 – see Sections 1.2, 2.1 and 2.2.
- Semi-structured interviews with teachers – see Section 1.3.
- Linkage of the quantitative and qualitative findings – see Section 2.3.

1.2 Observation of the quality of physics teaching (quantitative part)

The research instrument, used to observe the physics teaching (and its quality), was the tool developed by Žák (2008, 2014) using a rating system which has become an inspiration for proposals of other observation tools, e.g. the tool by Zlatníček (2011,

[6] This study does not deal with other teachers, for instance, with shorter teaching experience, with less developed reflective competence, or teachers from other types of schools than grammar schools. This is the limitation of the research.

[7] The researcher and the teachers agreed on the day when the teaching lesson would be observed. The dates were suggested by the researcher, and the teachers, in the majority of cases, agreed with the proposals. The teachers were not informed what exactly would be observed in order to observe a normal class and not a specifically prepared lesson. The number of seven to eight lessons of each of the teachers proved to be, in the previous research investigation of ten teachers (Žák, 2008), as sufficient; this number of lessons enables us to observe characteristic teaching features.

p. 124–129), falling into the area of the quality of foreign language teaching. The basic information about the tool can be found in Žák (2014, p. 69–71).[8]

Notes to the evaluation methodology of a longitudinal comparison of frequency of quality parameters occurrence (see more in Section 2.1). In this research part, we investigated the relative frequency of occurrence (realization) of teaching quality parameters[9] in the school year 2012/13, which was compared with the results from the year 2004/05. The relative frequencies were divided into three intervals:

- low occurrence – in 0% to 33% (included) of lessons – marked with 1 (Table 1);
- medium occurrence – 34% to 66% (included) – marked with 2;
- high occurrence – 67% to 100% – marked with 3.

In case that the relative frequencies fall into the same interval in both research phases (in the school year 2004/05 and 2012/13), there is one appropriate number only in the column for the school year 2004/05 in Table 1. If the relative frequencies in each of the research phases fall into different intervals, there are two different numbers (for each of the years separately). However, it is not possible to consider, automatically, a transfer from one interval to the other to be a significant change of the frequency of occurrence, as, for example, the change from the upper limit of the low occurrence interval to the lower limit of the medium occurrence interval (e.g. change from 32% to 35%) does not represent a real change. Significant changes marked with (*) are changes where the frequencies differ by at least 33%, which corresponds with the length of one interval. As there were, for each teacher, seven to eight observed lessons, 33% means about two to three lessons. The presented parameters (see the first column in Table 1) are only those parameters where it is sensible to investigate changes in the frequencies (we omitted, above all, the parameters with a low reliability, more detailed in Žák (2014, p. 71) and parameters whose scale does not contain the possibility N – "parameter was not observed").

Notes to the evaluation methodology of a longitudinal comparison of arithmetic means in parameters scales (see Section 2.2). The comparison was conducted in the way that the scale grades – –, –, +, ++ were denoted with the values –3, –1, +1 and +3, which express, besides other things, that the scale is equidistant. For each of the parameters, the arithmetic mean was calculated and rounded to the nearest stated values. Table 2 presents symbols – –, –, +, ++ for parameters whose frequencies of occurrence in both observed years are higher than 33% (other are

[8] Teaching quality is defined in different ways. In our case, the set up of particular parameters was based on the opinions of 15 different experts – methodologists of physics, grammar school teachers of physics, university experts in the field of pedagogy, and physicists-scientists. These parameters concern the teaching processes.

[9] The current Czech version of the record sheet of the research instrument with detailed characteristics is available from http://kdf.mff.cuni.cz/~zak/vyuka.php in section "výzkum a vývoj v didaktice a pedagogice" – "nástroj k posouzení kvality výuky fyziky". This version contains detailed delimitations of particular parameters of the teaching quality in Czech language (in which the tool was standardised).

marked with "not defined"). These are parameters which are marked, in Table 1, with values 2 or 3, or parameters where the frequency is automatically 100% (their scales do not contain the possibility N). If it is not possible to round an arithmetic mean unambiguously to one of the values −3, −1, +1 a +3, e.g. 2, Table 2 presents the corresponding pair of symbols, e.g. +, ++. The significant changes, marked with (*), are those changes where the arithmetic mean changed by 1.0 or bigger (it represents half of the distance of the neighbouring scale grades) and at the same time, the scale grade changed.

1.3 Interview with teachers (qualitative part)

Regarding the qualitative part of the research, we interviewed the selected teachers, and the interviews were semi-structured. The basic content scheme was given by the goal, which was to identify how the teachers see the teaching quality parameters of their teaching and their changes (the second research problem). Beforehand, we prepared a set of fundamental questions for each of the teachers, which should identify why the particular parameter is typical of their teaching, or how they explain a particular change. For example, *It was revealed that you often conduct physical experiments in your teaching. Why do you do that?… Why do you consider it important?* Or: *It seems that you care the most of all teachers about the active learning of your students – you try to make the students involved into the teaching process, you try to raise discussions … Do you consider it important? Why? … Does this approach have any negative aspects?* We asked the teachers different questions reflecting the given teaching quality parameters. At the same time, during the interviews, new questions were posed, and so the interviews got closer to non-structured interviews.

Written notes made by inquirers (researchers) were transcribed in the way that the content and structure of the transcriptions revealed connections between the teachers' answers and observed activities. In these transcriptions, the quantitative and qualitative findings are matched together if there is a connection – see section 2.3.

2 Results

2.1 Longitudinal comparison of parameters occurrence frequency[10]

The relative frequency of parameters occurrence for all three teachers are summarised in Table 1. The parameters are formulated in the way that higher frequency of occurrence can be understood as a more positive aspect than their lower occurrence. We can say that the teaching conducted by Teacher 1, regarding the frequencies of

[10] This part comes from the published text by Žák (2013).

the parameters, did not change after eight years. The teaching conducted by Teacher 2 changed only in one parameter out of 17 (in a negative way), and the teaching conducted by Teacher 3 changed positively in three out of 17 observed parameters. In total, the teaching changed only minutely, regarding the parameters occurrence (in 4 cases out of 51, i.e. in less than 10% of the cases).

Table 1 Relative frequencies of parameters occurrence divided into intervals[11]

Teachers	Teacher 1		Teacher 2		Teacher 3	
School year	04/05	12/13	04/05	12/13	04/05	12/13
1.1 physics expertise	3		3		3	
1.4 teaching aids	2		3		2	1
2.1 lecturing	3		3		2	3*
2.2 heuristic method	1		1		1	
2.3 experiments	2	1	3		2	1
2.5 mathematics	3		2	3	3	2
2.6 abstraction	2	3	3	2	2	3
2.9 knowledge structure	3		3		2	3*
2.10 work with text	1		2	1*	1	
3.1 students' interest	3		3		3	
3.3 linkage with practice	3		3		3	
3.4 inter-subject links	1		1	2	1	
3.5 art, culture	1		1		1	3*
3.6 students' activity	3		3		3	
3.7 demands placed on students	3		3		3	
3.8 use of assessment	3		3		3	
4.1 students' expressing	3		3		3	

2.2 Longitudinal comparison of arithmetic means for parameter scales

The arithmetic means for parameter scales (more precisely: grades − −, −, +, ++, which are the closest to the arithmetic mean) are summarised, for all three teachers, in Table 2. The parameters are formulated in the way that higher arithmetic mean (higher scale grade) can be understood in the way as more positive. For this reason, three changes are evaluated as positive, while five changes as negative. We can say that the teaching conducted by Teacher 1 changed, regarding the arithmetic mean, after eight years, rather negatively. The teaching conducted by Teacher 2 almost did not change, and in the case of Teacher 3, changed positively. Moreover,

[11] The numbering of the parameters in the left column is the same as in the original research instrument. For this reason, some of the numbers are missing.

the teaching changed, in total, only slightly regarding the arithmetic mean. Only the minority of the parameters changed, considering each of the teachers. If we compare the arithmetic means, there were changes only in 8 out of all 48 possible cases (when the arithmetic mean is defined), i.e. in less than 20% of cases.

Table 2 Arithmetic means at parameters scales

Teachers	Teacher 1		Teacher 2		Teacher 3	
School year	04/05	12/13	04/05	12/13	04/05	12/13
1.1 physics expertise	++		+		+	
1.2 teacher character	++	+*	++	+	++	
1.4 teaching aids	+	–, +*	+		not defined	
2.1 lecturing	++		+		+, ++	+
2.2 heuristic method	not defined		not defined		not defined	
2.3 experiments	not defined		+		not defined	
2.5 mathematics	++		++	+	++	
2.6 abstraction	+		+		+	
2.9 knowledge structure	+		+		+	
2.10 work with text	not defined		not defined		not defined	
3.1 students' interest	+	–*	+		+	
3.3 linkage with practice	+		+	++	+	
3.4 inter-subject links	not defined		not defined		not defined	
3.5 art, culture	not defined		not defined		not defined	
3.6 students' activity	+	–, +*	+		+	
3.7 demands placed on students	–, +	+	+		+	
3.8 use of assessment	+		+		+	
4.1 students' expressing	+		+		+	++*
4.2 relation cultivation	++	+, ++	+	++	+, ++	++*
4.3 atmosphere	+		+	++	+	++
4.4 active learning	+	–*	+		+	++*

2.3 Cases of teaching quality of particular teachers – linkage of quantitative and qualitative findings

In the following text, we link together findings from Sections 2.1 and 2.2 (rather of a quantitative nature) with information obtained during the interviews with teachers (rather of a qualitative nature).[12] The interviews with the teachers were orientated on both the parameters which are typical of a given teacher (in contrast to the other two), and to significant changes of quality parameters of their teaching after eight years. The following text is structured, above all, in this sense.

[12] Authentic word expressions of the teachers are in inverted commas.

The case of Teacher 1 – an expert in physics, lecturing, using ICT[13]. This teacher showed almost unchanged *physics expertise*[14] over time (1.1, sole ++, Table 2). Besides the university studies, his expertise was influenced by two grammar school teachers who taught him mathematics and physics. These two teachers, thanks also to their precision and enthusiasm, inspired him to become a teacher of mathematics and physics.

His *lecturing* was evaluated similarly as comprehensible and factually correct (2.1, sole ++), which is closely connected to the physics expertise. This teacher understands lecturing almost as a necessity, because he thinks that students are not able of self-study in comparison with the past – they do not, for example, do their homework. It is not only the fact that they do not do assigned homework. Sometimes teachers from that school are asked by the school management not to assign homework too often to their students. This recommendation is taken after the principal, after a discussion with the students, was told that the students felt overloaded, and that in the afternoon they have other interests and duties. The principal even expressed her opinion that the students should take less tests, in order not to complain. The school management also make their teachers aware of the fact the school cannot afford to lose students, due to weak school results. The school would be given less financial resources, which could end with a fewer teachers in the school. These opinions have been asserted by the principle for the last two years. The teacher expressed his hope that the principal would understand soon this is not the right way, as she started to teach an ordinary class (and not a selected group of interested students). This experience could bring her to the conclusion that her suggestions are not a suitable solution.

Regarding the *character of the teacher* (1.2), there was a slight worsening (1.2, from ++ to +), but the evaluation is still positive. The character of the teacher (considering the given scale) shows, beside other aspects, a willingness to discuss with students. The teacher stated that he is not used to "presenting the subject matter and leaving the class", but at the same time, he mentioned so called pseudo-interested students. These are students who, in the teacher's words, would like to discuss the subject matter more deeply, but the deeper understanding is above their mental possibilities. The teacher, in this case, tries to answer their questions in a simple way, and adds that they will deal with the particular topic later on in detail. Regarding students who are really interested in physics, he recommends them to participate in physics competitions.

This is the only teacher who showed worse *utilisation of students' interest* (3.1, from + to −). The problem is seen by the teacher above all in the students. He per-

[13] This is only an abbreviation which describes, only in a schematic way, and therefore roughly, the below stated characteristics. It is similar with the other teachers.

[14] Physics expertise of teachers exhibits mainly in the physical correctness of their way of expressing themselves. Regarding this, for instance, Campanario (2006) and Sliško (2006) point out wrong or misleading formulations in current textbooks, which is evidence that this is one of the permanent topics in didactics of physics.

ceives limits mainly in weak students (it is given by less populated years), and in students' insufficient home continual preparation.

The *students' activity* (3.6, slight worsening from + to −, +) is influenced, according to the teacher, for example, by which lesson the teaching takes place in. In the afternoon lessons, which was the case of the observed class in the school year 2012/13, the desirable students' activity is lower, and the students misbehave more often. However, it is not true that in the first lessons the students are always more active. The teacher observes in classes focused on Computer Programming, for example, a certain slowdown caused, probably, by a night spent in front of a computer. The atmosphere in the classroom also depends on the class itself, as some of the classes are less disciplined.

The above mentioned factor of time, and the mentioned pressure from school management make the teachers serve the subject matter "in a ready way" to the students, rather than to require a more active approach from them. This could be the cause of the worsening of *active learning* (4.4, from + to −).

Students' lower activity can be reflected in a limited *utilisation of teaching aids* (1.4, slight worsening from + to −, +). The teacher tries to bring physical aids and conduct experiments with them whenever he deals with a given topic, it means that he does not use them only in certain lessons. There are exceptions when it would be, for example, difficult to bring aids from remote school areas. In these cases, the teacher carries on experiments only in classrooms closer to the teacher's office, where all the aids are kept.

To the question as to what could improve the quality of teaching, the teacher answered that mainly the decline of his full-time engagement to 17 to 18 lessons a week (he teaches 23 lessons per week, it is more than the standard full-time engagement, as he has two children, which is financially demanding). Another limit is, in his opinion, the limited finance for buying physical aids (the costs are partially covered by financial donations from the parents of students). As potentially positive, the teacher perceives the fact that PowerPoint presentations, videos, and various animations have become an ordinary part of his lessons. In laboratory work, they use the measurement system ISES[15] (about 20% of all work). The teacher is aware of the limits of the technical equipment, which itself cannot secure a better standard of teaching. The teacher thinks that there is dispersion between the knowledge and skills of the students in different classes. He also notices that it is a significant change, considering the past, and it is connected with less populated years, and fewer students are interested in studying at the grammar school. There are students with average elementary school achievements who would not study at grammar school some years ago. Many of the students are also weak at mathematics.

Students do not possess some skills that they used to have in the past, for example, they are not able to make a continuous written text. For this reason, the

[15] Available from http://www.ises.info/index.php/en/systemises.

teacher uses materials created in various projects, e.g. a worksheet for optics, in which students fill in the required pieces of information (e.g. measured values). The teacher admits that this also makes his work easier, as it is not so time consuming to evaluate such worksheets. This approach is adequate in humanist classes; in science classes, it is suitable to ask students to make more demanding and a longer form of notes from laboratory work. Over the years, the continual home preparation of the students has worsened, and the school management has more or less accepted this lower level (see below).

The case of Teacher 2 – an experimenter, making linkage with practice, perceiving problems with mathematics and literacy. Teacher 2 excels in using *teaching aids* (1.4, sole 3 in Table 1 and + in Table 2), which is connected with the fact that she quite often conducts high quality *experiments* (2.3, sole 3 and +). The frequency and quality (arithmetic mean at the scales) of both parameters are, basically, unchanged over time. The teacher is fully aware of this fact, and she would like to carry out experiments even more often. On the other side, she knows that it is necessary to take care of the mathematical side of physics, even though experiments are closer to her heart. She manages to find financial resources for buying the physical aids, mainly from the parents of her students. When talking about experiments and students' motivation, she sees a problem in the fact that grammar school physics starts with mechanics which, due to its difficult mathematical apparatus, rather discourages the students, and the possibility of conducting experiments is limited. The teacher likes demonstrative things, for example electricity. She expresses this in a concise way as follows: "I like showing students that something works in practice." This is evidence that she tries to make a *linkage with practice and life* (3.3, sole ++).

Even though the teacher focuses mainly on experiments and linkage with practice, she knows that it is also important to support the *abstract imagination* of students (2.6, sole 2, other teachers 3). So she, for example, makes calculations with her students in the lessons, so the students can imagine how many particles are in ordinary solids, etc.

Regarding the *mathematical model* (2.5, sole +, other teachers ++), we can put the lower quality into connection with the teacher's favour for experimental physics. This might also be influenced by the fact that the students possess lower mathematical skills. For example, they cannot express an unknown quantity from an equation, or divide by a two digit number without the use of a calculator, which students used to know in the past. The teacher sees the connection between the problems with mathematics and the insufficient level of literacy of the students. The students face problems when reading results on their calculators (e.g. they forget to consider the exponent). The teacher also notices that her students cannot formulate such erudite questions due to a lower level of literacy than in the past.

Regarding the *work with texts*, it was less common than eight years ago (2.10, decline from 2 to 1), so the teacher got to the same level as the other two teachers.

However, she tries, in her own words, to make the students work with textbooks (e.g. she assigns homework from textbooks).

When talking about changes in the recent years, the teacher appreciates the fact that the school uses an electronic register. She has, besides teaching, more duties, because she is a head of the subject committee, co-operates on preparations of graduation balls and entry examinations. In the past, the school management used to be responsible for these duties, but recently, it is the teachers' responsibility. Another significant change is the decline in the students' literacy (see above). The students struggle with finding relevant information in mathematical-physical tables and generally, they work in a worse way with the book. The teacher perceives intensively that today's generation, which she teaches, is different. She could not say that worse, but "short-cutting". Another change is that the teacher can only assign the students less demanding written work, in comparison with the situation ten years ago.

The teacher thinks that the quality of her teaching could improve if her full-time engagement were lowered. Now, she has to teach 23 lessons per week. She would like to teach 4 lessons every day, for example two consecutive lessons, then she would like to have a break and then continue with other two lessons; it means 20 lessons per week. The teacher would appreciate having a person in the school who would be responsible for technical aspects, for example repairing teaching aids. The teacher likes it, and she considers herself as a skilful person, but sometimes she is not able or does not have enough time to deal with more complicated repairs. She would also like to have fewer than 30 students in the classrooms (she used to have about 40 of them 25 years ago). The teacher complains about the fact that she sometimes teaches far away from her office, so she has to carry teaching aids a long distance.

The case of Teacher 3 – linking physics with culture, communicative, supporting active learning. This teacher excels in the *relation of physics to culture and art* (3.5, sole 3 and sole improvement). The teacher perceives making connections between cultural and historical contexts and physics as a necessity. He considers the history of physics as an internal part of physics. It is suitable mainly for students with humanistic interests. However, the teacher is self-critical, he is aware of certain gaps in this area, and he tries to learn more to fill in the gaps.

He is the only teacher who reached the highest grade in parameter *teacher character* (1.2, sole ++). He added that he loses rarely patience in situations where the students break the rules of politeness.

It is also typical of the teacher that he rarely uses *teaching aids* (1.4, sole 1). The teacher said spontaneously that he admits that he would like to use teaching aids more often (and conduct experiments more often). The problem is that the students want him to talk more with them during the teaching process, and so he doesn't have so much time for experiments. However, the students use physical aids when experimenting during laboratory work.

The teaching of the teacher reached the highest arithmetic mean for parameters in the area of communication and upbringing. Regarding *students' expressing* (4.1, sole improvement from + to ++), the teacher prefers the students to make formulations of their thought in their own words first, and then he makes the explanation himself. The teacher is aware of the big disadvantage of this approach, as it is time consuming. He thinks that it is important to use professional language (when introducing new terminology) and, at the same time, to use "colloquial language" which is closer to the students. This communication can take place in cycles, where the professional and colloquial languages alternate. *Lecturing* (2.1, significant change of frequency from 2 to 3) cannot be omitted in the teaching process, especially at the upper-secondary level.

Talking about *working atmosphere* (4.3, ++) and *active learning* (4.4, sole improvement from + to ++), the teacher estimates that about one third of the students in the observed class work; the others rather wait, and they do not participate themselves. Regarding these two parameters and the parameter of *cultivation of students relation* (4.2, ++), the teacher adds that he and they have a "correct open relation". The observed class (Year 7) had in Year 5 and 6 two different (young) physics teachers, whose teaching was not assessed as good, either by the students or their parents. He thinks that physics was out of the interest among the students, they perceived it as useless. The teacher set certain rules at the beginning of Year 7, he clearly stated what he expected, and it seems that the students understood it. The teacher regards this class as slightly above average, considering behaviour.

Talking about the *mathematical model* (2.5, sole 2, other teachers 3), the teacher understands the use of mathematical means as an internal part of physics, he also considers it important that the students are able to solve a physical problem generally, and are able to think critically about a given general mathematical relation. Considering his experience, he thinks that a quarter of the students reject solving problems generally, but the majority of them know how to do it. It is important for him to conduct the dimensional analysis in his lessons which can help the students to understand better quantity equations ("formulae"), to make estimations and to make general solutions of physical problems, including critical thinking about quantity equations.

When the teacher was asked if it is important to build *knowledge structure* with the students (2.9, significant increase of frequency from 2 to 3), he answered positively. For example, he makes parallels between gravity and electrostatic field.

Talking about changes in the recent eight years, and what could influence the teaching quality, the teacher answered that at first sight, nothing. Then he added that he acquired a better view over the field, he thinks more carefully about what to teach. He does not implement everything that is given from FEP[16] and is contained in textbooks. In his opinion, textbooks are good manuals, but students are not able to

[16] Abbreviation for Framework Education Programme for Secondary General Education (Grammar Schools), available from http://en.vuppraha.cz (in Czech: Rámcový vzdělávací program, abbreviation RVP).

learn everything they contain. Requirements given by FEP and by universities (placed on their students) are, in his opinion, unreal (inappropriately high).

In connection with this, he formulates the opinion that today's students are in a more difficult situation than their counterparts in the past, as they are overloaded with information. They have a lower possibility of concentrating. However, it is not possible to base the teaching process only on the search for information by students. The teacher stresses that students have to be addressed with language they understand. He also admits that he is limited by the fact that he does not know the world of his students well.

The teacher can see, generally, differences between students of four-year and eight-year study programme in his grammar school. The students of the eight-year study programme may have better prerequisites, but they do not deal with their possibilities in a very responsible way. Sometimes, they seem to act like children. They have a longer time to explore the school system, and so they can outwit it more easily. Students of the four-year study programme can better use what they know, and they wipe out the initial deficit.

The teacher thinks that the quality of his teaching could improve if the administrative load placed on teachers were lowered. He meant, for example, mass mailing or inserting marks into the information system. Paradoxically, the load has increased with digitalisation. He would see as beneficial if the number of students decreased to 25, ideally to 20. He perceives the direct teaching counting 21 to 22 lessons per week as adequate, if the administrative load were lowered.

The teacher adds spontaneously that he would be happy with the salary of CZK 40,000 (approx. EUR 1,400), ideally CZK 60,000.[17] Let's add that this teacher teaches, besides in this school (14 lessons), also in an elementary school (12 lessons). If he taught only in one school, it would give him more time to work.

3 Conclusion and discussion

The results presented in Sections 2.1 and 2.2 were, thanks to the interviews with the teachers, enriched, in Section 2.3, with opinions and interpretations of the teachers. Let's first summarise the findings regarding the first research question. We can answer the question if *the parameters of the teaching quality of physics of the selected teachers changed over the period of eight years* that *they changed relatively minutely*. When quantifying this conclusion, the occurrence frequency of the observed parameters changed only in 4 out of 51 possible cases, i.e. in less than 10% of cases. However, there were differences between the teachers (none, one negative, and three positive changes regarding particular teachers). If we compare the arithmetic means for the parameter scales, we find out that there were chang-

[17] The average salary of teachers in the Czech Republic is approximately CZK 25,000, i.e. EUR 900.

es in 8 out of 48 possible cases, i.e. in less than 20% of cases. Again, the teachers differed – there were five negative changes, no change, and three positive changes.

It is clear that when making conclusions, it is important to be really alert, because it is a question as to whether 10% or 20% is really little. If we consider that teachers work for about 40 years, and that the observed period of eight years is a fifth of this period, the trivial extrapolation takes us to the values of 50 or 100%. This approach is rather problematic, for example, it is not possible to assume that the changes would take place evenly (the same number of parameters would change every eight years). As there was the curricular reform taking place in the investigated period (implementation of FEP and SEP[18]), and therefore the teaching before and after the reform was compared, the expectation could be that the changes would be more dramatic, which would be reflected in the observed parameters of the teaching quality of physics. However, such changes were not identified.

On the contrary, the research showed that the physics teaching of particular teachers have almost unchanged characteristics over time, but the teachers differ from each other. For example, as has been mentioned in Section 2.3, Teacher 1 showed high physics expertise and first quality lecturing, Teacher 2 uses aids and links physics with practice, Teacher 3 conducts experiments less often and stresses active learning. This finding about the teaching stability, mainly if we consider teachers' activities, i.e. teaching, corresponds very well with findings made by Seidel and Prenzel (2006, p. 238), that individual teaching routines are resistant to change. This stability cannot be generally assessed as solely negative or solely positive. Some of these routines, probably, contribute to the teaching quality, while others do not. For example, in classrooms with a high quality of class work, which, according to Seidel, Rimmele and Prenzel (2003), have indicators such as questioning the students, function of student statements, teacher feedback, the students find themselves to be more self-determined, motivated, and they keep their interest in physics over the course of the school year (Seidel et al., 2003).

The second research question *in what way do the teachers perceive these parameters, their (un)successful implementation in their teaching, and their possible changes in time* was answered in Section 2.3. Let's discuss and summarise some of the findings. Between 2004 and 2013, which represent the end points of the observed time period, a curricular reform took place in the Czech Republic. It seems that *the curricular reform, basically, did not influence the changes of the teaching quality* of the observed teachers. Significant changes in teaching quality were not observed, and even the teachers did not make the reform a topic in the interviews (only one teacher spontaneously mentioned it). After interviewing how the teachers perceive the reform, it was revealed that *they perceive it neutrally, or rather negatively* (see also Vašutová & Urbánek, 2010, p. 87). It can be supported by the below mentioned opinions of the teachers.

[18] Abbreviation for School Education Programme (in Czech: Školní vzdělávací program, abbreviation ŠVP).

For example, Teacher 1 understood the implementation of the FEP and the creation of the SEP as a "shock", "stupidity" and "tables remake" (compared with Janík et al., 2011, p. 406). The teacher sees one disadvantage in the reform implementation in the fact that a particular topic is presented to students in different schools in different periods. Then, it can happen that if students change schools, they miss some of the topics. The teacher defends the previous curricula under the condition that 20% of the content would be optional. According to Teacher 2, the teaching has not, essentially, changed since the reform implementation, the changes were rather formal. She stated that, for instance, physics teachers agreed with geography teachers on teaching astronomy in physics lessons in Year 1, as the topic is common to both subjects. They also discussed what to teach in Year 4 (transfer between lower secondary and upper secondary education level). As an impulse arisen from FEP, a project in which students should design and realise a route from their school to a museum by public transport was implemented in Year 2. However, there were no serious discussions, and the teacher thinks that it could be explained by the fact that the school is big, and mutual discussions are more difficult. She also mentioned another aspect, that there are older teachers. Teacher 3 mentioned that their school was a pilot school during the curricular reform, and the reform was connected with certain hopes. The creation of the SEP was accompanied by intensive work, as well as with feelings of despair. The teacher criticises the content side of the FEP, which contains some of the new physical topics, but, at the same time, almost all of the traditional topics. He thinks that some traditional topics should be omitted, as students would forget them anyway. As physics is compulsory at the upper secondary educational level in this grammar school for only three years, it was necessary to reduce the subject matter ("there was a fight what to omit"). The teacher sees as a benefit of the curricular reform that "it brought us together and made us discuss it". Discussions concerning the changes of physics teaching were sped up, but the teacher thinks that it was not the primary aim of the reform. The above mentioned opinions correspond with other findings, expressing a certain aloofness or rejection of the curricular reform by teachers (especially in the Czech environment Janík et al. 2010, p. 22–27). The resistance of the teachers to external changes, e.g. the requirement to implement the curricular reform, does not have to be perceived negatively. Moreover, it can express an effort to reach a dynamic balance (compare with Fullan, 2000). On the other hand, the finding that the implementation of the curricular reform has not significantly changed the quality of teaching may be seen, basically, as unflattering for the reform.

The teachers also notice various actors who influence the teaching quality. Naturally, these actors are *students*. One of the teachers' observations is that students in the given school have worse knowledge and skills than some years ago (concretely, they mention worse mathematical skills[19], literacy, inability to make a continuous

[19] This observation of the teachers corresponds with the PISA research, where the results of Czech students were statistically significantly worse in 2012 than in 2003 (Palečková & Tomášek, et al., 2013).

written text). The teachers also mention more generalised judgements about today's grammar school students (e.g. "short-cutting generation")[20]. It is interesting to talk about the moment of *overloaded students*. While Teacher 1 perceives it as a students' excuse (supported by the school management), Teacher 3 mentions it as a fact. Teacher 3 and his colleagues are trying to find ways to reduce the subject matter. They see the overload to be caused by the subject matter extent, which the students should master, and also by the time consumption (the students have many optional subjects in this particular school). They spend more time in the school, and they are not able to relax. The concrete reaction of the teachers is that the number of physics lessons will be reduced throughout the whole study, and the teachers know that they will have to teach in a different way. This could be considered as an emancipated reaction of teachers, because Czech teachers mostly require as many lessons per week as possible in the given subject (compare with Lepil & Svoboda, 2007, p. 32). Considering the awareness of the situation in this school, there is a hope that an interesting teaching project will arise there, and it would be sensible to investigate it in the future.

When talking about the students, a certain diversity was implicitly mentioned (Teacher 1). This teacher observes that in his classes, recently, there have been students with different knowledge and skills. It is obvious that this diversity is negatively perceived by the teacher. The question arises as to whether it is possible to create certain conditions to take advantage of this diversity, which would be beneficial (for all, or at least for the majority) of students, and teachers would consider it as positive.[21]

One teacher also mentioned the role of other actors who do not participate in his lessons. Teacher 1 opened the topic of *school management* that exerts pressure on teachers to assign less homework and fewer written tests (see Section 2.3). The same teacher brought up a concrete example of *parents'* influence in his school. The parents of some talented students try to transfer their children to different grammar schools, where they have to face higher demands. So it is in a way paradoxical that the original effort to keep as many students as possible by lowering the demands ends up with a loss of some of the students.

The teachers also mentioned in their answers and considerations the topic of *information and communication technologies* (ICT). This is one of the topics in physics education which has been discussed for a long time. Let's remember that some Czech authors think that today's physics education is so significantly influenced by information and communication technologies that they suggest calling the current approach to didactics of physics as *informational-communicative* (Nezvalová, 2011, p. 176; Lepil, 2012, p. 8). Still, there is the question, what is hidden under the

[20] For example, Carr (2011) claims that the addiction to clicking, which is typical of information presentations on the Internet, leads to a decrease of longitudinal concentration of people. Posnick-Goodwin (2010) talk, in this sense, about generation Z.

[21] Regarding this, Sukhnandan and Lee (1998) point out that grouping students according to the same academic achievement does not influence their performance, but it ruins their motivation and self-confidence.

utilisation of ICT in the teaching (of physics). In our research, we declared that the teachers use computers for presentations in their lessons (Microsoft PowerPoint, videos, animations), when their students use computers during laboratory work, or, for example, when using the class registers. One teacher did not mention ICT as a relevant topic in relation to teaching quality. Another teacher pointed out that the technical equipment in schools cannot guarantee better teaching quality. The teachers' opinions could be, simply speaking, summarised that *ICT in teaching should not be overrated*.[22] In connection with this, we should mention the conclusions of German researchers, that new media themselves do not support learning, but that it is necessary to take into account the teaching objectives anytime when we want to use them (Bayrhuber et al., 2004; compared with Dvořák et al., 2012, p. 328–329).

The teachers came with suggestions as to how to remedy the lacks of a technical, administrative, and organisational nature – e.g. the need of a person who would repair broken teaching aids, the requirement for diminishing the administrative load, the reduction of lessons in full-time engagement, the reduction of the number of students in classes, pay-rises. These suggestions support our assumption that the teachers, when making self-reflection of their teaching, are aware of the fact that the quality depends on other factors. These factors are perceived by different teachers in a different way.

It is clear that the teachers see the limits of the teaching quality mainly outside themselves. Only exceptionally do they admit that they are aware of their internal determinants (Teacher 3 said he does not know well the world of today's young people). On the other hand, external and internal factors (these are not precisely defined in this work) cannot be unambiguously separated, because, for example, a pay-rise could motivate teachers, the decrease of the administrative load may bring more time, which could be used for lesson planning, etc.

The research methodology and the fact that only three teachers were investigated in this study prevent us from making general conclusions. The ambition of the study is different; it should point out a wider context, which may influence the teaching quality of a particular subject, conducted by a concrete teacher, in a concrete school. This context, for sure, includes school management (the principals) whose decisions may significantly influence everyday teaching. Behind their decisions, there are often various economic factors, so we get from the level of teaching a particular subject and a given school to the level of the state administration. The context in which the teaching takes place is also co-made by students' parents. It is their decision whether their children will study in the given school. Their decision is not definitive (some parents arrange a transfer to another school during the studies).

During the interviews, it was revealed in what way the teachers see the quality parameters of their teaching and potential changes. We should remember that

[22] This opinion corresponds with many research studies comparing teaching without the use of ICT and computer based instruction (or eLearning). For instance, Bernard et al. (2004) and Mayer & Clark (2008) claim that there are almost no differences in the results of such teaching.

these are only reflections of the teachers and their interpretations, which cannot be considered as objective judgements. However, it seems that their reflections are relatively complex. This conclusion could be made because of the finding that the teachers' interpretations fall into the majority of areas which could be considered as relevant in the research of science education (Lee, Wu, & Tsai, 2009; Tsai & Wen, 2005) – teaching; learning (conception, context); objectives, education policy, curriculum and assessment; culture, society; history of science; information technologies in education (compare with Dvořák, Kekule, & Žák, 2012, p. 327–328). The teachers mention these, generally defined, areas in a different way, and it is satisfactory that they do not connect teaching quality solely with, for instance, students' learning, but they take into account a broader context. This is additionally evidence of what has been mentioned in the introduction, that the selected teachers possess a relatively developed reflective competence.

The question is in how to reflect these and other findings, if they prove to be relevant, in the initial teacher training or, possibly, in the further education of teachers, and how to deal with them in teaching practice in schools. Another question is if the topic of the influence of school management and parents, generalised ideas of teachers about today's generation of students, etc. captures enough attention in (future) teacher education. We emphasize that we reached these general topics organically when investigating the teaching quality of a concrete field (physics), and therefore it seems that topics of subject didactics are inseparably connected with, for instance, school management, communication with parents, etc. Therefore, all this could be taken as an argument to see topics of subject didactics from a broader perspective, and in a broader context than we are often willing to admit.

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