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An Insight into Teachers' Classroom Practices: The Case of Secondary Education Science Teachers

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Abstract: Teachers' knowledge rooted in classroom practices guides their actions when dealing with a specific subject matter. To assess the quality of these practices, a close examination of the "classroom reality" is needed. The present study, which was carried out in Greece, investigates secondary science teachers' practices. To record these practices, we used special classroom observation tools as well as questionnaires to record students' views of their teachers' practices. The observation tools and the student questionnaire focus on specifically formed criteria deriving from aspects of Pedagogical Content Knowledge (PCK). In total, 32 secondary science teachers and 1154 students participated in our study. The results indicated that the strong points of teachers' teaching practices concern their subject matter knowledge, the use of representations, their questioning, their communication of the instructional objectives to the students, and knowledge of students' difficulties. The weak points are related to the use of a variety of teaching approaches, the investigation of the students' alternative conceptions, the experimental and ICT-based teaching, and the implementation of inquiry-based activities. The methodology employed in our study was fruitful in providing a holistic view of science teachers' practices and can be used for investigating classroom practices of teachers of other subjects as well.

Keywords: teachers' practices; teachers' professional development; science education; science teachers; secondary education; students' perceptions; classroom observation; pedagogical content knowledge; Greek educational system

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1. Introduction

There is a strong correlation between the quality of education, quality practices in teaching and learning, and teachers' qualifications and knowledge. Researchers and educators have stressed the importance of teachers' knowledge and its relation to teaching practices (e.g., [1]). They suggest that teachers' knowledge informs their practices and directs their actions in the classroom (e.g., [2]). They also suggest that, most likely, relationships between teachers' knowledge structures, classroom practice and student achievement exist [3]. Thus, "issues related to what sort of knowledge teachers might need in order to become effective practitioners, what teachers know and how their knowledge informs the classroom practices are central questions to those concerned with teacher education and continuing professional development" [4] (p. 438), with the improvement of instruction as well as with students' achievements.

Many scholars suggest that the teachers' knowledge rooted in classroom practice which guides their actions when dealing with a specific subject matter in the classroom is the Pedagogical Content Knowledge (PCK) (e.g., [3,5]). Science teachers make instructional decisions that greatly impact the learning of their students. Some of these decisions pertain to how the curriculum can be modified and how science content can be presented to the students. Such decisions are largely influenced by their PCK. This knowledge "allows teachers to reason pedagogically and to make decisions pertaining to practice that ensures students will develop an understanding of science" [6] (p. 52). Shulman [7] relates teachers' practices directly to their PCK, which, according to Van Driel and Berry [8], can be influenced by the teachers' specific professional contexts. Sparks [9] suggests that a promising trajectory towards the improvement of instruction is a closer examination of individual teachers' classroom practices and needs. Questions such as what happens in the real science classroom, how teachers implement the curriculum and what kind of activities they adopt during the science lesson, how they organise these activities and what are their practices in the classroom can be raised. What is needed, thus, is to explore and describe science work in the classroom. Close examination of the "classroom reality" can provide answers to questions such as the above by enabling researchers to construct a picture of classroom work and contribute to the elucidation of teaching problems. The findings on "classroom reality" provide useful insights for improving science teachers' education and/or in-service training [10] (p. 50). The findings can also be useful to those interested in the design and implementation of professional development programs.

Examining the quality of teachers' practices is a central issue in the education systems of many countries as it is judged to be a meaningful and important process for both the teachers' professional development and educational improvement. However, in Greece, where the present study was carried out, there is a lack of data concerning secondary science teachers' classroom practices. This has also been stressed by international organisations [11] as a critical issue concerning teachers' professional development.

To record teachers' practices, special tools are required. Thus, in the present study, we developed a methodology and the related instruments using criteria deriving from aspects of PCK for collecting/recording data from the everyday science classroom. The analysis of the recorded data provided information on different PCK-related aspects of teachers' practices [7] that shape instruction in the classroom. Against this background, this paper presents the instruments used for recording the teachers' practices and investigates the following question: What is the quality of the PCK related teaching practices that secondary education teachers adopt when introducing different science subjects to their students?

The rest of the paper is organised as follows: Firstly, the "Background" of the study is provided. Secondly, the methodological tools and the context of the study are presented within the section "The study", followed by the presentation of the "Results". Thirdly, in the section "Discussion and conclusions", the results and the methodology followed are discussed in order to draw conclusions. Finally, the paper ends by reflecting on the limitations and implications of the study.

2. Background

2.1. Teachers' Pedagogical Content Knowledge (PCK)

Shulman [1] provided the substantial and essential framework for a knowledge base of teaching. This knowledge was classified into categories in terms of its domains and its relation to classroom practices. Shulman and Sykes [12] summarised this classification as subject matter content knowledge, general pedagogical knowledge, and pedagogical content knowledge. Pedagogical content knowledge (PCK) is the knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" [1] (p. 9). It is the knowledge that Shulman [7] (p. 8) characterises as the "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding," and according to him, consists of two key elements: the knowledge of instructional strategies incorporating representations of the subject matter (illustrations, analogies, explanations and demonstrations to make subject matter comprehensible to their students) and the understanding of specific learning difficulties and pupils' conceptions with respect to that subject matter (see [13–15]). Grossman [16] also includes PCK in the four general areas in which she distinguishes teacher knowledge that can be seen as the cornerstones of the emerging work on professional knowledge for teaching, with the others being: general pedagogical knowledge, knowledge of context, and subject matter knowledge. Other researchers (e.g., [17], p. 386) describe PCK as the knowledge that integrates seven domains of knowledge: pedagogical knowledge; representational knowledge; subject matter knowledge; curriculum knowledge; assessment knowledge; student knowledge; and context and social knowledge.

Lately, Shulman [18] suggested that non-cognitive attributes such as emotion, affect, feelings, and motivation should be incorporated into the original model of PCK. He states specifically that "the idea of PCK needs to place much-needed emphasis on teacher thought and emotion, but not by ignoring the role of action in teaching practice" [18] (p. 10). With regard to emotions, García-Martínez et al. [19] (p. 3) note that "the teaching profession is one of the professions with the greatest emotional burnout, since members are exposed to high levels of stress as a result of trying to cope with the growing demands they have to face in their professional lives".

2.2. Recording Classroom Practices

The most common data source of teachers' practices in real classroom settings is observation [20]. To foster the reliability and validity of the observation, researchers and observers use rubrics to record the different aspects of teaching. Rubrics are used to guide the focus of observations on specific aspects of teachers' classroom performance and drive a common scoring strategy. Additionally, rubrics can reduce the possibility of arbitrariness and misunderstanding in observation recordings [21]. To obtain valid results with this recording system, numerous observations are needed, although some researchers have found that many critical variables that affect the teachers' quality of teaching do not show variation from lesson to lesson [22].

However, scholars have noted that "classroom observation, no matter how well-focused, can only capture certain aspects of what a teacher has planned and indeed is undertaking in the classroom" [23]. A holistic outlook of the teachers' practices can be given by their students who spend most of their school life behind a desk or participating in activities designed by their teachers. Researchers (e.g., [24,25]) consider that the students' perceptions of their teachers' practices can provide insights into the teachers' weaknesses and strengths in everyday practice. A common practice in recording students' perceptions is to administer questionnaires specifically developed for this purpose. Although the student questionnaire on teacher practices seems to be overlooked by researchers and policymakers [20], over the last two decades, there has been a growing interest in their development and use, mainly for data collection on teachers' performance in order to evaluate the results of their PCK development programs (e.g., [17,20,26–28]). These researchers provide strong evidence on the validity and the reliability of students' perceptions of their teachers' practices.

For collecting reliable data, both sources need to be used. This need arises from the fact that some aspects of teaching are not observable, e.g., whether student assessment tools such as tests help them realise that they have or have not understood or learned what they have been taught. On the other hand, we cannot ask students whether an inquiry-oriented approach is used by their teachers, as they have no knowledge of teaching methodology. The latter can only be learned from lesson observations. In addition, students can give information about the frequency with which practice is applied in the classroom, while observation can provide data on the quality of the practices applied. Hence, both observations and questionnaires, can provide useful data on teacher performance, on the quality of teaching practices, on the frequency of use of a particular method or practice in the classroom, and on how effective these practices are in the students' view.

3. The Study

As noted earlier, the present study was carried out in Greece. The Greek Secondary Education is divided into two educational levels, High School and Lyceum. In High School, students' ages range from 12 to 14, and in Lyceum, from 15 to 18. Science disciplines such as Physics, Chemistry, and Biology, at both educational levels, are taught separately from each other and are usually not interconnected. Science teachers, depending on their specialty, hold a degree in Physics, Chemistry, or Biology but usually do not have training or a degree in science teaching. Secondary teachers are required to teach all the science subjects of the curriculum, including Geography.

3.1. Methodology

3.1.1. Participants

The study was conducted in a Municipality of North Central Greece, which includes rural, semi-rural, and agricultural districts. The sample of our study includes science teachers serving in public secondary schools (both high schools and lyceums) of the Municipality teaching the three major disciplines of Science Physics, Chemistry, and Biology. The teachers of our study, 32 in total, were those who agreed to participate after they were informed of the aim of the study. Seventeen (17) had a major in Physics, twelve (12) in Chemistry, and three (3) in Biology. Twenty (20) of them were serving in Lyceums and twelve (12) in High Schools. One thousand one hundred fifty-four (1154) students participated in the study (579 males and 571 females) from both High Schools (484) and Lyceums (667).

3.1.2. Development of the Instruments for Collection of Data

Taking into consideration the purpose of our study, to collect data related to science teachers' everyday classroom practices, the following instruments were used: a student questionnaire, an observation tool, and a scoring rubric. All the instruments focused on specifically formed criteria deriving from aspects of PCK.

In the present study, we have used the PCK conceptual framework and aspect categorisation by Jang et al. [5], which was based on Shulman's [7] PCK categories adapted appropriately to our context. The Jang et al. [5] analysis was considered appropriate for the purpose of our study, as it was created to explore knowledge with some kind of recording (for example, recording the students' perceptions). The same holds for the recording of classroom actualities since, as was presented earlier, Shulman provided the essential framework for a knowledge base of teaching classified into categories in terms of its domains and its relation to classroom practices.

A detailed presentation of the knowledge domains and the corresponding aspects is given in Table 1.

Table 1. The PCK analysis adapted from Jang et al. [5].

Domains	Aspects
Subject Matter Knowledge (SMK)	Knowledge of the subject (including the quality of language used during instruction) Impact of the theories and ideas on everyday life and society
Instructional Representations and Strategies (IRS)	Use of content representation (analogies, examples, metaphors and everyday objects) Use of teaching strategies (including experiments, ICT, discussion) Students' attentiveness-related reaction during instruction
Instructional Objectives and Context (IOC)	Knowledge of the instructional objectives Knowledge of the specific context Classroom management (including mutual respect between teachers and students, and among students)
Knowledge of Students' Understanding (KSU)	Ability to determine students' understanding before, during and after a lesson (including alternative conceptions) Effective use of assessment tools

Based on the above framework, we formed specific criteria for the purpose of our study, i.e., both for recording students' perceptions of their science teachers' classroom practices using a questionnaire and for systematically observing and recording teachers' practices using an observation tool and a scoring rubric. Table 2 presents the domains and the criteria in each Domain and the aspects included in each criterion and specifies which of these aspects were recorded by the questionnaire (marked with Q accompanied by the number of the question) and which by the observation rubric (marked with R).

Table 2. Domains, criteria in each Domain, and aspects included in each criterion.

Domain 1: Subject Matter Knowledge	
Criteria	**Aspects included in each criterion**
Subject Knowledge	Knowledge of the content (Q1)
	Adequete presentation of the topic (Q2)
	Adequately answering students' questions (Q3)
Language and Communication	Quality of the language used during the lesson (R)
	Didactic tranformation (Q4)
Connection with everyday life	Connection with everyday life (Q5 and R)

Domain 2: Instructional Representation and Strategies	
Criteria	**Aspects included in each criterion**
Instuctional Strategies	Instructional Strategies (Variety and appropriateness) (R)
	Strategies maintaining students' interest (Q8 and R)
Opportunities for students to express ideas and opinions, etc.	Students' attentiveness related reactions during instruction (Q9 and R)
Instructional representations	Use of examples, analogies, graphs, everyday objects (Q6,7,12, 14)
	Appropriateness of instructional respresentations (R)
	Usefulness of instructional respresentations (R)
Use of ICT	Use of ICT (Q11)
Use of experiments	Demonstration of Experiments (Q10)
	Students' experiments (Q13)
Type of Inquiry	Type of Inquiry (R)
Scientific skills promoted by the teacher	Scientific skills promoted by the teacher (R)
Questioning	Conceptual Level of teaching questions (R)
	Students' participation in questioning (R)

Domain 3: Instructional Objectives and Context	
Criteria	**Aspects included in each criterion**
Instructional objectives and goals	Instructional objectives and goals (communication and understanding) (R)
	Understanding of the lesson goal (Q15)
Interactive atmosphere	Teaching Adjustment based on students' reaction (Q16 and R)
	Discussion on students' questions (Q17)
Students participation	Students' participation (R)
Motivation for learning	Motivation for learning (Q18)
Additional teaching material	Additional teaching material (Q19)
Classroom management and mutual respect	Classroom management (Q20 and R)
	Mutual Respect (R)

Domain 4: Knowledge of Students Understanding	
Criteria	**Aspects included in each criterion**
Investigation and handling of alternative conceptions	Teachers' Questions before introducing a new topic (Q21)
	Alternative conceptions investigation (R)
	Strategies to handle students' alternative conceptions (R)
Knowledge of students' difficulties	Knowledge of students' difficulties (Q22 and R)
Assessment during the lesson	Use of different ways to access understanding (Q24)
	Formative Assessment during lesson (R)
	Variety of assessment methods and adjustment related to students' diversity (R)
Summative assessment (test, etc.)	Summative Assesment (tests, etc) (Q23,25)

Our questionnaire is an adaptation of the questionnaire originally developed by Jang et al. [5] to record students' perceptions of their teachers' PCK and, in the present study, was used to collect data of the students' perceptions of their science teachers' classroom practices. It includes 25 questions and uses a 5-point Likert-type scale with options: never, rarely, sometimes, often, always. The complete questionnaire is presented in Appendix A.

The structuring of the scoring rubric and the observation tool is based on studies focusing on methodological issues and the use of rubrics. Some of these studies provide information on past experiences of teacher evaluation using rubrics, e.g., [21,29–31], support the effectiveness of descriptive rubrics, e.g., [32,33], and provide methods for assessing their reliability and validity [34].

The observation tool, a representative part of which is presented in Figure 1, is a practical guide that helps the observer to focus on specific aspects of teaching, to record data by ticking the appropriate boxes and taking notes. The notes help the observer keep track of all the events and teaching practices, as well as the teacher's decisions taken during instruction and assists in decision making when scoring the teacher's performance in the rubric. The observation tool is designed to include various options for every aspect of teaching. The aspects included in each criterion of the observation tool for which data were collected (criteria presented in Table 2) are designed to be distinct and observable. For example, the observer could see if a representation used has the potential to help the students understand a phenomenon or an idea, but he/she cannot see if the students have understood the phenomenon that the teacher describes using this representation. The design of the tool was done in collaboration with expert teachers and educational advisors/evaluators. We reached the final form of the tool after it was tested in several in-class applications. Each application provided us with useful information, which helped us reform the aspects included in the criteria of the rubric and their descriptions in order to make them clearer and more comprehensible to the observer. Specific instructions accompany the observation tool on how the observer should implement it.

In the scoring rubric, the observer finds the observed aspects of teaching in each criterion and five short descriptions of the teacher's performance. Based on the observation tool and his/her recorded notes, the observer decides which description best fits the teacher's actions. Each description corresponds to a score that the observer inserts under each aspect. The descriptions were formulated by the researchers after a long collaboration with experienced teachers and qualified teacher evaluators. A part of the scoring rubric concerning the use of instructional representations is presented in Figure 2. Upon completion of the observations, the evaluator grades the teaching in the rubric.

The scores from the rubric and the results of the questionnaire for each specific teacher are inserted into the teacher's Personal Sheet (see Appendix B), which was formed to include all the quantitative results and provides researchers with a full picture of his/her practices. A scale was created to describe the level of achievement resulting from both the data coming from the questionnaire and from the rubric. The scale has four levels: Exceptional, Adequate, Weak, and Inadequate.

Observational tool

Class: Subject:

Number of students: Time of observation:

Instructional Representations and Strategies

Note 1 for the main teaching practice and 2, 3, etc. for the other practices observed during the lesson.

Strategies

	Lecture		Students' Presentations		Experiments conducting by students
	Demonstration of an experiment		Discussions or work in small groups		Use of a model to introduce a notion or an idea
	Discussion leading by the teacher		Inquiry		

Type of students' involvement during instruction

	Listen/watch the teacher		Participate in discussion (leading by the teacher or in small groups)		Conduct experiments proposed by the teacher or a students
	Participate in an inquiry activity		Read and answer questions as part of an activity		Work on an experiment worksheet
	Write a test		Use an educational simulation		Use technology to conduct an experiment
	Insert or analyse data on a PC		Present or watch students' presentations		Develop or use a model to understand an idea

Use of Instructional Representations

☐ Examples ☐ Analogies ☐ Graphs and Diagrams

☐ Everyday objects ☐ Other: ....

Observer Recordings

Appropriateness (manner and time):

....

Usefulness for the students:

....

Figure 1. Representative part of the observation tool.

Criteria	**Aspects of teaching recorded**	**5**	**4**	**3**	**2**	**1**
Instructional Representations	**Appropriateness of the instructional representations (IR)**	IR were appropriate for the activity. The time and the manner of the use was right and consistent with the lesson goals	IR were appropriate for the activity, the time. The manner of the use was sufficient and consistent with the lesson goals	IR were appropriate for the activity but not and consistent with the lesson goals	IR were generally appropriate for the activity, but other IR may be more appropriate and more consistent with the lesson goals	IR was inappropriate for the activity and not consistent with the lesson goals
	Score:					
	Usefulness of instructional representations	IR seemed to help all the students to understand	IR seemed to help the majority of students to understand	IR seemed to help half of the students to understand	IR seemed to help the minority of the students to understand	IR seemed to not help the students to understand
	Score:					

Figure 2. Part of the scoring rubric concerning the use of instructional representations.

3.1.3. Validation of the Instruments

To assess the reliability of the instruments (questionnaire, observational tool, and rubric), we tested them in a pilot study with a sample of 12 secondary teachers and their students (333 in total) in 11 secondary schools.

In the first phase of this study, the questionnaire was completed by the students in 6 High Schools and 5 Lyceums in Northern Greece.

Questionnaire reliability is usually assessed by calculating the Cronbach's Alpha coefficient, while a rubric's reliability is usually assessed by calculating the Spearman rho for data gathered by two or more observers [34]. In order to indicate that the questionnaire can provide reliable data when the sample is small, Cronbach's Alpha was calculated once for the total sample of students and once for 12 sub-samples, each consisting of students of an individual teacher. The latter is useful from the point of view that if the questionnaire is reliable for small samples, it could also be used in individual cases.

The data collected by the questionnaire were statistically analysed and, for the total sample, Cronbach's alpha was calculated to be 0.921. According to the literature (e.g., [35]), questionnaires investigating opinions or perceptions are considered reliable when Cronbach's alpha is higher than 0.7. Our questionnaire is therefore considered highly reliable. Cronbach's alpha was also calculated for each sub-sample of students and concerned each individual teacher, and calculated values ranged from 0.806 to 0.906, which indicated that the questionnaire is reliable for individual evaluation as well.

In the second phase, observations using the scoring rubric were carried out in six representative public and private High Schools and Lyceums. Twelve science teachers with an average of fifteen years' experience were observed (eight physics teachers and four chemistry teachers). Observations were carried out simultaneously in the same classroom by the researcher and the above-mentioned educational advisor, who was also a trained evaluator serving in secondary education. The observed lessons were randomly chosen.

In order to assess the reliability of the scoring rubric, the data collected by the two independent observers were statistically analysed, and Spearman's rho was calculated for each of the teachers. A significant positive correlation was found between the two observers/evaluators' scoring, ranging from 0.704 to 0.894. Additionally, the mean of the differences of the observers was calculated and was found to be 0.1905 (N: 252, St. Deviation 0.414, N refers to the number of scores for all teachers), indicating very small differences between the two observers. The above findings suggest that the observation tool and the scoring rubric led observers to score the teachers' performance consistently using a common scoring strategy.

3.1.4. Data Collection and Analysis

Data were collected using the validated instruments following the procedures described earlier (see Section 3.1.2 'The development of the instruments for data collection'). The students' questionnaire was anonymous and, for the same teacher, was answered by students in two different classes of the same education level. For every teacher, the observer (evaluator) performed direct, first-hand observations of two one-hour lessons and recorded them. The data coming from the questionnaires were statistically analysed using SPSS to calculate each question's mean for every teacher. The data collection was conducted during the school year 2016–2017.

As noted earlier, the means of the questionnaire and the scores from the rubric were inserted into each teacher's Personal Sheet (a number was assigned to each teacher). The Personal Sheet, therefore, included all the findings concerning the teaching of each teacher, providing researchers with a full picture of his/her practice. More specifically, the researchers compared and synthesised the results from both sources and reached decisions about the teacher's level of performance for every criterion (a sample of Personal Sheet is presented in the Appendix B). Two researchers worked independently for each teacher and compared their decisions in order to reach a consensus on criteria that had contradicting outcomes. The decisions were based on the four-level scale described earlier.

It should be noted that the data on teacher practices were analyzed for the two levels of secondary education as well as for the entire sample separately. Below, we present the results for the whole sample as the differences that occurred in the teaching of the Lyceum teachers were identified only in a few points and are not due to their education or teaching experience but to factors that will be discussed and interpreted in the section 'Discussion and conclusions' of the present paper.

4. Results

In what follows, we present the results of the entire sample of our study by Domain: Subject Matter Knowledge; Instructional Representations and Strategies; Instructional Objectives and Context; Knowledge of Students Understanding (see Table 2).

4.1. *Subject Matter Knowledge*

In the Domain of Subject Matter Knowledge, most of the teachers were graded as exceptional or adequate in all criteria (Figure 3). The results indicated that the teachers in both the upper and lower secondary education have good knowledge of their subject.

Regarding the language they used during the lesson, the percentages of scientifically accurate language stood high at 75%. A percentage of 25% of the teachers made minor mistakes and were graded as adequate. Some of them occasionally used animistic phrases or words. Nevertheless, these phrases and words were rare and did not seem to confuse or mislead the students.

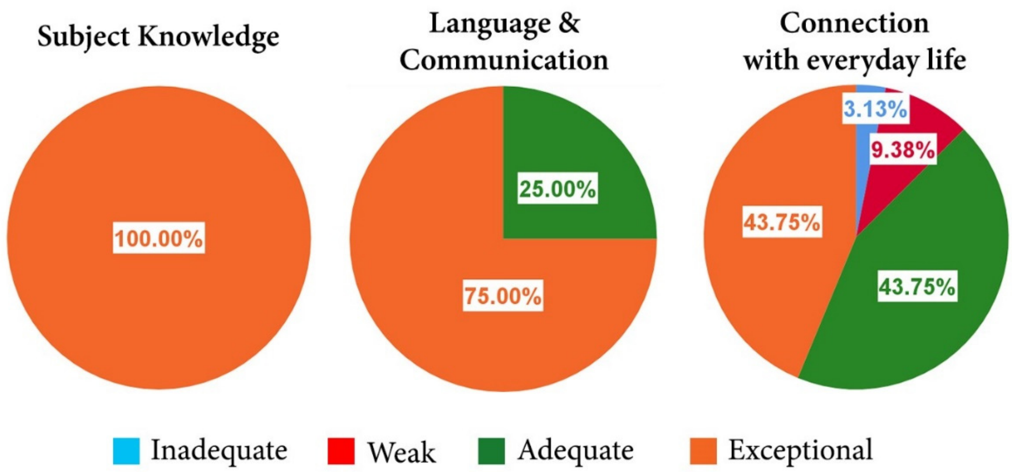

Figure 3. Results of Domain 1: Subject Matter Knowledge.

With regard to connecting content (concepts and phenomena) to everyday life, 43.7% of the teachers (of both levels) were graded adequate, and an equal percentage of them were graded exceptional. Only small percentages of the teachers (about 1 out of 10) were inadequate or weak in doing so. These teachers taught mostly in the upper secondary education.

4.2. Instructional Representations and Strategies

In the second Domain, the results indicate that several teachers of both levels of secondary education faced difficulties related to the use of a variety and appropriateness of instructional strategies/techniques and means. Just over 55% of them were graded exceptional (see Figure 4) in using different teaching strategies and engaging students in their lesson, giving them the opportunity to express their opinions and ideas thus maintaining their interest. Moreover, 22% of teachers were considered adequate and another 22% were graded as weak. Both groups, to a large extent, seem to have clung to the well-known traditional way of teaching. Most of these teachers were teaching in Lyceum.

Of the teachers who used inquiry, 40% of them engaged students in strictly guided inquiry-based problem-solving activities, while 12.5% of them engaged students in a context that prompted open inquiry in the sense that they had the freedom of deciding and planning an experiment or problem-solving activity themselves. However, the majority (about 47%) of them rarely or never used inquiry as an instructional technique. Similarly, 40% of the teachers promoted mainly basic science skills to their students, while 12.5% of the teachers introduced students to more complex science skills. About 47% of them rarely or never promoted any science skills.

With regard to instructional representations, teachers of both levels of secondary education widely used them, and the majority of them were graded as exceptional. Small percentages of them were not successful in using instructional representations that were proper or effective (see Figure 4).

Regarding the use of technologies and the use of experiments, only a very small percentage of teachers included experiments in their lessons. As presented in Figure 4 (Use of ICT), more than half of the teachers rarely use or do not use technologies or experiments at all in their everyday practice. The latter is more frequent in Lyceum.

In terms of questioning, and specifically the conceptual level of the questions posed during instruction, the teachers were either exceptionally successful (almost 28%) or adequate (47%) in moving their questions from a lower to a higher conceptual level.

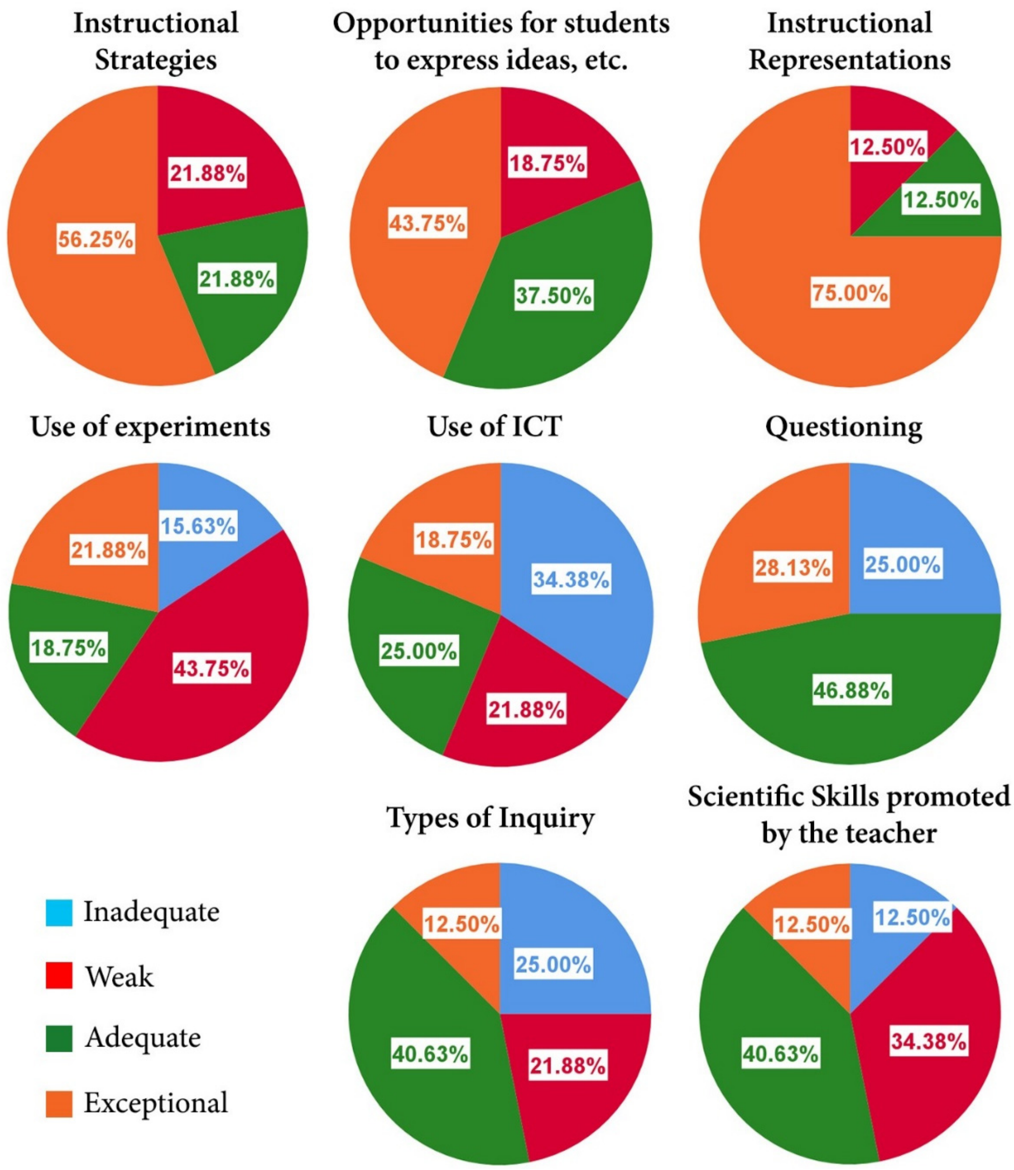

Figure 4. Results of the Domain 2: Instructional Representation and Strategies.

4.3. Instructional Objectives and Context

Most of the teachers (68.75%) were exceptional in successfully communicating to the students the objectives and the goals of their lesson in one or more ways. However, only one-third of them were exceptional in achieving their students' participation in the lesson and in creating an interactive atmosphere in the classroom. Another one third (34.38%) was graded adequate in doing so, while one-third of them (31.25%) were graded weak in creating an interactive atmosphere and faced difficulties in understanding students' reactions and in adjusting their teaching accordingly. This holds for the teachers of both levels of secondary education.

Regarding motivation for learning, students considered themselves motivated for learning by a large percentage of teachers (62.5% adequate and 12.5% exceptional). However, this does not hold for one-fourth of the teachers—mainly those who work in Lyceum—who, according to their students' view, seem to face difficulties in this aspect (see Figure 5).

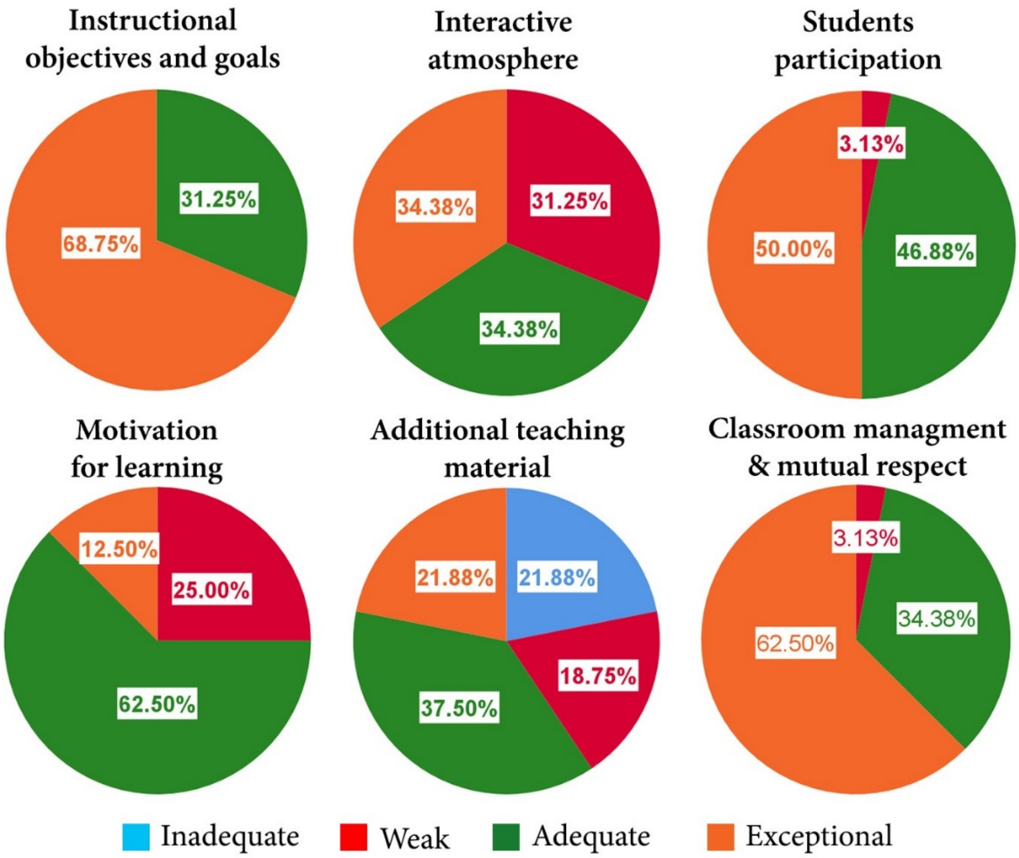

Figure 5. Results from Domain 3: Instructional Objectives and Context.

A satisfactory percentage (57%) of teachers were exceptional or adequate in providing additional instructional materials to the students. However, in this aspect, 19% of teachers were graded weak, and another 22% were graded inadequate.

Regarding classroom management, a high percentage of teachers were adequately or exceptionally successful in managing their classroom effectively, creating an atmosphere of mutual respect (Figure 5).

4.4. Knowledge of Students Understanding

In this last Domain (Figure 6), in the criterion 'knowledge of students' difficulties', a large percentage of teachers were graded as exceptional or adequate (65% and 28%, respectively). These teachers are aware of the difficulties students usually face in specific topics and successfully design their lesson to focus on them.

With regard to students' alternative conceptions, about three out of ten of the teachers began their instruction by first exploring students' conceptions related to the topic related conceptions. These teachers also handled successfully or adequately (22% and 12.50%, respectively) their students' alternative conceptions. However, half of the teachers did not investigate the related to the topic of the lesson students' ideas, while 15% of them, before instruction, posed questions that were not aimed at exploring alternative ideas that students might have had about the specific topic. This aspect of teaching seems to be more challenging for the teachers of Lyceum than of High School.

The use of formative assessment during the lesson allows teachers to record the level of their students' understanding. The results showed that about 6 out of 10 teachers use assessment methods successfully or adequately (28% and 31%, respectively) and adjust their lesson to meet the students' needs. However, 4 out of 10 (40.63%) who were graded as weak, seem to use assessment only for compliance with the rules set by the syllabus or without adjusting their lesson based on the students' responses.

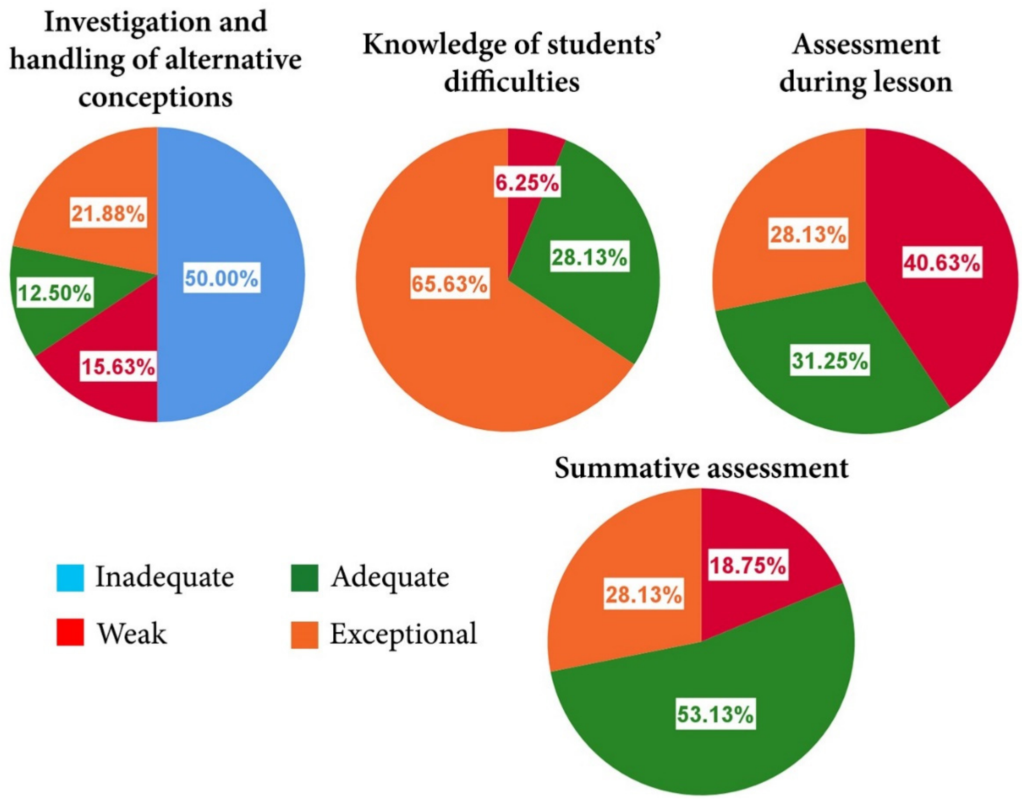

Figure 6. Results of Domain 4: Knowledge of Students' Understanding.

The last criterion in this Domain reflects students' perceptions of the summative assessment methods with regard to their accuracy and effectiveness. Specifically, this criterion includes students' perceptions of how often the summative assessment informs their teachers accurately of what they *know*. It also includes their views about how successful these assessments are in determining what exactly they have *not* understood on a particular topic. The results indicate that only 3 out of 10 teachers seem to use summative assessment successfully.

5. Discussion and Conclusions

The aim of the present study was to gain an insight into the quality of secondary education science teachers' practices and identify the strengths and weaknesses of these practices. As shown by the results, the main strong points of the teachers' teaching practices concern their subject matter knowledge, the use of representations, their questioning, their communication of the instructional objectives to the students, and the knowledge of students' difficulties. The main weak points of the teachers' practices relate to the use of a variety of teaching approaches, the investigation of the students' alternative conceptions, the experimental and ICT-based teaching, and the implementation of inquiry-based activities.

Regarding weaknesses of the teachers' teaching, some of them were encountered more frequently in Lyceum than in high school. There are differences in some aspects of the teaching of the teachers of Lyceum and of High School. These differences are related to the variations that exist between the contexts of the two educational levels. For instance, the teachers in the upper secondary education implement a more demanding curriculum in terms of both content and quantity, which they are obliged to complete in a limited time. Limited time does not allow them to deviate from the guidelines set by the curriculum and to include practices that are not contained therein.

However, although the findings mentioned above seem to be more frequent in Lyceum due to the limitations of time, the absence of experiments, technology, and inquiry-based activities seem to form an interconnected pool of weaknesses of the teachers from both levels of secondary education, which are related to their limited skills to effectively incorporate them in their lesson plans. These findings reflect the weaknesses of the education system. Most of the teachers were not educated on how to develop inquiry-based activities or to design experiments in order to promote related skills to their students [36]. The teachers of secondary education may have university degrees in their science subjects, but as was mentioned earlier, they have not been educated in the didactics of science nor in pedagogy. Similarly, university graduates do not seem to have a satisfactory level of qualifications in digital competencies and sufficient technical experience to teach ICT in secondary education and help students develop adequate technological skills critical for work, communication and even leisure [37].

It is surprising, however, that despite the weaknesses in the teachers' education, the positive results related to their knowledge of students' difficulties are encouraging. Good knowledge of students' understanding seems to be related to aspects of PCK that are highlighted as critical by most scholars [38–40]. The above-mentioned results could be attributed to the fact that this is a type of knowledge developed through experience as the teachers of our study had at least 10 years of teaching experience in public schools. Van Driel et al. [39] call it teachers' practical knowledge, and Clermont, Borko, and Krajick [41] point out that these practices are developed through teachers' experience and form a kind of "craft knowledge" of teachers.

A strong point emerging from the analysis of teachers' teaching practices is their good knowledge of their subject. This holds for the teachers in both upper and lower secondary education. This specific finding seems to be consistent with the educational background of the teachers, i.e., that they hold university degrees in their subject.

Another strong point in the teachers' teaching is the use of scientifically accurate language. This is an encouraging result as language is considered to be a decisive factor for the development of the students' scientific concepts. Inaccurate or misused scientific language and misleading and confusing expressions could lead to misconceptions and become a serious impediment to learning science. Scientifically inaccurate language of teaching can cause students' common misconceptions to remain, with little chance of being eradicated, since, in this situation, they are continually reinforced by the teachers themselves [42].

The results also indicate that a large percentage of teachers was successful in connecting content (concepts and phenomena) to everyday life: 'Connecting science to students' everyday life experiences is an important theme in science education discourse' [43] (p. 107). It is argued that making connections of content with everyday life is an important pedagogical tool for motivating students (e.g., [43]). There was only a small number of Lyceum teachers who were not successful in this aspect. This could be due to the fact that Lyceum textbooks do not include connections between topics and everyday life compared to the books of the lower level of secondary education.

The methodological approach of the present study with the combined use of observations and questionnaires provided a wealth of data from the classroom and also of the students' views and justifies the choice of utilising two different methods for data collection (e.g., [5,23]), offering a more holistic view of teachers' everyday practices [8]. In addition, the use of the same criteria by both methods arising from the PCK conceptual framework and aspect categorisation based on Shulman's [7] PCK categories and adapted appropriately to our context, enabled us to evaluate aspects of the knowledge of the teachers that are considered critical to their teaching and provided an answer to our research question about the quality of the PCK related teaching practices. In addition, our choice to adopt the analysis done by Jang et al. [5], which is considered appropriate for both recording students' perceptions and classroom actualities, was fruitful from the point of view that it provided the essential framework for a knowledge base of teaching classified into categories in terms of its domains and its relation to classroom practices [7].

6. Limitations and Implications of the Study

The findings of the present study underline the strengths and weaknesses of the Greek secondary education science teachers' practices and the challenges they face and provide a foundation for designing in-service training and professional development programs of the specific teachers based on their needs [11]. Our study is subject to limitations: it was carried out in a single country and with an average number of teachers. However, the methodology used in the present study, which was fruitful in providing useful information and a holistic view of science teachers' everyday practices, can be used for investigating the classroom practices of the teachers of other subjects as well. In addition, this methodology could be exploited by designers of teacher training and professional upgrading programs in other countries as well where similar studies need to be carried out.

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Appendix A

Questions of students' questionnaire divided into the four Domains.

Subject Matter Knowledge (SMK)

1. My teacher knows the content he/she is teaching
2. My teacher clearly explains the content of the subject
3. My teacher knows the answers to students' questions about the ideas and phenomena that he/she teaches
4. My teacher uses a variety of teaching approaches to transform subject matter into comprehensible knowledge
5. My teacher explains the usefulness of subject matter to society

Instructional Representation and Strategies (IRS)

6. My teacher uses appropriate examples to explain ideas or phenomena related to subject matter
7. My teacher uses familiar analogies to explain ideas or phenomena of subject matter
8. My teacher's teaching methods keep me interested in this subject
9. My teacher provides opportunities for me to express my views during class
10. My teacher uses demonstrations to help explaining the main concept
11. My teacher uses multimedia (e.g., video) or technology (e.g., P.C. or smartboard) to present the concept of subject
12. My teacher uses appropriate diagrams and graphs to explain science concepts.
13. My teacher gives us experiments to conduct or presents experiments when is required to help us understand a theory or concept
14. My teacher uses real objects to help us understand science concepts

Instructional Objective & Context (IOC)

15. My teacher makes me clearly understand objectives of this course

16. My teacher pays attention to students' reaction during class and adjusts his/her teaching attitude
17. My teacher discusses students' questions with us before he/she gives an answer
18. My teacher creates a classroom circumstance to promote my interest for learning
19. My teacher prepares some additional teaching materials
20. My teacher manages classroom properly and provide a good atmosphere

Knowledge of Students' Understanding (KSU)

21. My teacher investigates students' prior knowledge about an idea or a phenomenon before the instruction
22. My teacher knows students' learning difficulties of subject before class
23. My teacher's assessment methods evaluate my understanding of the subject
24. My teacher uses different approaches (questions, discussion, etc.) to find out whether I understand
25. My teacher's tests help me realise my learning situation

Appendix B

A part of the Personal Sheet.

Subject Matter Knowledge					
Criteria	***Subject Knowledge***			***Language and Communication***	***Connection with everyday life***
Questionnaire result	Knowledge of the content (Q1)	Adequete presentation of the topic (Q2)	Adequately answering of students' questions (Q3)	Didactic transformation (Q4)	Connections with everyday life (Q5)
Mean					
N					
Std. Deviation					
Rubric Result				Quality of the language used during the lesson	Connection with everyday life
Score					

Instructional Representation and Strategies								
Criteria	***Instuctional Strategies***			***Opportunities for students to express ideas and opinions, etc.***	***Instructional representations***			
Questionnaire result	Strategies maintaining students' interest (Q8)			Students' attentiveness related reactions during instruction (Q9)	Use of Examples (Q6)	Use of Analogies (Q7)	Use of Graphs (Q12)	Use of everyday objects (Q14)
Mean								
N								
Std. Deviation								
Rubric Result	Variety of teaching strategies	Appropriateness of teaching strategies	Strategies maintaining students' interest	Students' attentiveness related reactions during instruction	Appropriateness of Istructional Representations		Usefulness of instructional representations	
Score								

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