International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

Impact of error on teacher professionalization: The case of teachers of physical and chemical sciences in Moroccan qualifying high schools.

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Abstract

This article presents a qualitative study exploring the impact of error on the professional development of teachers of physical and chemical sciences working in qualifying secondary education in Morocco. Error is an inescapable aspect of teaching and learning, but little research has examined how teachers manage and use error in their pedagogical practice. The study is based on in-depth interviews with a representative sample of teachers of physical and chemical sciences in Moroccan qualifying secondary schools. The researchers examined how teachers perceive error in their teaching, how they manage it, and how it affects their professional development. The results of the study vary from one teacher to another: error is recognized as important in the teaching-learning process, despite the diversity of postures; it is an opportunity not only for the learner to improve his or her learning, but also for the teacher to develop his or her professional skills; it is also said to be a source of difficulty and a source of failure. This article discusses the importance of training teachers to recognize and deal constructively with error, and the need for professional development strategies that integrate it into teaching practices, given the formative impact it can have on the professionalization of teachers, particularly those of the physical and chemical sciences.

Keywords: Teacher Professionalization, Error, Competence, Teaching Practices, Training.

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1. Introduction

The concept of training has evolved over the last few decades: it is no longer a question of training in the classic, "closed" training systems represented by training centers and schools, but also through professionalizing field courses that take into account "error" as a natural process inherent in training and practicing the profession [1]. Hence the importance of integrating the practice-theory-practice paradigm into any professionalizing system; this dual perspective would include observation, classroom training, tutoring, monitoring, gradual "real-life" assumption of responsibility in the job and assessment. The business, simple and logical on the surface, is not free of difficulties and contradictions that make it both complex and fragile until the status of error is studied and clarified [2]. Whether forbidden, encouraged or accepted, error is closely linked to professionalization, with professional skills that are reinforced or cancelled out according to the postures adopted and the degree of awareness of both trainer and trainee.

Forbidden, error forces us to adopt an attitude in which it is completely absent, a situation of absolute "zero-defect", which presupposes levels of performance that are impossible to achieve. Evelyne Blain-Joguet argues that "the notion of competence (and its inevitable corollary of incompetence in the event of failure) takes on a particular color when the places to which it gives access are limited. We live in a time when we are expected to achieve results quickly: in economics, in social reform and even in

education" [1]. The contradiction here arises from the impossibility of reconciling the natural right to make mistakes with the absence of shortcomings required in the professional world, to such an extent that depression is essentially provoked by the feeling of inadequacy and of not feeling up to scratch, rather than stemming from any form of Freudian guilt, as psychoanalysis suggests [3]. Other, positive postures are important for the professionalization and development of the trainee, where mistakes are encouraged as a learning factor and accepted as long as a protective, empowering framework is in place [4]. Learning to recognize and manage errors is therefore an integral part of the initial and ongoing professionalization process, enabling mistakes to be made and reflexive reflection on them to take place at the same time: authorizing and protecting go hand in hand, thanks to a protocol of autonomy and intervention by the trainer/inspector, and the shift from a logic of guilt to one of responsibility is made possible [5]. As a teaching tool, error is also an extraordinary training tool. So how does it impact on teacher professionalization?

We address this issue by studying the relationship between these two phenomena through the performance of physical and chemical science teachers at Regional Academy of Education and Training (RAET) Rabat-Sale-Kenitra. In the remainder of this text, we will first define the concepts of professionalization and error in order to identify the nuances and specificities that will constitute our working tools. We will then identify the teachers' representations of error and measure the extent and limits of its impact on the development of the professional skills of the sample studied.

2. Professionalizing through mistakes

2.1. Teacher professionalization

Teacher professionalization is an ongoing process of professional development for teachers, aimed at improving their skills, knowledge and pedagogical practices [6]. This complex process aims to equip teachers with skills that will transform them into qualified, effective, expert and reflective professionals [7]. This dimension is all the more important as professionalization is based on a combination of academic knowledge, pedagogical skills, practical experience and professional ethics. This is why it originates in rigorous, practice-oriented initial teacher training, based on the results of research in education and didactics [8], [9]. In this way, teachers are prepared to meet the many complex challenges of student diversity, special needs, ever-evolving educational technologies, and innovative teaching methods [10]. Moreover, teacher professionalization is not limited to training centers, but is intended to accompany the teacher throughout his or her professional career [11], notably through professional development programs, skills development opportunities, exchanges of good practice and a collaborative learning culture. Teachers are thus encouraged to keep abreast of advances in their respective fields, hone their skills and adapt to the changing needs of students, schools, and society [12]. In our view, this long and difficult path to becoming a professional teacher implies recognition of the teacher's autonomy and responsibility for the pedagogical and didactic choices he or she makes in the classroom [13]. As a result, as teachers gain in maturity and mastery of their field of action, they should be consulted and involved in drawing up educational policies, designing curricula and evaluating reforms [14].

2.2. What is the relationship between professionalization and error?

Error, as in any discipline, is a natural and inevitable part of the learning process in the physical sciences [8]. Students may make mistakes in their reasoning, experiments or interpretations of physical phenomena. However, these errors should not be regarded as failures [15], but rather as opportunities for learning and developing scientific understanding. As professionals, teachers in this sense play a central role in how students approach and understand scientific concepts, particularly in the physical and chemical sciences. The way they approach and respond to students' mistakes can have a significant impact on these students' learning and development as critical and scientific thinkers [16]. In the context of teacher professionalization, we believe it is necessary to train teachers in the recognition and constructive management of errors [17]. Rather than simply regulating errors internally or externally, pedagogical approaches that encourage students to reflect on, understand and correct their mistakes themselves can be tried out. Studies[18], [19] have, in fact, shown that pedagogical approaches that actively incorporate the consideration of student errors promote better conceptual understanding and deeper learning of the physical sciences.

2.3. The benefits of integrating error into the professional training process

The use of theory in initial training plays an essential role in understanding and analyzing the teaching profession and the pedagogical practices implemented in the classroom [20]. This structured framework makes it possible to examine the various dimensions that contribute to the quality of teaching and learning. Two major components are considered: the professional component and the didactic component, which we represent in the diagram Figure 1. By combining the two strands, occupation, and didactics, within a single theoretical framework, researchers, educational practitioners, and teacher trainers gain a holistic view of the teaching profession and pedagogical practices [21], [22]. This perspective enables a better understanding of the complex interactions between teacher training, professional representations, skills, teaching strategies used in the classroom, the influence of modeling on student learning, and the consideration of errors as learning opportunities. In this way, it is possible to continuously improve the quality of teaching and learning, with a focus on teachers' professional development and optimizing students' educational experience [23].

3. Context of the research design

3.1. Errors in qualifying secondary school science subjects: the case of the physical and chemical sciences

Recent decades have seen the development of numerous studies and representations of error, particularly in the sciences, in teaching and learning, and in the literature on the subject [24]. This interest has been accompanied by a kind of confusion about error. It has always been consubstantial with the birth and development of science and has also been confused with "fraud" and "fault" [25]; it has also been used

to distinguish "fraudulent sciences" from "honest sciences" [26] and "false ideas" [27]. Error is not unique; it is variable and depends on the scientific situations in which it occurs. In the teaching and learning of the physical and chemical sciences and other disciplines, the error detected through different types of assessment, both formative and summative, is consubstantial with the didactic act, and is an expression of teaching difficulties and learning problems. The integration of error into science teaching is a necessity that interests prescribers and teachers at the highest level. It's no longer just a question of calculation errors, for example [28], students are entitled to ask what justifies the passage from one physical law to another, or from one theory to another. This is why errors are at the heart of science learning, and why they enable students to adopt appropriate attitudes during learning or laboratory experiments. It goes without saying that students are usually graded on the basis of the discrepancy, considered as an error, that they establish between theory acquired and experiment carried out, whereas the question of discrepancy is far more complex. Indeed, learning to experiment and learning physics are two different yet complementary orientations, with experiments generally aimed at confirming theory. However, if students seem to be able to learn to experiment with physical phenomena without being able to master their theoretical underpinnings, it's because, it seems to us, teachers tend to establish numerical safeguards. This is because, it seems to us, teachers tend to establish numerical safeguards - measurements - for the variables that students are obliged to respect; if they understand the measurements, they cannot understand the reasons behind these choices. Under these conditions, shouldn't teachers teach their students the meaning of a law through experience, rather than confirming its validation through the same process?

3.2. The research framework

With the aim of defining teacher professionalization through professional representations, the value of error and remediation strategies, as specified in the theoretical approach, we have chosen to follow a methodological set-up with diverse and complementary methods and techniques. Our aim is to characterize a central representational core relating to the two objects of reflection, error in the physical and chemical sciences, by identifying elements of dispersion and those of convergence that bring the subjects closer or further apart [29], [30]. This study is part of a configuration that aims to be innovative, taking as its object the impact of error on professionalization on the one hand, and attempting, on the other, to bring to light new professional practices that the semi-directed interviews will inevitably reveal. We have also chosen to use the questionnaire as a research model to provide an insight into the experience and training of teachers of physical and chemical sciences [18]. The chosen corpus concerns 120 qualifying secondary school teachers, working in the provincial department of Rabat-Sale-Kenitra, Morocco. The aim of this questionnaire is to determine the sample to be interviewed, characterized by their interesting years of experience and training. The interviews we conducted focus on professional representations of error and methods for dealing with it in the physical sciences. They also address students' reactions to their errors, the importance of the learning environment, the learning opportunities fostered by errors, and teachers' obligations in terms of knowledge about errors. This reflection integrates the observation of the relationship to knowledge to identify practices based on didactic questions [31].

The interview is organized around 6 questions:

1. What does the learner's mistake in class mean to you?
2. How do you define it?
3. What status do you give it in the learning process?
4. How do you analyze learner errors?
5. How do you deal with them?
6. What methods do you use to prevent learners from making mistakes?

4. Data collection and interpretation

4.1. Errors in relation to professionalization

As mentioned, we have focused our attention on two fundamental elements from which it seemed possible to measure the extent of professionalization among qualifying secondary school teachers of physical and chemical sciences: the impact of experience and training on the model of representation that these teachers develop in relation to error.

4.1.1. *Teaching experience in physical and chemical sciences*

When asked what experience the teachers we interviewed had accumulated, we were interested in the number of years they had been teaching, convinced as we are that teaching is in itself a period of learning, and therefore of professionalization. "The profession, says Perrenoud, is not like any other. It's a profession characterized by long training, a high degree of individual responsibility, and the mobilization of high-level knowledge in situations of uncertainty and urgency, in the face of complexity" [32]. It's clear from this reflection that working years also count in training, since they enable us to deal with the unexpected and regulate teaching and learning. In the light of the question relating to life in the profession, we note that the majority of respondents are new recruits whose years of experience do not exceed 5 years (56%), i.e. a trend towards the rejuvenation of the teaching profession. The other category accumulates years of experience ranging from 5 to 30 years, with a crucial decrease in the number of respondents in the latter group, i.e. 6%, as shown in figure 2.

4.1.2. Teacher training in physical and chemical sciences

The question of professionalization confirms the result obtained in the previous question. Indeed, while 60% said they had been adequately prepared in initial and in-service training for teaching methods and approaches in the physical and chemical sciences, 56% of them were young people. Figure 3 below shows this result:

4.2. Presentation of semi-structured interview data

The 30 teachers who agreed to answer our questions represent a sample of qualifying secondary school teachers who have shown a particular interest in the subject of this research. They have followed different training courses (university, ENS, CRMEF) and work in the three levels of qualifying secondary school. They have between 5 and 20 years' teaching experience and work in various schools in the Rabat-Sale-Kenitra regional directorate. Their opinions are reported in a decontextualized way for research purposes. The

spirit of these interviews is in line with the directions taken by the questionnaire, which enabled us to identify three fundamental axes:

- Perceived causes of error,
- Emerging causes of error,
- The impact of error.

These three dimensions put into perspective teachers' skills in identifying errors and the impact they can have on the practices they implement to remedy them. We summarize all these elements in this table 1. We need to clarify what we mean by perceived and emergent causes [33]. The former presupposes a representation of the error, inviting the identification of clues that can be used to grasp it and guide the teacher's didactic choices; it is known and experienced; the latter is to be defined as an accident in the teaching-learning process, and is therefore ignored, requiring the identification of clues and a representation of the error in order to choose the appropriate regulation practice.

4.2.1. *Perceived causes of error*

As these causes are expected in relation to the teaching content planned for the session and the teacher's experience, reactions are both intuitively and strategically programmed. As the teachers interviewed put it, teachers tend to act immediately, or to carry out an analysis that allows them to deepen their students' reflection on the knowledge they have been taught, by means of precise questioning. The aim of this analysis is to make learners more aware of their mistakes and to encourage them to take responsibility for their mistakes. The usefulness of errors is clear. The processes followed consist first and foremost in the detection of errors, an action made possible by exercises and all forms of assessment, by students' reactions and behavior, and by the questions they ask and repeat. To remedy the situation, the teachers in the interview confess to using a variety of strategies, but these follow the usual processes such as analysis of the didactic situation and intuitive actions, questioning and further reflection on the difficulty encountered, motivating pupils and making them more responsible and, finally, improving relationships and verbal interactions within the class group.

4.2.2. *Emerging causes of error*

As is the case for known causes of error, perceived causes require detection, which can only be achieved through analysis of the didactic situation and awareness on the part of the teacher. The more difficult and complex the content, the greater the teacher's vigilance. Indeed, he or she becomes attentive to hesitations and difficulties in grasping concepts (mass and weight, power and electrical power). The teacher frequently needs to check for understanding and perception of knowledge, and make numerous clarifications, prompting him to adjust his practices according to the impact of the error on learning, the level of the pupils and the disciplinary context; in such cases, reinforcement exercises are planned.

4.2.3. The impact of error

Whatever their causes, known or emerging, errors are linked to a variety of factors: nature of the discipline, subject content, teaching methods, learning approaches, teaching or learning responsibility. As mentioned below, they modify teaching strategies and call for the adoption of a number of different, complementary strategies: direct action, intuitive reflexes, group or individual work modalities, peer learning, precise questioning, multiplication of feedbacks, reformulations and paraphrases, over-support, control and teaching postures [34], planning of remediation and support sessions.

Although the cause of error may seem insignificant, it is of vital importance, as it determines the choice of resources and concepts to be integrated into lessons and assessments; it pushes the teacher towards reflexivity and forces him or her to innovate. Similarly, the reactions of learners who, because of the scale of the difficulties they discover, find themselves in a situation where they need explanations, require the teacher to inspire confidence, create a climate conducive to intervention and learning, and propose new situations that encourage free interaction. When faced with a mistake, teachers do not hesitate to question themselves and encourage their students to do the same. They point out that their perception of error has a huge influence on their practices and postures, that it is not a fault to be punished, and that thanks to their professionalism and competence, they reject any negative attitude and seek the best for their students. Their actions draw on creativity, concern for quality and the usefulness of learning. Having said that, the interviewees consider that students do not put enough effort into learning and that they do not demonstrate autonomy, homework and exercises are not always done, and work is generally not or only relatively well prepared. When it comes to the usefulness of error, they agree that it influences their behavior, develops their skills and remains an opportunity to learn and improve learners' knowledge. Mistakes are a way of keeping the search alive for new and effective teaching and learning methods, and they often raise the question of their roles and functions. However, the majority of respondents feel that mistakes are poorly perceived by students and society alike, despite the fact that they are part of human nature. It is both inevitable and necessary, and therefore useful.

5. Discussion

Pre-requisites are a fundamental source of errors made by students, and one that the teachers interviewed consider. This is one of the perspectives studied by Astolfi [35], who argues that curricula require the mobilization of prerequisites according to disciplines, and that teachers tend to ignore this crucial dimension. They would normally be expected to guide their students towards a perspective of knowledge integration, whereby they would be able to distinguish between disciplinary prerequisites and mobilize the appropriate resources for solving the proposed problem situations.

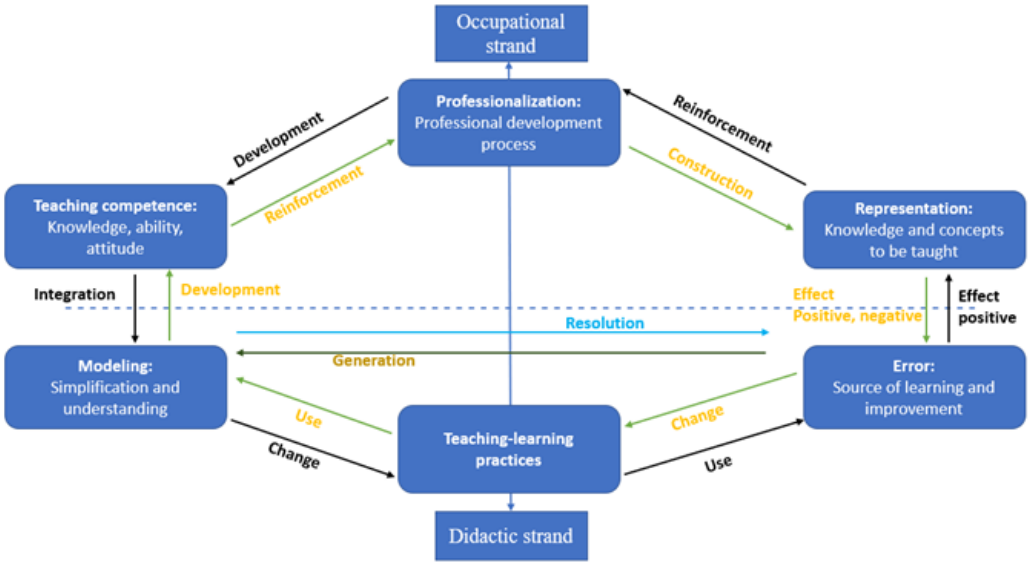

Figure 1: Mistake between theoretical conception and practical perspective:

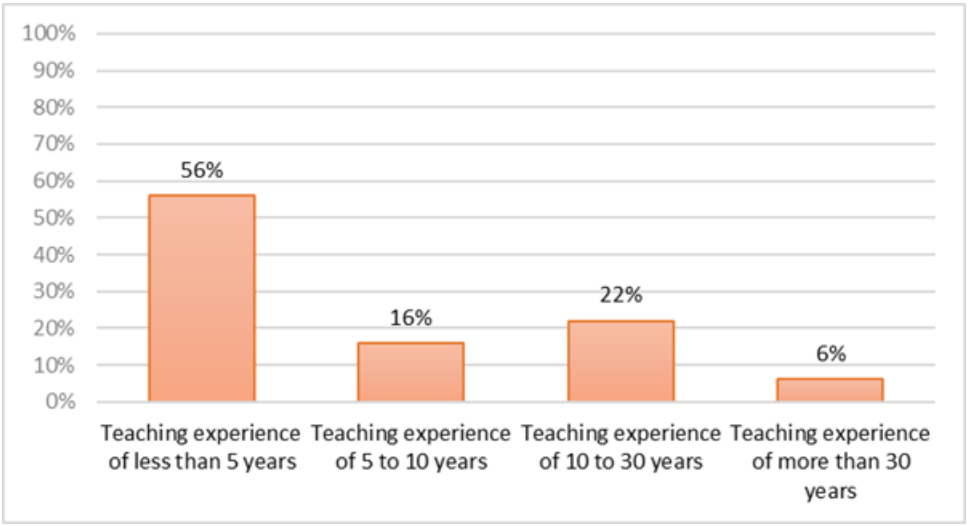

Figure 2: Teaching experience in physical and chemical sciences

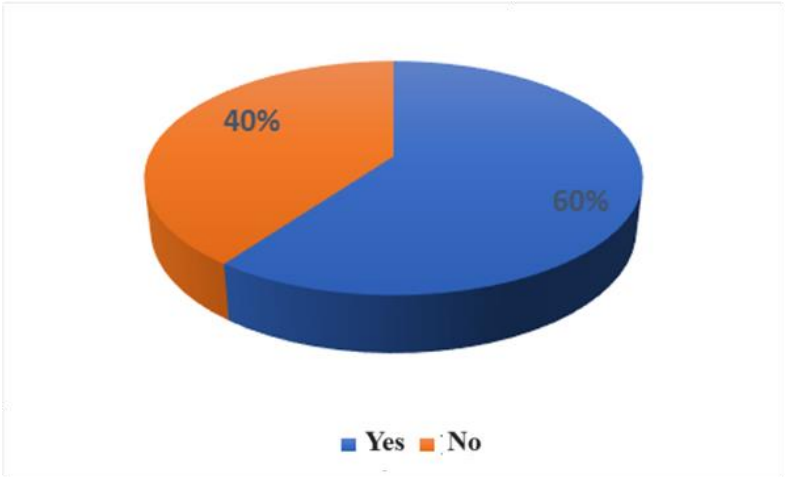

Figure 3: Teacher training

Table 1: Different causes of error and concordant teaching practices

Axes	**Perceived cause**	**Emerging cause**	**Representation**
Interview objectives	Identify teaching practices in relation to perceived errors	Analyze concrete practices in the face of error	Defining the representations that influence practices
Sub-themes of actual classroom practices	Error identification	Error identification	
	Situation analysis	Situation analysis	
	Error characteristics	Situation analysis	
	Learning activities	Learning activities	
	Interaction / error	Interaction / error	
	Responsibility (teacher, student, content, methods)	Responsibility (teacher, student, content, methods)	Usefulness of mistakes / teaching
		Exploiting the error	Usefulness of error / learning

This question is directly linked to the progression of content from one school level to the next, which must be taken into account by the teacher. teachers need to take into account in order to make up for the shortcomings through feedback and rigorous weaving. This is part of their their professionalism and competence.

5.1. Errors as an object of didactic transposition

The semi-structured interview with the interviewees revealed a high level of awareness among teachers of the role and function of error in the teaching and learning of physical and chemical science subjects. However, due to lack of time and large class sizes, teachers admit to resorting to "classic" teaching methods. While the school's main concern is "the scheduling the programming of learning and testing according to rescheduled sequences [to enable] the progressive acquisition" [36] of knowledge, the learning objectives that are supposed to support the effective construction of knowledge are not in place, even though these teachers are trained to do so. As a result, students are not confronted with teaching processes that help them to construct knowledge; they are content to passively follow lessons deprived of any interactive or epistemological scope.

Similarly, at a time when socioconstructivist approaches are encouraging greater openness and reflexivity in the acquisition of resources, the teachers interviewed believe that textbooks and curricula propose truths that students cannot discuss. This is a form of dogmatism that is strongly criticized in school circles, especially as the epistemological and historical dimensions specific to the physical sciences, i.e. the history of science, are completely ignored. This gives rise to "a succession of errors" [37]. Guedj draws attention to the role of the history of science in modifying errors and in the construction of knowledge and understanding of concepts. Unfortunately, the scientific experiments carried out in physics and chemistry classes are carried out independently of an understanding of the rational motives that led scientists to question the objects of the world they observed and experimented on. Isn't science basically "a set of approximate and provisional models and theories for solving problems?" [38]. The teacher is therefore limited to dispensing knowledge in complex situations, without taking into account the theoretical underpinnings on which they are based. underpinning them [39].

5.2. Errors in teacher representations

Teachers' representations of error provide information about their mastery of the curriculum and physical concepts. We note a strong tendency on the part of these teachers to define the physical relationships of facts in relation to concepts, while taking into account the level of complexity of the phenomena studied [40]. However, during the experiment, we noted that many of them admitted to limiting themselves to generalities on the pretext that some concepts are difficult to master and transpose, and that they require recourse to mathematics, which is lacking in students, in order to understand them [41] ; they would also find it difficult to make explicit the links that may exist between the processes studied and presented to students and the definition of the concepts and phenomena they are working on, as is the case when using mathematical models of functions and derivatives in the fields of mechanics and nuclear physics. Finally, the teachers questioned are convinced that students are at a much lower level than the concepts and theories they are called upon to learn.

In the light of these various justifications, we understand that there is a "tension between the domain of academic mastery and the level of teaching practice" [42] on the one hand; on the other, we note a leaning towards externalizing responsibility for the difficulty of teaching and learning physics. Mistakes are not only possible, but also and above all frequent in the discipline. Pupils end up internalizing the fear of a disciplinary field that they find difficult to define, all the more so as, to do so, they need to delimit the contours of another disciplinary field, mathematics. As for teachers, the training they receive to teach physics has not succeeded in distancing them from the academic training in which physics was a field of study and reflection, and they continue to teach it as they learned it, i.e. close to scholarly knowledge. To enter the profession, it's not enough to be trained in pedagogy and the profession, but we believe it's necessary to construct a new representation of disciplinary content. High school physics courses can never be an extension of university courses. The representation of physics is an obstacle that generates errors [43].

5.3. Impact and didactic treatment of errors

5.3.1. *Impact of error on teaching practices*

Given that the majority of teachers interviewed have a positive opinion of error, they are at the same time aware of its influence on their teaching. A review of adopted professional practices is necessary and should be carried out in line with official guidelines, which seem to impose a constructivist and socioconstructivist conception of subject teaching and learning. The error begins by influencing teachers' professional practices, inviting them to reflect on the academic or university knowledge they have acquired and the way they use it in the classroom. In our view, this "reflective practice" [44] helps them to understand the problems encountered by their pupils and the difficulty of the professional gesture, all the more so as academic scientific knowledge is difficult to apply in the school environment. Professional practice situations are generally characterized by "complexity, uncertainty, instability, particularism and conflict of values" [44]. In this way, teachers professionalize themselves by practicing, and thanks to this "learning by doing", in the discipline of physical and chemical sciences, they can confront problems and reconstruct them. In this sense, Schön argues that "in the concrete world of practice, problems don't arrive ready-made in the hands of the practitioner" [44].

Errors are therefore not simply an everyday phenomenon in teaching practice but can be a decisive learning factor for both teacher and student. as it is for the student. The former finds himself obliged to rethink his patterns of action and reorganize the elements of the didactic situation and its framework [45].

5.3.2. *The status of error*

The status accorded to error, whether by teachers or students, is directly related to the consequences it represents in terms of learning failure for teachers and academic failure for students. It is generally considered to be a factor the gap between what is taught and what is actually learned.

Paradoxically, while teachers have developed a mastery of what error can be and understand the reasons for it, they are reluctant to take the appropriate measures to deal with it in a teaching situation. They recognize error as a tool for teaching and learning, and continue, forced as they are by the norms of the education system and official prescriptions, to link it to evaluation-sanction, to a grade [46] against which today's schools try in vain to rebel.

5.3.3. *Didactic treatment of errors in the physical and chemical sciences*

The procedures in question are generally not easy to put in place, especially as they can represent a significant learning dynamic. Indeed, the teacher's main concern is to know how to dose his or her interventions so as to guide the student towards effective ways of remedying errors. Errors have an impact on students' psychology and emotions, and therefore on their self-esteem. To avoid destabilizing students, we have observed that the teachers we have observed often move away from the classic transmissive approach towards pedagogical choices that motivate students and take situations into account. Decision-making or proposing solutions is left to the students themselves, a way of building their own confidence by making them aware of the mistakes they have made [47] and giving them a sense of responsibility. In this way, they avoid becoming inward-looking, and are welcomed by other students. Some teachers tend to make positive use of errors in their learning strategies, turning them into a reason for progress and helping to establish the mechanisms for of thinking-saying-acting in complex situations. This is achieved through various forms of oral and written regulation. The timing of these error-regulation actions varies. Some wait until the end of the task proposed to the pupil before inviting him or her to take it up again; others call on other pupils to identify what's going wrong, discuss it and find the exact solution; others hold scientific debates that enable pupils to access the knowledge taught, develop decentralization and critical thinking skills, and encourage them to engage in argumentation and involvement in the task in hand. It is through the confrontation of subjectivities that errors are understood, and solutions found, since "cognitive conflict remains the theoretical presupposition most conducive to the production of knowledge when experimental corroboration is impracticable" [48].

6. Conclusions

Teacher professionalization is an ongoing process that aims to improve the quality of education by valuing teachers as qualified, reflective professionals. By investing in teachers' initial and in-service training, providing them with adequate support and recognizing their essential role in education, teacher professionalization helps shape a better educated, more enlightened and more prosperous society [49]. However, there has been a shift in the way teachers view the status of error as a tool for teaching and learning, and this is reflected in a renewal of professional practices and systems for dealing with error. The concern for developing students' skills in the physical and chemical sciences, which young teachers [50], [51] are constantly emphasizing, is driving them to devise different strategies and problem situations to lead students along the path to effective learning, where pedagogical innovation through internal and external regulation, cognitive debate and problem-solving is the order of the day.

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