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Scientific Experiments in Moroccan High Schools Life Science Courses: Constraints and Solutions

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Abstract: The teaching of experimental sciences in high school contributes to the development of a set of cognitive, methodological, and psychomotor skills among learners. Combining, both theoretical and practical aspects, it involves an important use of scientific experiments in the process of knowledge construction. With the help of appropriate tools that include interviews and observation of teaching practices, data related to the constraints encountered in the implementation of scientific experiments in the high school life sciences classroom was collected as well as proposals of solutions to overcome these constraints. The results show the existence of a set of constraints that oppose the realization of experiments in class. These constraints are not only limited to insufficient or deficient external factors but also to the teachers' relationship to knowledge which influences their choice of teaching activities within a predefined curriculum.

Keywords: *Scientific experiment, life science, constraints, solutions.*

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Introduction

Teaching of life sciences is both a theoretical and an applicative practice, as it requires a mix of conceptual and applied topics. Through its nature, experimental life science teaching facilitates the acquisition of concepts by learners and introduces them to laboratory techniques (Giordan, 1999). It also offers them the opportunity to develop a range of methodological, psychological, sensory and motor skills as well as the building of an empirical conceptualization reference (Beaufils & Larcher, 1999; Coquidé-Cantor, 1998; Galiana, 1999).

The practice of experimental activities in the classroom represents a break from transmissive pedagogies (Dinh & Phan, 2018), as it provides learners with active learning and promotes their development of methodological and technical skills (Bouzit et al., 2020; Coquidé, 2010; Millar, 2004). It also allows the concretization of knowledge theoretical objects by bringing reality close to the understanding of learners (Kochkar, 2007; Nguyen et al., 2021) which facilitates their assimilation of concepts (Mutti & Reginelli, 2012).

In addition, when learners experiment directly or indirectly, they undertake, in an intellectual journey, a set of operations that go from the formulation of a problem to the results and conclusions through the elaboration of a hypothesis, the design of an experimental protocol, and the execution of the experiment (Hrairi, 2004; Nguyen et al., 2021). This process allows a student to develop his scientific reasoning and particularly his experimental approach (Bernard, 1865; Bouzit et al., 2020; Dewey, 1929).

However, the reality of experimental science education in Morocco reflects a paradoxical aspect. Indeed, the experimental character of the discipline requires an explicit integration of scientific experiences in classroom activities whereas the national exam is denuded of any experimental practice (Ministry of National Education and Vocational Training, 2007).

This incompatibility between the discipline characteristics and the curricular vision that guides teaching practices led us to an exploration of the reality of experimental practice within life science's courses in Moroccan high schools.

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Indeed, Moroccan curricula and pedagogical guidelines for high schools' life sciences teaching (Ministry of National Education and Vocational Training, 2007) present an abundance of formulations that emphasize the experimental character of the discipline and highlight the role of scientific experiments through the different intellectual and motor abilities mobilized by experiments for the benefit of learners. These guidelines are similar the ones published whining the French official curricula (Cariou, 2015).

However, Moroccan pedagogical guidelines remain vague on the type of science experiments and the amount of time required to conduct it. This suggests an inconsistency between the pedagogical expectations of the discipline and the curriculum to be taught. Therefore, Moroccan life science teachers struggle to find the appropriate scientific experiments to integrate into classroom teaching, while respecting an imposed and fixed schedule. That's explain why 68% of Moroccan teachers carry out only less than 50% of the experiments in class (Chekour et al., 2015).

In addition to highlighting the importance of implementing experimental activities in high school life science classes, the Moroccan ministry of education has mobilized a significant budget to equip laboratories with adequate tools and products, as well as with technical support staff to facilitate experimental practice. Ministerial guidelines also recommended splitting classes to reduce the number of students per class (Ministry of National Education and Vocational Training, 1969, 1979, 1982). However, teaching practice highlights a current degradation of the conditions specified by the ministerial guidelines. Indeed, life science laboratories have been increasingly abandoned and made to serve as repositories for defective tools. Moreover, the abandonment of class sessions duplication caused an overload of learners per class. Finally, life science laboratories lack basic supplies coupled with an almost total absence of lab helpers.

Challenges in life science teaching have also been reported in the literature at the European level. Indeed, surveys conducted at the European level, show the existence of difficulties in implementing experimental activities (Flageul & Coquidé-Cantor, 1999). These difficulties are pedagogical and organizational as well as class and time management related. These studies also highlight that the fear of finding unexpected experimental results, or being confronted with unmanageable student behavior, or even of facing difficulties related to the handling of laboratory tools, push teachers to favor experimental activities based exclusively on documents.

Other studies show that even when teachers plan to carry out experiments in class, they propose an experimental protocol and proceed to experiment without integrating learners. They justify their attitude by citing the fear of damaging laboratory tools or simply the lack of time (Ounini, 2019).

All the above-mentioned difficulties in life science teaching whether at the Moroccan or the European level highlight the challenges in implementing experimental activities in class. As demonstrated in previous studies, the practical and applied character of life science teaching is essential to the leaners knowledge assimilation (Bernard, 1865).

Therefore, it is important to identify the relevant constraints preventing an effective implementation of experiments in Moroccan life science high school classes and explore adequate solutions to overcome these constraints.

The research questions are, therefore:

- ✓ What are the different constraints to an effective realization of scientific experiments in life science courses in Moroccan high schools?
- ✓ How can these constraints be overcome?

Methodology

Research Design

This study has a qualitative, descriptive approach that aims, in one hand, to highlight the different constraints to the effective realization of experiments in Moroccan life science high school classes and the other hand, to collect solutions to overcome these constraints. Indeed, this type of research makes it possible to describe the problem in question, study it in depth, and obtain relevant and significant answers and explanations.

The validity of the qualitative method requires collected data to be representative of reality. To this end, the combination of data collection methods such as observations and interviews has made it possible to guarantee the reliability and validity of this research work.

Sample and Data Collection

We used two complementary investigation tools, namely interviews and observations:

Interview: A semi-structured interview guide was designed by the principal author according to a reflective analysis of the main research, which allowed to extract a set of items concerning constraints as well as solutions. These items were then classified into principal, complementary, and clarification questions are formulated using simple vocabulary, accessible and clear language. An introduction to the research subject was also made to specify the contribution of the interviewee regarding the improvement of experimental teaching.

The interview guide was first validated by experts and pre-tested on a small group of teachers before being administered to the research sample. This made it possible to delete, add, rephrase (to simplify) some questions that were considered ambiguous and improve the structure of the questions sequences.

Table 1. Semi-Structured Interview Guide

Themes of the interview	Principal questions	Complementary questions	Clarification questions
Constraints to the realization of experiments	Do you think there are any constraints with conducting a science experiment in a life science classroom?	Can you mention the constraints encountered in this project?	Can you specify whether these constraints are related to resources, the nature of the discipline, your training, or other issues? Can you give examples?
Proposals of solutions	What would be the solutions to these constraints?	What do you think about the feasibility of these solutions?	Did you try to overcome these constraints? How did you proceed?

The sample was made up of 13 subjects: 9 teachers (7 females and 2 males) and 4 inspectors (1 female and 3 males) of life sciences from different high schools in the Marrakech-Safi region. The inspectors' group helped us proposing perspectives by sharing their experiences in the evaluation of teaching with their pedagogical skills in training design and implementation.

The number of interviews conducted was not determined in advance, but depended on the originality of the information provided by the interviewee which led to a saturation of the collected information. The data collection process stopped at the saturation, it's when the interview has no longer provided any new information.

The interview has been conducted by the principal author and the process varied between face-to-face and phone calls conversations which lasted from 15 to 30 minutes. The interview process was accompanied by voice recording or note-taking, depending on the interviewee's choice.

Indeed, the interviewer has the possibility of changing the order of the questions according to the progress of the interview. The interviewer can even add or eliminate certain questions, which allows her to frame the debate and to delimit the field of answers in order to avoid any irrelevance.

However, the data collected through the interview does not always represent reality. The interviewees tend to say what they think instead of what they actually do, hence the need to reinforce the findings with observations (see observation section below).

Observation: The observations was passive and participatory. We aimed to complete the interview by detecting various problems encountered during the realization of the experiments at class. Also, the solutions of the teachers that has been proposed or adopted to solve the problems. The observations were sometimes accompanied by questions aimed to enhance the understanding of the subject's behaviors.

The observations were participatory as it was carried out in the workplace of the observer – a high school in the province of Rhamna in the region of Marrakech-Safi – for a period starting from the beginning to the end of the school year 2020–2021 (what makes approximately 120 observations). It is worth mentioning that an alternating teaching mode has been adopted in Morocco due to the coronavirus pandemic. Therefore, the number of classes doubled and students did half the hourly volume on-site and the other half through remote learning.

The observation was carried out during the teachers' meeting time, (i.e., before and after each class session) in the shared life science laboratory. The opportunity to be in constant contact with subjects had an impact on the representativity of the collected data, since the risk of change in the subjects' behaviors was mitigated by the length of the observation period.

The laboratory where the observation was carried out, was shared by five life science teachers (1 male and 4 females), including the observer. The teaching seniority of the observed panel varied between 4 to 10 years. The observer remained passive as she did not participate in the activities of the subjects but she could always interact with them. The observed teachers were informed of the observation and they expressed a firm desire to see an improvement in experimental science teaching.

The observations were unstructured as it carried out in a free manner without the use of a real observation grid. Although the use of a grid allows for a clear understanding of the field and a superior structuring of the data collection process. In our case, being tied to a grid would have deprived observer of any new unexpected or unusual information and consequently risked causing her to miss some important information to support the understanding of the study subject. In terms of note-taking techniques, pencil and paper were used. The technique's flexibility and ease of use were perfectly adapted to the type of aimed observation.

Findings / Results

Interview Results

From a database containing voice recordings and notes, transcripts of interviews have allowed us to reproduce the teachers' and life sciences inspectors' words. We carried out this transcription process, on one hand, to avoid missing any significant elements and on the other hand to facilitate analysis and interpretation of the data.

The transcription, which was carried out immediately after the data collection. Collected information was sorted and rephrased when necessary. Repetitions, hesitations, side remarks and answers that did not fit with the theme of the interview were deleted.

Constraint Results: The following table summarizes the various responses' transcripts from the interviews with the participating teachers and inspectors followed by a category of reporting constraints related to the non-performance of experiments in the high school life sciences class.

Table 2. Summary of Interview Responses Related to Constraints

	Examples of responses related to constraints
C1	'Laboratory tools are insufficient and sometimes defective.'
C2	'How do you want me to experiment with a total absence of chemicals? The room is not even supplied with water.'
C3	'The lab contains equipment that is partially inappropriate for the content of the program.'
C4	'It takes a lot of effort, especially in the absence of a lab aid'
C5	'It takes time, you have to come in early to prepare for the experience and leave late after tidying the room'
C6	'With a class of 40 people, you have to get them quite first before you think about experimenting!'
C7	'The program is too busy, which does not leave time for the actual realization of the experiments'
C8	'I try to spend more time doing exercises to prepare students for the exam. Experiments! That's not how they're going to be evaluated!'
C9	'Computer-assisted experimentation is available in the lab, but I don't know how to use it!'
C10	'I have not received any training regarding the realization of the curricula experiments, so I don't bother!'
C11	'I would rather use a video of the experiment than sacrifice lives' / 'The sacredness of life must be limited to the big science laboratories'

The analysis of the interviews' results allows to group the highlighted constraints according to its categories, namely technical, pedagogical and ethical:

- *Technical, Material, and Infrastructure Constraints (C_1, C_2, C_3, C_4, C_5, C_6):*

C_1 and C_2 constraints show that life science laboratory is poorly equipped in terms of apparatus, chemicals, and organic samples. In addition, C_3 constraint shows that only a portion of the available equipment aligns with the current program while the remainder aligns with old ones or even with middle schools (the equipment is transferred to a middle school in many cases).

As for the specialized rooms, C_2 constraint shows that gas, water, and electricity are generally not provided. Furthermore, C_6 constraint adds that the abandonment of double sessions in most high schools along with the high number of learners makes it difficult to carry out effective experiments in class. Besides, C_4 and C_5 constraints mention that the lack of laboratory staff in a high school adds to the usual duties of a teacher the additional and heavy tasks of preparation, storage, and cleaning.

- *Pedagogical and Experimental Training Constraints (C_7, C_8, C_9, and C_{10}):*

C_7 constraint shows that the busy science program does not leave teachers enough time to carry out scientific experiments in class, and they claim to be obliged to adopt alternative approaches, such as videos or photos illustrating an experiment or to do without the experiment altogether by simply stating its results. In addition, C_8 constraint shows that the absence of an experiment in the evaluation system directs the teachers' objectives towards theoretical and methodological approaches. C_9 and C_{10} constraints highlight the problem of a lack of initial and ongoing training in the conduct of experiments and in the use of new equipment, which leaves teachers helpless in the face of demands for experimentation.

- *Ethical Constraints (C11):*

Another type of constraint was raised C11. Indeed, teachers renounce to conduct experiments on life sacredness grounds. Some teachers who raised this constraint were firm in their attitude, while others argued that the use of living matter should be limited to large laboratories working for the advancement of science.

Solutions Results: The following table summarizes the various responses' transcripts collected following the interview with practicing teachers and inspectors. The answers cover the solutions proposed to overcome the constraints related to the non-realization of experiments in the life sciences classes in high school.

Table 3. Summary of Solutions-Related Interview Responses

	Examples of answers related to solutions
S1	'We need to think about equipping the labs with what is appropriate for the program
S2	'Start by reducing the load on programs to free up time for experiments'
S3	'First of all, it is necessary to re-adopt the doubling of classes in order to reduce the number of students in the practical sessions
S4	'The evaluation must take into account the practical side as well as the theoretical side, which will push the professors to plan the realization and consequently the evaluation of the experience in their courses
S5	'At the faculty, half a day (4 hours) is devoted to the realization of the practical work and this in the presence of two professors and a laboratory assistant, and the number of students does not exceed fifteen. It is, therefore, necessary to reproduce these conditions to make the realization of experiments possible in high school classes.'
S6	'Initial and ongoing training of teachers in conducting experiments and using the new equipment is necessary
S7	'In my opinion, it is necessary to integrate hours of practical work in the teachers' schedule under inspectors' supervision'
S8	'Faced with the ethical problem of the sacredness of life, it is advisable to use models, interactive boards, computer-assisted experimentation, educational software and films, interactive tablets, social networks

An analysis of the interview results yielded several solutions that would allow for the effective implementation of science experiments in the life science classroom. These solutions were grouped into categories as follows:

- *Solutions to Technical, Material, and Infrastructure Constraints (S_1 and S_2):*

Proposed S_1 and S_2 solutions point to the need to rethink laboratories equipment strategy while ensuring alignment with the programs content as well as reinstating class duplication to reduce the number of learners per class and consequently make it possible to carry out experiments during life science sessions.

- *Solutions to the Pedagogical and Training Constraints Related to Experiments (S_3, S_4, S_5, S_6, S_7):*

The proposed solutions S_3, S_4, S_5, and S_6 show that the teachers and inspectors who were the subjects of our survey agree on the importance of reducing the programs load, the planning of initial and continuous for teachers' training to prepare them for the realization of experiments as well as to the use of laboratory tools, the recruitment of at least one laboratory assistant for each high school and the addition of scientific experiments to the evaluation system.

Solution S_7 insists on the importance of formalizing sessions for experiments' realization either in programs or in teachers' schedule.

- *Solutions to Ethical Constraints (S_8):*

Faced with ethical constraints, S_8 solution suggests the use of alternative methods in the form of models, mock-ups, interactive boards, computer assisted experimentation, software and pedagogical films, interactive tablets, social networks which minimize the pain and/or the sacrifice of living beings.

Observation Results

In addition to the constraints revealed in the interview, observations made it possible to demonstrate that the teachers' reluctance from carrying out experiments was also due to internal constraints. This conclusion is based on the abstentious behaviors adopted by the teachers when external conditions to the realization of the experiment were met. The table below summarizes the different behaviors observed among teachers concerning the effective realization of the experiment as well as the provided justifications:

Table 4. Behaviors Among Faculty Toward Conducting Experiments and the Rationale for these Behaviors

Observed behavior	The rationale for the observed behavior	
A teacher does not carry out an experiment even when sufficient and necessary conditions for its realization are met. He/she leans towards alternatives (use of photos instead of microscopic observation; use of videos or documents instead of experimenting).	**R1**	Teachers prefer to present ready-made results rather than results from an actual experiment. Example 1: 'I prefer to present ready-made results; it guarantees good readability and avoids wasting time.' Example 2: 'I avoid the risks that experiments would present, especially in the absence of sanitary measures in the laboratories.'
	R2	Teachers underestimate the manipulative side of experiments and assign great interest and time to the theoretical and methodological sides. Example 1: 'The most important thing is the construction of concepts and the application of a scientific methodology.' Example 2: 'Experiments are only for the illustration of already deduced knowledge.'

The observation of the teachers' behaviors regarding the realization of the experiments showed that the teachers renounced the actual realization of the experiment even when necessary and sufficient conditions for its implementation were met. They leaned towards the adoption of alternatives, such as videos, photos or even documents (experiments in the form of an integrated exercise).

To give meaning to the behaviors observed among teachers, we allowed ourselves, from time to time, to ask them clarifying questions. Apart from the technical, pedagogical, and ethical constraints which were highlighted in the interview, other constraints were grouped in two categories as follows:

- *Epistemological Constraints Related to the Nature of Life Sciences (R_1):*

R_1 shows a preference for presenting ready-made results rather than results from experience which is generally related to the nature of the discipline.

- *Epistemological Constraints Related to Teaching Practice (R_2):*

R2 shows an under-estimation of the practical side of an experiment and an allocation of interest and time to the theoretical and methodological sides (construction of scientific concepts and acquisition of scientific approaches).

Discussion

Discussion of the Interviews and Observations Results

Constraints Discussion

The various responses of the interviewees tend rather toward external constraints linked to the absence or insufficiency of materials and/or human resources (C_1, C_2, C_3, C_4, C_5) and also to the high number of learners per class (C_6). These findings align well with those of Taoufik et al. (2016) research. The author showed the existence of a deficit in the infrastructure and equipment of laboratories of experimental sciences in Moroccan high school. She also showed that more than 80% of the laboratories studied lacked a lab assistant, which explains the low percentage of teachers reporting their usage of laboratory facilities.

Besides, the overloading of the life science's teaching programs in high school (C_7, C_8) with a lack of training in experimental teaching (C_9, C_{10}) make it difficult to carry out experiments in class. Indeed, In the EFA Global Monitoring Report (UNESCO†, 2014), the quality of an educational system is intimately linked to teachers, so it is necessary to support their training to facilitate students' learning quality improvement. Indeed, initial and continuous training in science education in general and in experimental education, in particular, seems to be essential for the proper acquisition of professional skills related to the design and implementation of scientific experiments within life science courses (Bressoux, 2012; Favre & Verseils, 1997; Senayah et al., 2016).

Finally, ethics about the sacredness of life (C_{11}) can present a several constraints for teachers and students. Coquidé-Cantor (2000) shows the existence of a hierarchy of living organisms intended for experimental purposes. According to her, teachers refuse to sacrifice living beings during their experimental practices in class but they feel a low level of guilt when they handle plants or cockroaches.

In this context, the European Union established an official journal specifying the guidelines for the protection of animals used for scientific purposes (Directive of the European Parliament and Council, 2010). The journal takes up the principle of the 3R rule (Russel & Burch, 1959) which aims to reduce the number of living beings used in experiments, replace

† United Nations Educational, Scientific and Cultural Organization

them, if possible, with in vitro or silico models (software), and finally refine the methods of realization by decreasing the constraints and the pain of the living beings whether it is upstream or downstream of an experiment.

The observations results shows that the specificities of the biological object limit the effective realization of an experiment. Indeed, the variability and diversity of vital, anatomical, and physiological characteristics, which have already been the subject of epistemological problems in research on living organisms (Beaufils & Larcher, 1999; Coquidé-Cantor et al., 1999), present the risk of leading to non-significant or erroneous results. Thus, the dangerous character of certain experiments that lack sanitary measures could put teachers in situations of embarrassment and improvisation.

Previous studies (Coquidé-Cantor et al., 1999; Coquidé-Cantor, 2000) explored the didactic stakes presented by experiments in biology as a field of investigation on the living. The studies highlighted the resistance of reality due to its diversity, its variability, its complexity, and its irreversibility. Indeed, an experiment carried out on an earthworm is not the same as one carried out on a mealworm. In addition, even within a single population, each individual is led to react differently. These biological objects characteristics make it difficult to conduct an experiment and cause concern to teachers about their experimental practice in the classroom.

The observation results shows also that some teachers give up experimenting because they think that the experiment does not really have an important role in the creation of scientific knowledge and that its role is essentially limited to the illustration of knowledge already discovered or to the subsequent verification of laws and rules. This epistemological posture influences the practice of experimentation in the classroom and could be conveyed to learners. The interviewed teachers are generally unaware of their attitude, which explains the absence of this type of constraint in their statements.

Solutions Discussion

The solutions proposed by the interviewees relate, to the adequacy of laboratory equipment to the content of the program as well as to the number of learners per class (S_1) and the reduction of the program load (S_2). To alleviate the problem of the absence of or inadequacy of laboratory tools, Ministerial Note 133X18 (Ministry of National Education and Vocational Training, 2018) introduces the possibility of high schools lending laboratory tools to other high schools. It is not a proper solution that does not solve the initial problem because in the course of a program, teachers usually arrive at the same level at the same time and therefore they have the same needs for laboratory tools necessary to carry out experiments.

Other solutions involve the reduction of the number of learners per class (S_3), the integration of experimental practice in the evaluation system (S_4), the need to provide technical laboratory personnel (S_5), the programming of training in experimental work, whether upstream or during the teaching career (S_6) and the formalization of practical work sessions in the official curriculum and in the schedule allocated to teachers (S_7). It is worth mentioning that this system has unfortunately been abandoned since the educational reform of October 1971 (Ministry of National Education and Vocational Training, 1971).

As for duplicating science classes, Ministerial Note number 43 (Ministry of National Education and Vocational Training, 2006) states the necessity of adopting doubled classes when the number of learners exceeds 24. This exclusive advantage granted to science classes is due to its experimental character that requires the implementation of practical tasks. However, in response to a question raised in parliament concerning the abandonment of doubled classes, the Ministry of National Education specifies that the mandate of the previous note (Ministry of National Education and Vocational Training, 2006) is still maintained and that this abandonment is mainly due to a lack of human resources.

Finally, the adoption of alternative methods (e.g., Computer-assisted experimentation, mock-ups and software) for ethical purposes and life preservation (S_8). These methods can be used in the case of experiments with insufficient conditions of realization or in the case of experiments that are impossible to carry out in a laboratory (e.g., because of extreme time, environmental, or size constraints) (Mahdi et al., 2017; Nafidi et al., 2018). However, the use of these methods would deprive the learner from sensory-motor or manipulative activity (Marzin-Janvier & Kermen, 2015) and would cultivate in teachers a certain habit of ease and dependence on these alternative methods.

Conclusion

The research carried out on experimental teaching with teachers and inspectors showed the existence of several constraints which hinder the good and effective realization of life sciences experiments in Moroccan secondary schools. It confirmed the existence of technical, pedagogical and ethical constraints in accordance with similar studies at the European level. However, it also highlighted the existence of epistemological constraints (related to the nature of the subject and the teaching practices) which were not reported in the literature. These constraints deprive learners of any sensory-motor investigation attitude and alter the experimental character of life science teaching.

As for the pedagogical objectives of experimental teaching at the secondary level, neglecting the practical and manual sides of the experiment, highlighted by the present research, would lead students to face difficulties in their university training and consequently to an increase in the dropout rate at the university level (the dropout rate at Cadi Ayyad University in Marrakech is 50% in the first year and 25% in the second year (Razouki et al., 2019).

Nevertheless, the advent of technology in the field of education might open up several perspectives and new opportunities to teach experiments in high school life science classes. Technology in the service of education will certainly face different constraints detected in this study and will be able to improve the quality of education by proposing new ways of doing things, ways that take into account national socio-economic and cultural specificities.

Recommendations

Several recommendations should be considered to ensure that science experiments are effectively conducted in the classroom. These are intended to the national ministry of education in Morocco and concern a set of levels.

Firstly, the technical, material and infrastructural level; laboratories must be equipped with necessary elements to conduct scientific experiments in class like water, gas and electricity. Their equipment must be sufficient for the number of students per class and also in accordance with the program.

Secondly, the Pedagogical and training level; the integration of scientific experiments into the curriculum should be explicitly stated, with the time required for their completion. Also, teachers should be trained on conducting experiments and using laboratory tools. And in order to guarantee an effective implementation of the experiments and to accompany the teachers in this practical side of life science teaching, a pedagogical and administrative follow-up is necessary.

Thirdly, the ethical sector; the adoption of alternative methods based on an ethical perspective should be encouraged among teachers. Therefore, the information and communication technology must open new forms of teaching the experimental without having to resort to the sacrifice of the living beings.

Finally, professorial epistemology, as highlighted through observation, influences teachers' classroom practice. Hence the need of rethinking current and future teachers training. Indeed, the training must ensure the integration of the practical side within the experimental approach, as well as grow an awareness among teachers to the different practical and manual skills mobilized or developed by students.

Limitations

Although this study has highlighted various constraints to experiments realization in a science classroom, it may have left other constraints undetected. Indeed, increasing the sample size of interviewed teachers and inspectors may enhance the probability of uncovering additional constraints. Furthermore, collecting additional observations from different secondary schools would also help to detect any variability of these constraints due to schools' sizes and geographic location. This would allow to distinguish between intrinsic and extrinsic constraints.

Authorship Contribution Statement

Bouzit: Conceptualization, design of the research, analysis of the data and writing. Alami: Editing, reviewing and supervision of the research. Selmaoui: Supervision, reviewing of the research and proofreading the article. Rakibi: Contribution to the analysis of the data.

References

Beaufils, D., & Larcher, C. (1999). L'expérimental dans la classe [Experimental in the classroom]. *Aster: Recherches en Didactique des Sciences Expérimentales*, *28*(1), 3-8. https://bit.ly/3Tk2zwY

Bernard, C. (1865). *Introduction à l'étude de la médecine expérimentale* [Introduction to the study of experimental medicine]. Digital version produced by Gemma Paquet. https://bit.ly/3Jk65EA

Bouzit, S., Alami, A., Selmaoui, S., Zaki, M., & Agorram, B. (2020). Didactic modes of scientific experiments in Moroccan high schools: Photosynthesis as an example. *European Journal of Educational Research*, 9(2), 775-785. https://doi.org/10.12973/eu-jer.9.2.775

Bressoux, P. (2012). L'influence des pratiques enseignantes sur les acquisitions scolaires des élèves [The influence of teaching practices on students' academic achievement]. *Crossed Perspectives on the Economy, 12*, 208-217. https://bit.ly/3JH3i8r

Cariou, J. Y. (2015). Le statut épistémologique de l'expérience dans les nouvelles approches préconisées pour l'enseignement des sciences [The epistemological status of experimence in new approaches to science teaching]. *RDST - Recherches en Didactique des Sciences et des Technologies, 12*, 59-85. https://doi.org/10.4000/rdst.1132

Chekour, M., Laafou, M., & Janati-Idrissi, R. (2015). *Les facteurs influençant l'acquisition des concepts en électricité* [Factors influencing the acquisition of concepts in electricity. The case of Moroccan high school students]. Adjectif. http://bit.ly/3JgPaT3

Coquidé-Cantor, M. (1998). Les pratiques expérimentales: Propos d'enseignants et conceptions officielles [Experimental practices: Teachers' comments and official conceptions]. *Aster, 26,* 109-132. https://doi.org/10.4267/2042/8694

Coquidé, M. (2010). Face à l'expérimental scolaire [Facing the school experiment]. HAL Open Science. https://bit.ly/40dUdJT

Coquidé-Cantor, M., Bourgeois-Victor, P., & Desbeaux-Salviat, B. (1999). "Résistance du réel" dans les pratiques expérimentales [Resistance of the living in experimental practices]. *Aster, 28*, 57-77. https://doi.org/10.4267/2042/8716

Coquidé-Cantor, M. (2000). Le rapport expérimental au vivant dans la formation des enseignants. [The experimental relationship with life in teacher training]. *Tréma, 18*, 5-21. https://doi.org/10.4000/trema.1593

Dewey, J. (1929). *Experience and nature.* W W Norton & Co. https://doi.org/10.1037/13377-000

Dinh, B. Q., & Phan, H. T. T. (2018). New approaches in teaching Biology. *Journal of Educational Studies, 435*(63), 40-63.

Directive of the European Parliament and of the Council. (2010). The protection of animals used for scientific purposes (Text with EEA relevance). *Official Journal of the European Union, 276*, 33-79. https://bit.ly/3Yvas3D

Favre, D., & Verseils, I. (1997). Étude de l'acquisition et du réinvestissement du concept de surface portante [Study of the acquisition and reinvestment of the concept of bearing surface]. *Aster, 25,* 33-57. https://doi.org/10.4267/2042/8679

Flageul, R., & Coquidé-Cantor, M. (1999). Conceptions d'étudiants professeurs des écoles sur l'expérimentation et obstacles corrélatifs à sa mise en oeuvre à l'école élémentaire [Student teachers' conceptions of experimentation and related barriers to implementation in elementary schools]. *Aster, 28,* 33-55. https://doi.org/10.4267/2042/8715

Galiana, D. (1999). Les pratiques expérimentales dans les manuels scolaires des lycées (1850-1996) [Experimental practices in high school textbooks (1850-1996)]. *Aster, 28,* 9-32. https://doi.org/10.4267/2042/8714

Giordan, A. (1999). *Une didactique pour les sciences expérimentales* [A didactic for experimental sciences]. Belin.

Hrairi, S. (2004). *Formes et fonctions des expériences dans l'enseignement de la biologie: Cas de la digestion dans le curriculum* tunisien [Forms and functions of experiments in the teaching of biology: The case of digestion in the Tunisian curriculum] [Master's thesis, Ecole Normale Supérieure, Cachan]. HAL Open Science. https://bit.ly/3yfZJQ1

Kochkar, M. (2007). *Les déterminismes biologiques. Analyse des conceptions et des changements conceptuels consécutifs à un enseignement sur l'épigenèse cérébrale chez des enseignants et des apprenants* tunisiens [Biological determinisms. Analysis of conceptions changes resulting from teaching on cerebral epigenesis among Tunisian teachers and learners]. [Master's thesis, Claude Bernard University-Lyon]. HAL Open Science. https://bit.ly/3L0ShQz

Mahdi, K., Sofi, A., Laafou, M., Janati-Idrissi, R., & Madrane, M. (2017). Impact des simulateurs informatiques dans l'enseignement de sciences physiques [Impact of computer simulators in physical science education]. HAL Open Science. https://bit.ly/3YqEQfy

Marzin-Janvier, P., & Kermen, I. (2015). L'expérimental réel ou virtuel en classe de sciences [Real or virtual experiments in the science classroom]. *RDST, 12,* 9-23. https://doi.org/10.4000/rdst.1125

Millar, R. (2004, June 3-4). *The role of practical work in the teaching and learning of science* [Paper presentation]. The Comittee on High School Science Laboratories: Role and Vision, National Academy of Sciences, Washington, DC.

Ministry of National Education and Vocational Training. (1969). *Ministerial note N°56 for Organization of experimental activities, management of laboratories and the use of apparatus and products in Morocco*. Moroccan Archives of the regional academy of national education and Vocational Training.

Ministry of National Education and Vocational Training. (1971). *Pedagogical guidelines and curricula for the teaching of life and earth sciences in qualifying secondary education.* Moroccan Archives of Program Direction.

Ministry of National Education and Vocational Training. (1979). *Ministerial note N°112 for Organization of experimental activities, management of laboratories and the use of apparatus and products in Morocco*. Moroccan Archives of the regional academy of national education and Vocational Training.

Ministry of National Education and Vocational Training. (1982). *Ministerial note N°18 Organization of experimental activities, management of laboratories and the use of apparatus and products in Morocco*. Moroccan Archives of the regional academy of national education and Vocational Training.

Ministry of National Education and Vocational Training. (2006). *Ministerial note N°43 Organization of experimental activities, management of laboratories and the use of apparatus and products in Morocco*. Moroccan Archives of the regional academy of national education and Vocational Training.

Ministry of National Education and Vocational Training. (2007). *Pedagogical guidelines and curricula for the teaching of life and earth sciences in qualifying secondary education.* Moroccan Program Direction.

Ministry of National Education and Vocational Training. (2012). *Answer to an oral question about 'the abandonment of the system of duplication of classes in science subjects in middle and high school' edited by the Ministry of National Education in Morocco*. Moroccan Archives of the regional academy of national education and Vocational Training.

Ministry of National Education and Vocational Training. (2018). *Ministerial note N°133X18 Organization of experimental activities, management of laboratories and the use of apparatus and products in Morocco*. Moroccan Archives of the regional academy of national education and Vocational Training.

Mutti, J.R., & Reginelli, A. (2012). *De l'importance de la pratique expérimentale dans l'enseignement des sciences* [The importance of experimental practice in science education] [Master's thesis, Haute école pédagogique du canton de Vaud]. Patrinum. https://doi.org/10.22005/bcu.17185

Nafidi, Y., Alami, A., Zaki, M., El Batri, B., Hassani, M. E., & Afkar, H. (2018). L'intégration des tic dans l'enseignement des sciences de la vie et de la terre au Maroc: Etat des lieux et défis à relever [The integration of ICT in the teaching of life and earth sciences in Morocco: status and challenges]. *European Scientific Journal, 14*(1), 97-121. https://doi.org/10.19044/esj.2018.v14n1p97

Nguyen, N. V., Pham, H. T., Nguyen, M. T., Nguyen, N. T. H., An, T. B., & Do, L. T. (2021). Developing experiment skills for pre-service teachers of biology in Vietnam. *Educational Sciences: Theory and Practice, 21*(3), 57-73. http://bit.ly/3JhypGo

Ounini, K. (2019). *Les conceptions des futurs enseignants relatives aux pratiques expérimentales* [Future teachers' conceptions of experimental practices] [Unpublished master's thesis]. University of Cadi Ayad.

Razouki, A., Rafouk, L., Bouab, W., EL Hariri, K., Alagui, A., & Nafis, A. (2019). University dropouts and disparities: What's the relationship? *Revista Romaneasca Pentru Educatie Multidimensionala*, *11*(1), 163-176. https://doi.org/10.18662/rrem/103

Russel, W., & Burch, R. (1959). The principles of humane experimental technique. *The Medical Journal of Australia, 1*(13), 252. https://doi.org/10.5694/j.1326-5377.1960.tb73127.x

Senayah, K. E., Tchagnaou, A., Djagnikpo, O.E., & Devi, M.K. (2016). Le rôle de la formation des enseignants dans l'acquisition des compétences par les élèves du secondaire 1 au Togo [The role of teacher training in the acquisition of skills by secondary 1 students in Togo]. *African Education Development Issues, 7*, 139-153. http://bit.ly/3Z2f5Tp

Taoufik, M., Abouzaid, A., & Moufti, A. (2016). Les activités expérimentales dans l'enseignement des sciences physiques: Cas des collèges marocains [Experimental activities in the teaching of physical sciences: The case of Moroccan colleges]. *European Scientific Journal*, *12*(22), 190-212. https://doi.org/10.19044/esj.2016.v12n22p190

United Nations Educational, Scientific and Cultural Organization. (2014). *Teaching and learning: Achieving quality for all.* https://bit.ly/3L191XS