Modelling Activities in Qualifying Training for Future Primary School Teachers: An Attractive Way to Train Competent and Innovative Teachers

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Received: June 2, 2024 Accepted: July 3, 2024 Online Published: July 31, 2024

doi:10.5430/jct.v13n4p15 URL: https://doi.org/10.5430/jct.v13n4p15

Abstract

This paper investigates the outcomes of implementing a model-based training approach at the Centre Régional des Métiers de l'Éducation et de la Formation de Tanger Tetouan Al Hoceima (CRMEFTTH). The primary objective is to enhance the scientific knowledge of future primary school teachers, correct misconceptions about scientific concepts, and develop their creative and innovative thinking abilities, essential for science teaching. The approach involves trainee-teachers producing and utilizing scientific models, following a structured process prioritizing reflection and creativity.

The training process begins with a pre-test to assess trainees' existing knowledge, followed by modelling activities where groups manipulate models based on specific instructions. This phase concludes with a post-test to evaluate the impact of analogue modelling on the understanding and appropriation of scientific concepts. Additionally, a satisfaction questionnaire is analyzed to assess the effectiveness of the approach.

The results demonstrate that this modelling approach significantly enhances the training of novice teachers by improving their comprehension and representation of scientific concepts. The analysis of the questionnaires revealed that trainee teachers were highly satisfied with their achievements and the skills they developed, including observation, conceptualization of phenomena, production and evaluation of models, imagination, and team spirit.

The implications of this study suggest that implementing modelling-based training approaches in teacher education programs can significantly improve the quality of science teaching in primary schools. By equipping future teachers with the necessary skills and knowledge to effectively construct scientific concepts to young learners. This approach has the potential to transform science teaching at primary level.

Keywords: modelling, teaching tools, scientific concepts, trainee teachers, qualifying training

1. Introduction

Quality education for future citizens depends on appropriate curricula and well-trained teachers capable of implementing particular programs. Successive reforms of the Moroccan education system have made teacher training a fundamental condition for success in school (Lahchimi, 2015). Teacher training in Morocco has undergone significant changes, which can be attributed to the various reforms and curricular revisions that have affected the education system since the 1990s. The latest reforms have focused on professionalizing training and adopting innovative teaching practices and approaches as the foundation for qualifying trainee teachers for the teaching profession.

1.1 Qualifying Training for Trainee Teachers at the CRMEFs

The CRMEFs (Centre regional des métiers de l'éducation et de la formation) were created in 2011 as the sole training and qualification structures for future teachers in Morocco. This has led to a new model of teacher professionalization, which focuses on developing the skills required to carry out teaching and learning activities. The CRMEFs aim to develop planning, managing, and evaluating skills over two semesters of training. The training is divided into mostly pedagogical/didactic training and a minor part of disciplinary training. This training model considers pedagogical research as a crucial element of professional teacher training. It enables teachers to reflect on their practice in relation to the theoretical foundations of pedagogy. The training system, based on the competence approach, alternates between theoretical training and practical exercises, following the practice-theory-practice paradigm (Conseil Supérieur de l'Education de la Formation et de la Recherche Scientifique [CSEFRS], 2014).

Teacher training in Morocco is a top priority and concern, with a dedicated focus on renewing the teaching, training, and management professions. This is in line with the strategic vision of the 2015/2030 reform, as approved by law 51-17. (Lever 9, Strategic Vision, page 30) (CSEFRS, 2017). The Ministry of National Education, Vocational Training, Higher Education and Scientific Research has recently reformed the teacher training system in the CRMEFs. The training engineering has been renewed and the systems have been modernized in partnership with the United States Agency for International Development (USAID) as part of the Higher Education Partnership - Morocco (HEP-M). This program aims to support the Ministry's efforts in implementing Framework Law 51.17, which pertains to the education, training, and scientific research system. Specifically, it focuses on the initial training of primary school teachers (Royaume du Maroc, 2020).

The Regional Centers have been developing a new training system from the 2020-2021 training year onwards. They have improved the existing systems and taken into account the latest developments in modern teacher training around the world. The new system is based on the competency-based approach as a methodological framework for its development. It follows a modular-program structure and adopts sandwich training, with a focus on professional activities as part of the practice-theory-practice paradigm. Regarding the reflective dimension, the new qualification program for the teaching profession at the CRMEFs was mainly influenced by the analysis of practices, didactic production, and guided autonomous training.

1.2 Modelling and Production of Teaching Aids

Although the term 'teaching aid' typically refers to any material device used in the teaching-learning situations, such as a blackboard, computer, video projector, or textbook, we will use the term 'teaching aid' here to refer to any non-ordinary material created by the teacher specifically to facilitate learners' understanding of a scientific concept or phenomenon. This material has been created by the teacher for teaching purposes. It includes analogue models and mock-ups that aim to simplify and facilitate the acquisition of scientific concepts that are generally abstract or difficult to teach.

Teaching aids are crucial in the teaching and learning process as they facilitate the understanding and representation of concepts. In scientific activities, these tools are indispensable for teachers as they help in the understanding and simulation of natural phenomena, making it easier for learners. However, the role of academic writing is not limited to explaining phenomena. It can also be an excellent means of developing practical professional skills for trainee teachers.

Models are abstract and simplified representations of a system of phenomena that make its central features explicit and visible and can be used to generate explanations and predictions (Harrison & Treagust, 2000). They are widely used in science and technology to represent and explain scientific phenomena that are difficult to access or even abstract (Aurousseau, 2017; Krell, Walzer, Hergert, & Krüger, 2019; Schwarz, Salgado, Ke, & Manz, 2022). They provide a simplified representation of complex phenomena that cannot be directly observed, unlike experiments carried out under real conditions. They are tools that allow teachers to replace reality, which is generally complex and inaccessible to experience, with a simpler intermediary that is easier to understand and recognize as a model. The latter reduces the complexity of reality to make it understandable and comprehensible to the learner, while allowing simulations that would be impossible on the object itself (Drouin, 1988). Model-based reasoning and the creation of models are essential elements of human cognition and scientific research (Lankers, Timm & Schmiemann, 2023; Schwarz et al., 2022). Practical research has shown that adopting models in science teaching has a positive effect on learning, improving learners' knowledge at several levels (Mierdel, & Bogner, 2021; Mierdel, & Bogner; 2019; Wilson, Long, Momsen, & Speth, 2020). Models are seen as tools for encouraging learning and developing scientific reasoning by generating scientific research questions and referring them back to the models (Werner, Förtsch, Boone, Von Kotzebue, & Neuhaus, 2017).

We are talking here about explanatory models associated with physical systems, not predictive models, which are generally reserved for mathematical systems. They are defined by Blanquer and Picholle as "a fiction, endowed with a certain degree of generality, whose object is a simplified vision of the physical world, of a part of it, or of phenomena taking place in it" (Drouin, 1988).

Scale models are concrete objects built to resemble the object being studied. They facilitate the observation of scientific phenomena that would otherwise require a great deal of time and space, and the visualization of phenomena that are inaccessible and complex to imagine. Scale models are used to represent all or parts of an object or project in order to obtain a faithful representation of it and to assess whether it can be built. However, a model can also be made for a simpler purpose, that of a more playful role or even a simple game, but also to develop the learner's sense of creativity and imagination. The art of statically representing an object or phenomenon in two or three dimensions, reduced or enlarged, highlighting it, simplifying its operation and pedagogically demonstrating its mechanisms, makes the model a very important teaching tool.

Modelling can be defined as the practice of investigating and explaining complex phenomena or systems (Berland & Reiser; 2009; NGSS Lead States, 2013; Krell et al., 2019). It refers to the multiple processes of design, production, experimentation and evaluation of these didactic tools in the form of models and mock-ups designed for didactic purposes. Modelling is seen as a creative process linked to the production of tools and the validation and dissemination of scientific knowledge (Gilberti, Boulter, & Elmer; 2000). The modelling process consists of several complex stages related to the acquisition of information about the entity to be modelled, the production of a mental model of it and its expression in an appropriate form of representation, its mental and empirical experimentation, and finally the evaluation for possible revision of the model (Justi & Gilbert, 2002; Schwartz & White, 2005)

At least three basic methodological skills can be mobilized through modelling (Blanquet & Picholle, 2015):

- A conscious distance or distinction between the physical world and its representations, with the idea that it is the great simplicity of the model that makes it operational;

- Navigation between the model and the represented system;

- Identifying and extracting the parameters and mechanisms relevant to its operation.

Consequently, this tool is a very important means to reflect on the establishment of relationships between the different components of the model and to stimulate scientific understanding, argumentation and justification of the different choices made during the design and the objectives set for each model (Maia & Justi, 2009). In this way, student participation and involvement in modelling activities will promote mastery of the practices involved in constructing and evaluating scientific knowledge (Schwartz & White, 2005; Lehr & Schauble, 2007; Wilson et al., 2020). This will be more effective in an environment that provides opportunities for investigation and discovery (De Jong et al., 1999). This is a context in which scientific modelling allows elements of the practice of model construction, use, evaluation and revision to be combined with the meta-knowledge that guides them, namely an understanding of the nature and purpose of models (Schwarz et al., 2009; Louca & Zacharia, 2012).

Modelling is the process of representing a complex system with a simpler one that is easier to understand than reality. It is used in various ways in science teaching (Streiling, Hörsch, & Rieß, 2021; Kiesewetter & Schmiemann, 2022). In our training context, we consider it a process through which trainee primary school teachers exercise their ability to design models that facilitate the assimilation of complex scientific concepts and phenomena at their formulation levels in primary cycle. The modelling approach is explicitly presented in the training system at the CRMEFs. This is particularly covered in a module devoted to didactic productions, which includes several types of teaching output. These range from teaching sheets for planning sequences, learning situations, and assessments to the production of teaching/learning tools required for teaching scientific concepts and extracurricular activities. In view of the different aspects included in this module, the time allocated to modelling is too limited.

1.3 Issues and Objectives of the Study

The training schemes implemented during the years of reform and reorganization have produced bilingual, multi-skilled primary school teachers with a range of professional and multidisciplinary skills. This study focuses on science training, specifically related to 'Scientific activities' or 'scientific awareness' as it is referred to in the primary education cycle in Morocco.

This subject was reviewed as part of the renewal of the national school's missions. The aim is to create a lively and open environment that is responsive to scientific and technological developments. This can be achieved by adopting a diverse, open, efficient, and innovative teaching model (Curriculum Directorate, July 2020). The 2021 primary cycle curriculum has undergone changes in scientific concepts covered, hours allocated to the subject, and integration of technological projects and computer science. The new curriculum design includes basic cognitive content, scientific practices and skills, and values and attitudes. The content is divided into five areas: life sciences, physics, earth and space sciences, technology and computing. Scientific practices revolve around the investigative approach adopted in science teaching at the primary level, including all stages of its implementation. The new curriculum places significant emphasis on integrating values and attitudes such as scientific curiosity, analysis, research, and cooperation into the teaching programs. This integration is to be carried out in its three conceptual, spiritual, and operational dimensions, which are linked to knowledge, know-how, and life skills.

Disciplinary skills related to scientific subjects require new training practices for trainee teachers. This will produce responsible and innovative teachers who are capable of achieving the objectives set for science teaching and learning. Our work focuses on a new training practice based on the production of didactic tools. This practice aims to simplify scientific concepts taught in class and help trainee teachers acquire the fundamental skills necessary for the teaching profession. We start by acknowledging that training trainee teachers at the CRMEFs level is challenging due to the great heterogeneity of trainees with different academic specialties, most of which are far from the scientific domain (El Hnot, Cherai, & Sibari, 2023), in addition to the minority disciplinary training provided for trainee teachers.

Our study aims to address the following question: What is the contribution of modelling activities to the training of competent and innovative primary school teachers?

To achieve this, we reflect on the training of bilingual and multi-skilled trainee primary school teachers within a systemic and coherent vision of all the components of their qualification for the teaching profession in training centers.

The objective of this study is to investigate how the modelling approach can enhance the training of trainee teachers, making it easier for them to comprehend, represent, and simplify scientific concepts for teaching at the primary level. Additionally, it aims to identify the obstacles faced by trainee teachers in designing and using models to explain scientific phenomena and concepts. The aim is to characterize the process of using modelling as a means and technique of training trainee teachers to teach science.

The present study aims to translate knowledge into practical action and stimulate innovation in trainees. It encourages them to contribute to the creation of training activities that consider the heterogeneity of trainees, with the goal of developing their creativity and making them inventive and creative actors. To achieve these objectives, we worked with trainee teachers at the CRMEFTTH, Tetouan branch, in workshops dedicated to the creation of didactic tools and models for teaching scientific concepts.

2. Method

Based on these considerations, and to answer the question regarding the role of the creation of didactic tools and analogical models in the professionalization of the training of future teachers, we have chosen to work with trainee teachers in interactive and reflective workshops dedicated to the design of tools and analogical models that facilitate the teaching-learning of scientific concepts. These training workshops are linked to the 'didactic production' module and associated with the sessions for upgrading scientific concepts relating to the 'support for basic training' module, which is part of the qualifying training provided by the CRMEF.

2.1 Approach

This approach uses modelling to teach scientific concepts at the primary level. The study aims to achieve two objectives: Firstly, to reduce the gaps in the disciplinary knowledge of science that some trainee teachers have, as well as the obstacles they encounter by simplifying these concepts in order to teach them to primary school pupils. Secondly, to develop the trainees' ability to devise and innovate simple ways of presenting these concepts in learning activities for the benefit of primary school pupils. This involves examining and analyzing the practices that trainee teachers use to create didactic tools and analogical models for teaching purposes.

This study tested an approach based on modelling activities on a population of 110 trainee primary school teachers at the Tetouan branch, during the 2022-2023 qualifying training year. We carried out this study in the following stages:

i. Step 1: A diagnostic test.

This test was given at the beginning of the course and focused on basic science concepts that are of great interest in primary science learning (Trudel, Prent, & Métioui, 2010).

The observations made during the previous years of training and the results of the diagnostic test of these trainee teachers led us to conclude that the majority of them lacked the disciplinary skills necessary to construct scientific knowledge and teach these concepts to primary school pupils. This observation may be associated with deficiencies in their understanding of the basic concepts of science (El Hnot et al., 2023).

ii. Step 2: Establishing a conceptual and methodological framework for the development of teaching materials.

This involved training trainee teachers in the principles and techniques of scientific modelling and the usefulness of analogue models for teaching and didactic implementation of scientific concepts taught at primary level. The aim has been to introduce trainees to the techniques of designing didactic models and mock-ups that can be used to describe scientific phenomena or concepts qualitatively and quantitatively and to present them in a simplified and comprehensible way as an object of learning. This stage was integrated in the first sessions of the module, as part of the recognition of the different scientific concepts covered in the primary cycle in the discipline of "scientific activity" and the different materials that can be used for the design and production of different teaching aids. We were therefore able to choose the scientific concepts to be modelled: the solar system, electricity, digestion and respiration.

This step was taken to motivate trainee teachers to create alternatives that would enable them to overcome the constraints associated with teaching abstract concepts that are incomprehensible to primary school pupils, while encouraging them to relate science to the world around them.

iii. Step 3: Create a case study to test the modelling approach in training.

With this in mind, we chose to work on the concept of breathing, following the three steps below (Figure 1):

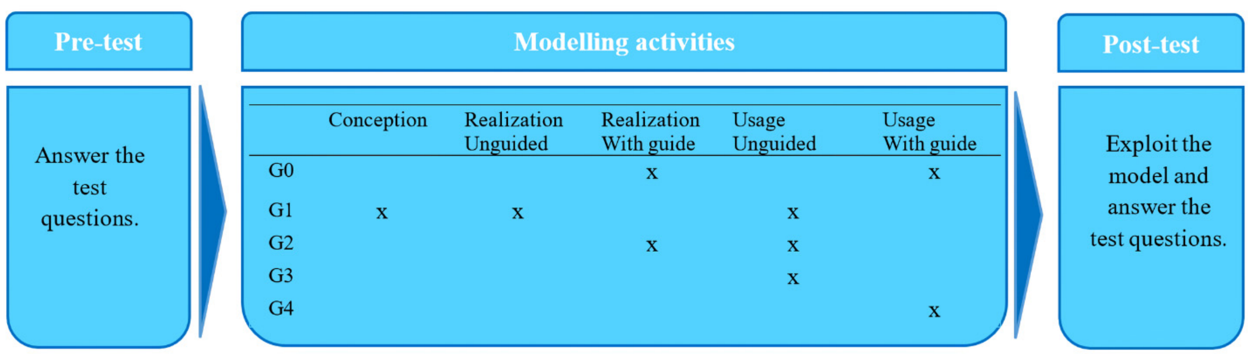

Figure 1. Case Study Design

- The pre-test

Firstly, a pre-test was carried out to assess what these trainee teachers had learned about human respiration before moving on to modelling and to see its impact on their learning. The aim of the test was to assess their knowledge of the relationship between ventilation and the movements of the diaphragm and ribcage. It consisted of filling in diagrams with arrows showing these movements and then explaining the phenomenon in a few lines (Figure 2).

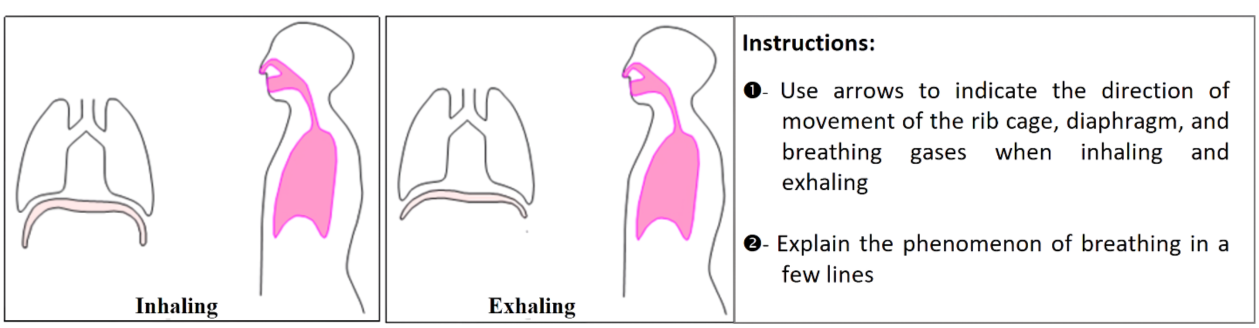

Figure 2. Diagrams Used in the Respiratory Concepts Test

- Modelling activities

The model was made using simple plastic materials (a tube (20 cm), a bottle, two rubber balloons, a rubber band, etc.) and ordinary school materials (scissors, cutter, string, modelling clay, etc.) according to the steps shown in figure. 3a. Each element of this constructed model is similar to a part of the respiratory system, as shown in figure. 3b.

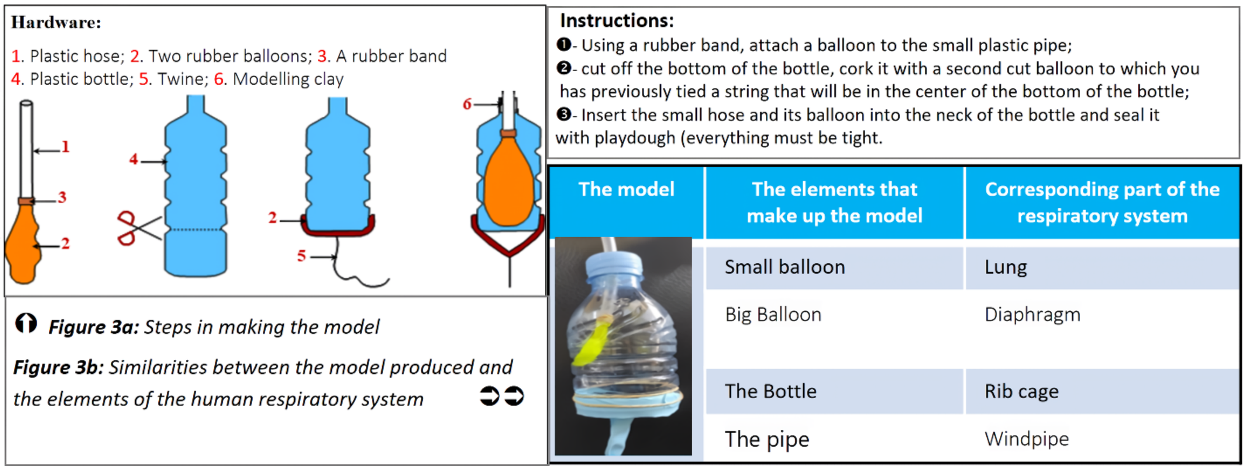

Figure 3. Model Elements Corresponding to Parts of the Respiratory System

For the implementation of modelling activities, our study sample was divided into 5 class groups of 22 trainee teachers each, and for each group we presented the materials needed to make the model that was the subject of the training, while specifying the tasks and instructions for each group (Figure 1). During this activity, the instructions for each group were chosen to create difficulties at different levels of creating an analogue model of the human respiratory system, designing it, making it, operating it and finally using it to answer the test questions. The G0 group was considered to be a positive control group, as it benefited from all the conditions necessary to create the model and use it to answer the test. The other groups, G1, G2 and G3, each had at least one difficulty to overcome. Group G4 was chosen in order to anticipate the students' ability to use existing didactic tools (models, scale models) to teach the scientific concepts covered in the primary cycle (refer to Table 1).

Table 1. Materials Presented, and Instructions Required for Each Group

Group	Featured material	Instructions	The difficulty to overcome
G0 (control group +)	Material + model diagram + guides for making and using the model	Make the model of the respiratory system, operate it, and answer the same test a second time.	No
G1	Hardware	Make the model of the respiratory system, operate it, and answer the same test a second time.	- Designing a model, making it and using it, - Innovation - Creativity
G2	Material + Model Diagram	Make the model and use it to answer the same test a second time.	- Production of the model from a schematic. - Using the model.
G3	Model already produced	Use the model and answer the same test a second time.	Use of the model and linking its function to the functioning of the human respiratory system.
G4	Model already produced + guide to using the model	Use the model as described in the instruction sheet and answer the same test a second time.	Interpret by making similarities between model and human respiratory system.

- Post test

It consists of answering the same test given previously a second time, using the model produced or the one already presented.

iv. Step 4: Assessing the reliability of modelling in the acquisition of scientific concepts.

In order to assess the effectiveness and importance of this modelling approach in improving the qualification of trainee primary school teachers, we evaluated the effect of these activities on the appropriation of scientific concepts. In addition to knowing the direct effect on the improvement of correct answers to the test's questions in the case study, the aim was to assess the level of satisfaction of the beneficiaries of the whole training course with the model-based activities. To carry out this post-training evaluation, we chose to use a questionnaire focused on the three training activities (knowledge, know-how and interpersonal skills) in the didactic production module (scientific pole). This was designed in three different dimensions related to the operationalization of the training activities:

- The first dimension is related to the methodology used in the training and the resources made available. It comprises five complementary variables: the relevance of the approach taken in the training (MM1), the clarity of the workshop objectives (MM2), the appropriateness of the materials and tools provided (MM3), the training climate (MM4) and the simplicity and effectiveness of the resources used (MM5).
- The second dimension relates to the pedagogical framework and content of the training. It comprises six different variables: the theoretical and practical content of the training (CA1), the responsiveness of the workshop content to the trainees' expectations (CA2), the clarity and relevance of the instructions (CA3), the pedagogical leadership and mastery of the approach by the trainers (CA4), the support and help received from the supervisors (CA5), and the sharing and exchanging among the beneficiaries (CA6).
- The third dimension relates to the impact of the modelling activities on the acquisition of the scientific concepts covered in the training and any other benefits derived by the trainee teachers. Five variables were used to assess this dimension: (EAM1) Achievement of workshop objectives, (EAM2) Correction of representations and assimilation of scientific concepts, (EAM3) filling of gaps and bringing scientific knowledge up to standard, (EAM4) Usefulness of the approach taught and ability to implement and reuse it. (EAM5) Stimulation of the imagination and development of the sense of observation and (EAM5) Stimulation of the imagination and development of the sense of observation.

The 16 variables related to the three evaluation dimensions above were measured using a Likert scale ranging from 0 (not at all satisfied) to 3 (very satisfied). The data collected were statistically processed and analyzed using SPSS (IBM SPSS Statistics 25).

It should be noted that the questionnaire used in this evaluation underwent a validation process before being implemented. This validation was based on the opinions of 11 experts in science didactics and teacher training at the CRMEFs. After being revised by the experts, the questionnaire was tested on 44 trainee teachers in order to assess its reliability using Cronbach's coefficient, which gave a score of 0.78 for the internal consistency of the questions asked in our test.

2.2 Characteristics of the Study Population

The study targets the primary school teacher trainees during the academic year 2022-2023 at the CRMEFTTH, Tetouan branch. The majority of this population is female (78.12%), aged between 20 and 30, with the 23-26 age group dominating with 69.25% of the population. The population is very heterogeneous in terms of higher education qualifications and type of initial training, with 35.73% having a bachelor's degree in economics and management, followed by (25.48%) with a bachelor's degree in law. Trainees with a science degree in any discipline accounted for only 21.05%, while those with a bachelor's degree in education represented only 7.20% of the population (Figure 4). They are part of the reform program of the education management training system, launched in 2018 with the creation of the Bachelor of Education (CLÉ) in the Higher Normal Schools (ENS), the Higher Education and Training Schools (ESEF) and the faculty of sciences education (FSE). They present the profiles required for teaching at primary level, giving effect to the five-year teacher training architecture introduced by the recent reform of the education management training system.

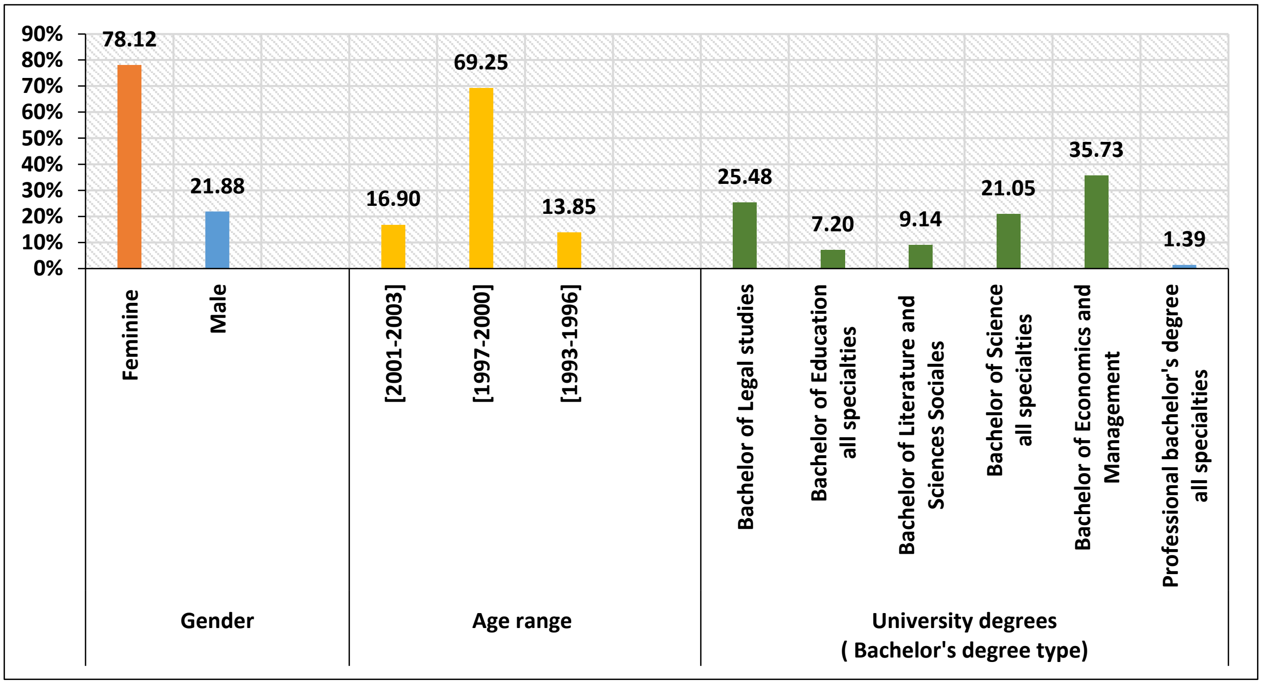

Figure 4. Histogram Showing Statistics for Study Population Characteristics

3. Results

3.1 Pre-test Results: Level of Mastery of Concepts Related to Respiratory Ventilation

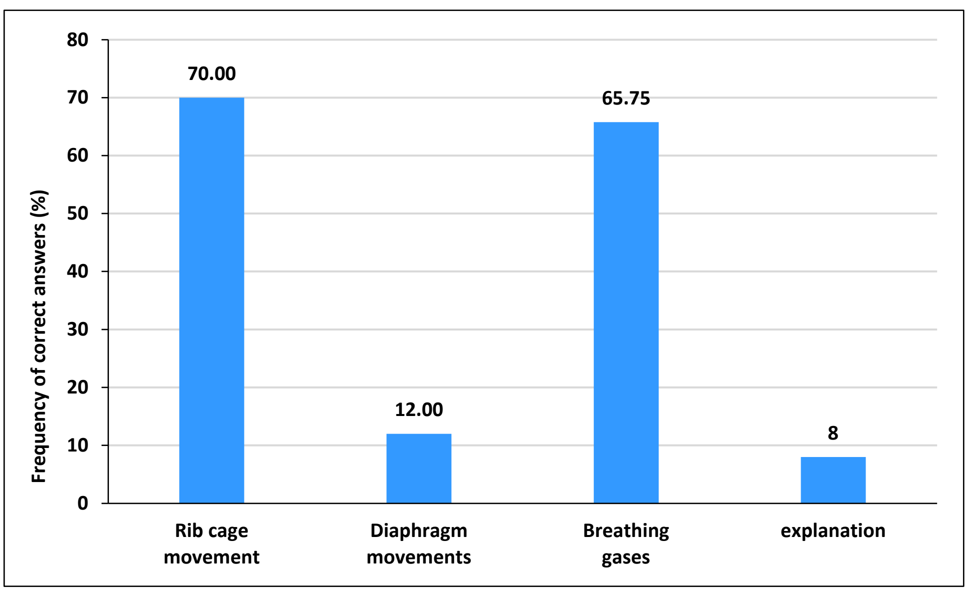

Figure 5. Pre-test results: Level of Mastery of Concepts Related to Respiratory Ventilation

In order to assess the pre-service teachers' knowledge of the subject "scientific activity", which includes concepts of experimental science intended for primary school students, we decided to analyze the answers to the questions of the pre-test, which focused on concepts related to respiration. The graph in Figure 5 shows that the frequency of correct answers for all members of the sample was over 65% for understanding the movements of the respiratory gases and the thoracic cage (70%), whereas knowledge of the movements of the diaphragm and its relationship to ventilation was very poor, with only 12% answering this question correctly. The explanation given for this phenomenon had only 8% correct answers. This shows that these trainee teachers had difficulty explaining the relationship between ventilation and the movements of the diaphragm and thoracic cage due to a poor understanding of the concepts related to breathing at the lowest level of formulation. It is evident that in order to comprehend the respiratory system at this cognitive level, it is necessary to establish a relationship between the various elements involved. This can be achieved by defining inspiration as the result of a contraction that takes place in both the external intercostal muscles, causing the ribs to rise, and the diaphragm, which lowers, leading to an increase in lung volume. This, in turn, creates a depression inside the rib cage, which calls for air to enter. The relaxation of the external intercostal muscles causes the ribs and diaphragm to drop, exerting compression on the lungs and causing air to be expelled into the atmosphere. This outflow of air is the embodiment of the process of expiration, which follows inspiration, together causing pulmonary ventilation.

3.2 Results of Modelling Activities

3.2.1 Results of Tests Before and after Model Creation and Use in Groups G0, G1 and G2

Analysis of the results of the tests before and after the creation and use of the model shows that these modelling activities had no significant effect on the understanding of the movements of the thoracic cage and the respiratory gases in the three groups G0, G1 and G2 (refer to Figure 5). It is assumed that the majority of trainee teachers are already familiar with these basic concepts and have no difficulty in understanding them. However, understanding the movements of the diaphragm during breathing was a problem for most of them and it can be seen from the results (graph) that modelling made a remarkable contribution to overcoming these problems, especially in groups G0 and G1, where the frequency of correct answers increased from 31.81% to 90.90% and from 31.81% to 36.36% respectively. This represents a 60% improvement for the G0 group (Figure 6). This is due to the fact that this group was given all the information they needed to build the model and use it correctly. For the G2 group, there was an improvement of 36.88%, but it was still unsatisfactory. This can be explained by the fact that this group was not given prompts on how to use the model, which is why the majority of the trainees were able to create the model but had difficulties in using it (Figure 6).

The results for group 1 were unsatisfactory. This can be explained by the fact that these trainee teachers were not able to construct an analogue model with the materials available, so there was no clear improvement in understanding the movements of the diaphragm and the respiratory gases.

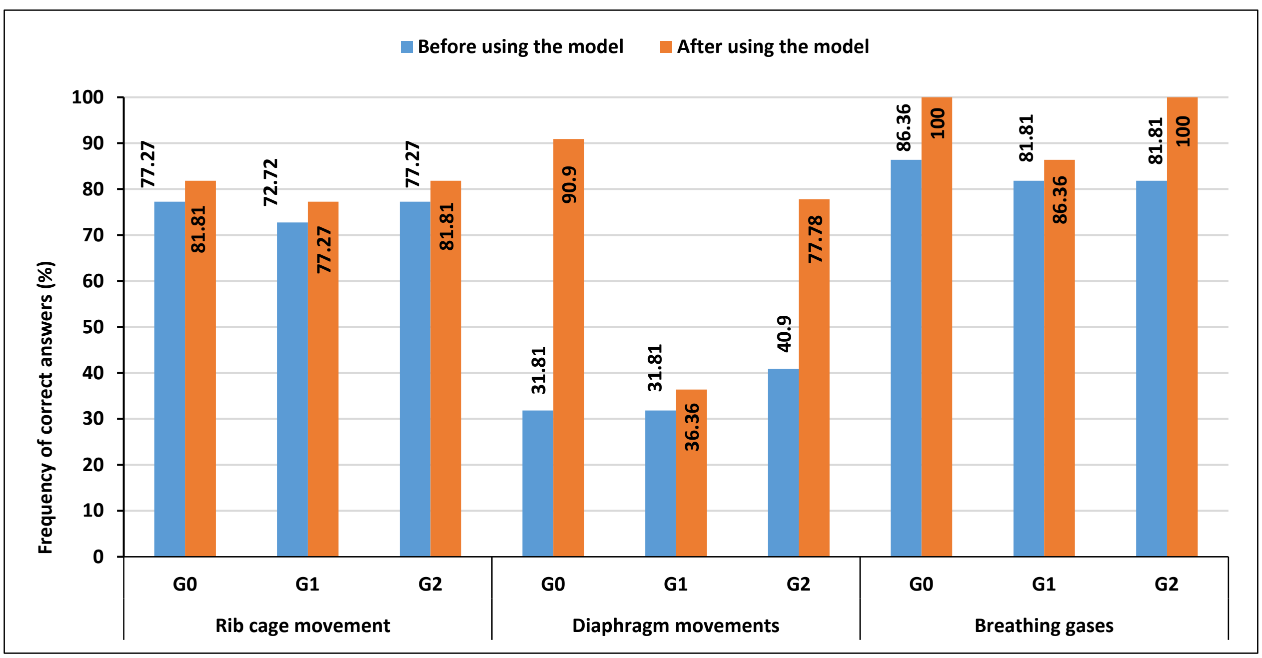

Figure 6. Test Results before and after Model Creation and Use in Groups G0, G1 and G2

By closely monitoring the practical activities associated with the individual construction of the model and its use to accomplish the test instructions, we were able to detect differences between the students' abilities to relate this model to the functioning of the human respiratory system. Only 45.46% of the students in Group 1 were able to use the model, and 59.10% of them used it incorrectly. In the absence of support and assistance, the model posed a number of problems for the trainee teachers. In fact, during the session we noticed that some trainees blew into the 'trachea' tube, others tried to crush the 'thoracic cage' bottle and some did not know what to do with the model. This can be explained by the fact that these students do not have the concept of the autonomy of the organism to guarantee the functioning of the respiration, so they blow to make the air enter the bottle.

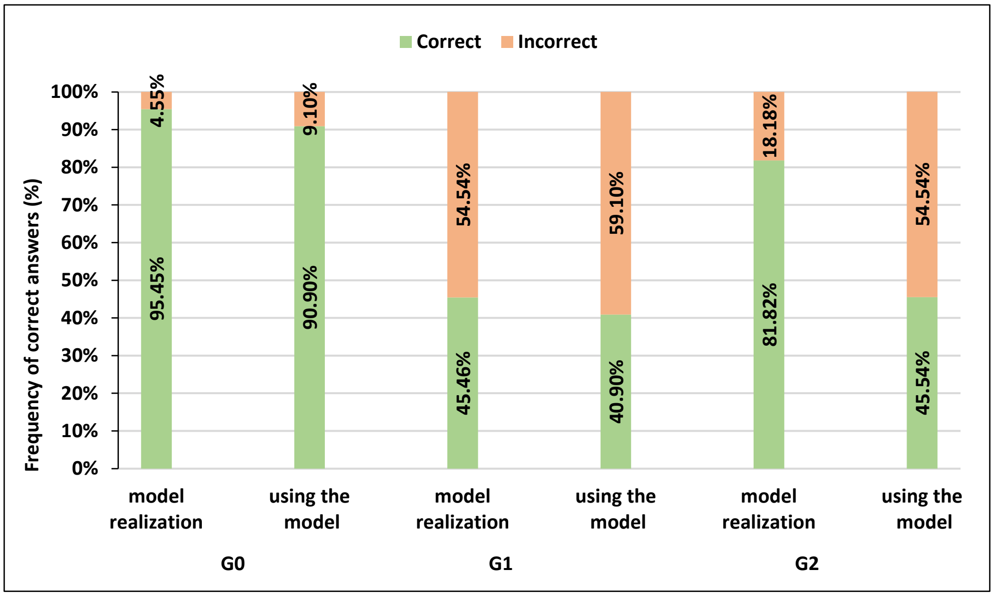

Figure 7. Model Realization and Use Skills of G0, G1 and G2 Trainees

When the student blows into the tube (i.e. exhales), his chest collapses and so he places the arrows on his body according to what he observes. However, at the level of the model, the student is in the process of inhaling (taking air into the bottle), which suggests an increase in the volume of the chest (bottle). However, due to the rigid wall of the latter, the trainee does not observe these movements. This is one of the limitations of the model.

Group 2 demonstrated a high level of proficiency in completing the model, with 81.82% of trainee teachers achieving this outcome. However, only 45.54% of them demonstrated the correct use of the model. This indicates that while providing teachers with didactic tools is beneficial, it is equally important to provide them with support in using these tools effectively during their teacher training.

3.2.2 Pre and Post Model Test Results in Groups 3 and 4

For groups G3 and G4, we have chosen to give them models that have already been developed. This allows us to check whether the fact of building a model has an influence on the understanding of a concept and to test the ability of the trainee teachers to use the didactic tool in the act of teaching-learning and to use it to assimilate the functioning of the human respiratory system and then to be able to answer the questions of the test.

The results show that, as in the G1 and G2 groups, the concepts of chest movements and the movement of respiratory gases do not pose problems for the trainee teachers. However, it is the movement of the diaphragm that poses a difficulty for them. The graph in Figure 8 shows that after using the analogue model, the movements of the diaphragm were correctly understood by 81.81% of the trainee teachers in the G4 group, compared to 27.27% before using the model. On the other hand, in the G3 group, only 40.90% of the answers were correct. This is because, without a user guide, the trainees in this group were unable to get the model to work properly to answer the questions. It should also be noted that the result in the G3 group was low compared to the G2 group who also did not have the guide to use the model. It can be concluded that the development of the model, while promoting manual and creative activity, plays an important role in the acquisition of operational skills leading to the understanding and assimilation of the concept, which was well reflected in the improvement of the test results.

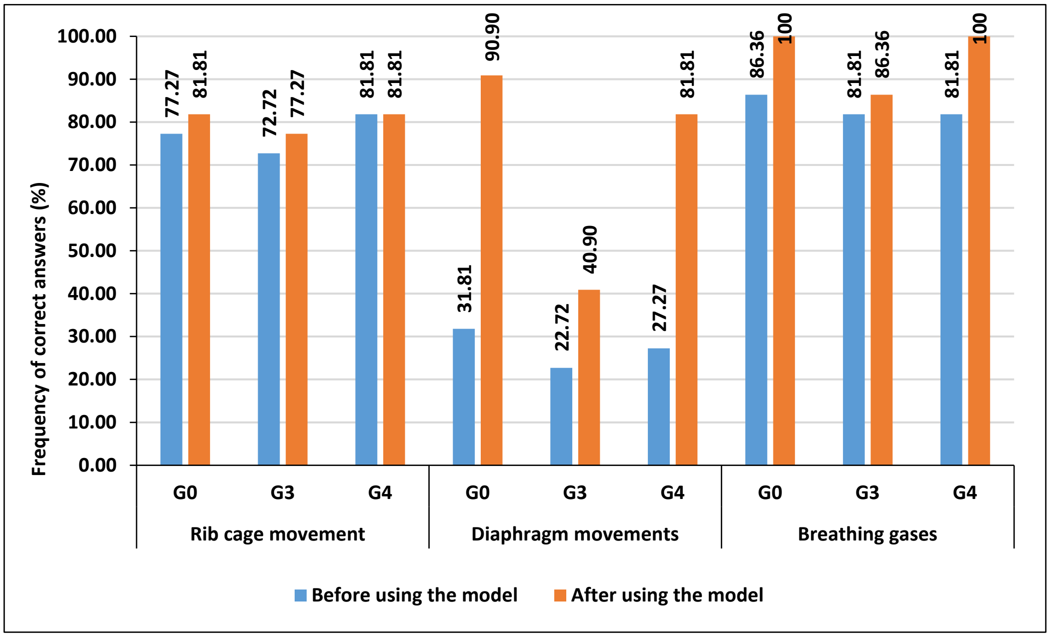

Figure 8. Pre and Post Model Test Results for G0, G3 and G4 Groups

In order to test the ability of the trainees to use the didactic tool in the process of teaching and learning, and to use it to understand the functioning of the human respiratory system and subsequently to be able to answer the questions of the test, we decided to present the two groups G3 and G4 with a model that had already been established, with an instruction manual for the benefit of group 4. The results show that the teacher trainees in the G3 group, although they had access to the model, were not able to use it correctly (63.64%) to know the mechanisms of inhalation and exhalation (refer to Figure 9). On the other hand, the G4 group, which had access to the manual in addition to the model, performed much better, with 100% of the trainees answering the test correctly.

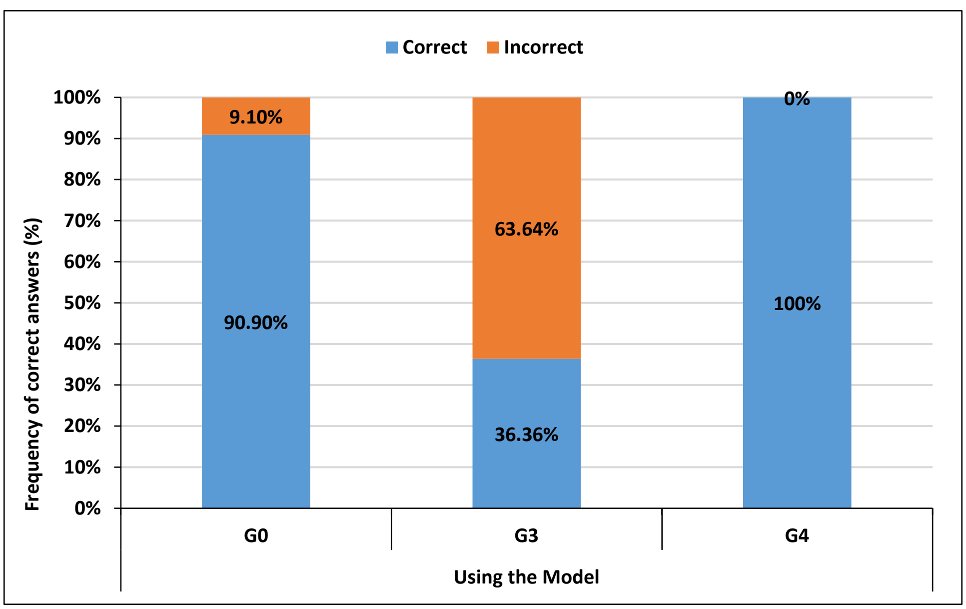

Figure 9. Model Usability of G0, G3 and G4 Trainees

3.3 Results of the Evaluation of Trainee Teachers' Satisfaction with the Modelling Training Approach

In addition to the observations and comments made during the training activities, we decided to evaluate our training modelling approach at the end of the training using a questionnaire designed for this purpose.

For this qualitative post-training evaluation, we present here the results of a cold questionnaire that was administered one week after the end of the training in order to allow the trainees to answer with some hindsight. The questionnaire is structured to provide closed-ended questions that require quantifiable responses according to the Likert satisfaction scale (refer to Table 2). For each dimension, several variables were selected and measured on a scale ranging from 0 (not satisfied) to 3 (very satisfied). These variables focused on the methodology used in this training, the equipment provided, the facilitation techniques used and the impact of this approach on improving the knowledge and skills needed to teach scientific concepts in primary schools.

In order to use the results of this evaluation tool, we carried out a statistical, descriptive and inferential analysis of the data collected.

Table 2. Dimensions and Variables of the Assessment of Trainee Teachers' Satisfaction with Modelling Activities in Training

Assessment Dimensions	Satisfaction variables	Answer Options			
		0	1	2	3
Methodology and resources put in place (MM)	**MM1:** Relevance of the approach followed in the training	3.67%	7.18%	19.32%	69.83%
	MM2: Clarity of workshop objectives	4.24%	8.28%	19.75%	67.73%
	MM3: the adequacy of the equipment and materials made available	2.71%	10.37%	24.55%	62.37%
	MM4: The climate of training	1.10%	4.37%	21.78%	72.75%
	MM5: Simplicity and efficiency of the means used	1.56%	3.32%	33.36%	61.76%
Content and facilitation of the training (CA)	**CA1:** Theoretical and practical content of the training	2.11%	8.37%	23.77%	65.75%
	CA2: Response of the content of the workshops to the expectations of the trainees	5.17%	11.58%	28.77%	54.48%
	CA3: Clarity and relevance of instructions	9.13%	8.02%	23.10%	59.75%
	CA4: Pedagogical animation and mastery of the approach on the part of the trainers	3.09%	11.17%	20.59%	65.15%
	CA5: Accompaniment and help received from supervisors	2.11%	8.37%	23.77%	65.75%
	CA6: Sharing and exchange between beneficiaries	1.08%	2.27%	18.63%	78.02%
Effect of modelling activities and benefit to trainees (EMA)	**EMA1:** Achievement of Workshop Objectives	2.11%	8.37%	23.77%	65.75%
	EMA2: Correcting representations and assimilating scientific concepts	6.21%	8.11%	29.52%	56.16%
	EMA3: Filling gaps and upgrading scientific knowledge	9.71%	9.71%	23.29%	57.29%
	EMA4: usefulness of the approach transmitted and ability to implement and reuse it.	4.23%	5.78%	43.17%	46.82%
	EMA5: Stimulation of the imagination and development of the sense of observation	2.71%	12.12%	32.55%	52.62%

0 : Not at all satisfied, 1 : Not very satisfied, 2 : satisfied 3 : Very satisfied

3.3.1 Descriptive Analysis of the Results

The descriptive analysis of the data corresponding to each dimension of the assessment is mainly based on the analysis of the response frequencies of the assessment test for each variable and then on the analysis of the combinations of variables belonging to the same dimension.

3.3.1.1 Satisfaction with the Methodology and Means Used during the Training

With regard to the five variables chosen to assess the quality of this training approach in terms of its methodology and the means used, the trainees interviewed expressed their great satisfaction with practically all of them: 69.83% very satisfied with the relevance of the approach followed in the training and 67.73% very satisfied with the clarity of the objectives of the workshops. For the other variables, the responses ranged from satisfied to very satisfied, with 24.55% and 62.37% respectively for the adequacy of the equipment and materials provided, 21.78% and 72.75% for the climate of the training and 33.36% and 61.76% for the simplicity and effectiveness of the tools used. The mean score for the variables related to the methodology and tools used during the training was 2.55 with a standard deviation of 0.56 (refer to Table 3).

3.3.1.2 Satisfaction with the Training Content and Facilitation Techniques

Concerning the content of the modelling activities and the facilitation techniques used in this training, the results show responses from satisfied to very satisfied with 23.77% and 65.75% respectively for the theoretical and practical content of the training, 28.77% and 54.48% for the clarity and relevance of the instructions, 23.10% and 59.75% for the clarity and relevance of the instructions. 23.10% and 59.75% for the clarity and relevance of the instructions, 20.59% and 65.15% for the pedagogical animation and mastery of the approach on the part of the trainers, 23.77% and 65.75% for the support and help received from the supervisors. The trainees were very satisfied with the sharing and exchange between the beneficiaries, with a score of 78.02%. The mean score for the variables of training content and facilitation techniques was 2.49 with a standard deviation of 0.62 (refer to Table 3).

3.3.1.3 Satisfaction with the Impact of Modelling Activities and the Benefit to Trainees

In this study, five variables were selected to measure the impact of the modelling activities and the benefits that the trainees derived from this training approach. The results show responses ranging from satisfied to very satisfied for all variables, namely the achievement of workshop objectives (23.77% and 65.75%), the correction of representations and the assimilation of scientific concepts (29.52% and 56.16%), the filling of gaps and the improvement of scientific knowledge (23.29% and 57.29%), the usefulness of the approach taught and the ability to implement and reuse it (43.17% and 46.82%) and the stimulation of imagination and the development of the direction of observation (32.55% and 52.62%). The mean score for the variables related to the impact of the modelling activities and the benefits received by the trainees was 2.35 with a standard deviation of 0.80 (refer to Table 3).

Table 3. Measuring the Frequencies of Satisfaction Dimension Variables

Satisfaction dimensions	N	Likert	Mean	Standard deviation	Min	Max
MM	110	0-3	2.55	0.56	0.40	3.00
CA	110	0-3	2.49	0.62	0.67	3.00
EAM	110	0-3	2.35	0.80	0.00	3.00

3.3.2 Inferential Analysis of Results

In order to determine whether there is no or no significant linear relationship between the evaluation dimensions, the correlation study between the evaluation dimensions (MM), (EAM) and (CA) was used. The results show that there is a significant correlation between the methodology and means used (MM) and the impact of modelling activities and their benefits (EAM). It can be concluded that there is a moderate positive linear relationship, with a Pearson correlation coefficient of 0.600 as shown in Table 4.

Table 4. Correlation between MM and EAM Dimensions

		Methodology and resources put in place (MM)	Effect of modelling activities and its benefits (EAM)
Methodology and resources put in place (MM)	Pearson correlation	1.000	0.600[a]
	Sig. (bi-variate)		0.000
	N	110	110
Effect of modelling activities and its benefits (EAM)		0.600[a]	1.000
		0.000	
		110	100

a. Significant at 0,05 level

The results also show a strong correlation between the content and facilitation of the training (CA) and the effect of modelling activities and their benefits (EAM). It can be concluded that there is a strong positive linear relationship with a Pearson correlation coefficient of 0.828 (refer to Table 5).

This shows the strong influence of the content of the training and the type of pedagogical animation and support on the effect of modelling activities and its benefits. The choice of training content that met the expectations of the trainees, the choice of approach and the creation of a climate of sharing and exchange were crucial elements in these results.

Table 5. Correlation between CA and EAM Dimensions

		Content and facilitation of the training (CA)	Effect of modelling activities and its benefits (EAM)
Content and facilitation of the training (CA)	Pearson correlation	1.000	0.828[a]
	Sig. (bi-variate)		0.000
	N	110	110
Effect of modelling activities and its benefits (EAM)		0.828[a]	1.000
		0.000	
		110	100

a. Significant at 0,05 level

4. Discussion

Through this study, which focuses on the modelling activities in the qualifying training of trainee teachers in the primary cycle at the Regional Centre for Education and Training Professions, we discuss the results of the implementation of a modelling training approach. The latter is designed to involve the trainees in all its stages in order to motivate them and to face the main obstacles of their training: the heterogeneity of the trainees and the reduced time allocated to the module. The stages of this approach begin with a diagnostic test on the main concepts covered in the primary cycle, followed by a theoretical framework on modelling and the production of analogue models, moving on to experimentation with modelling in a series of actions, and ending with a general evaluation to see the benefits derived from this practice. The route of these different actions chosen during the training by modelling approach was based on a case study based on the division of trainee teachers into groups differentiated by the equipment used and the instructions and tasks required. These different practices and activities were carried out with the aim of improving the disciplinary skills related to the scientific subject, linked to the development of the trainee teachers' modelling skills, namely the definition of the model to be used, its design and its conscious use.

The analysis of the results obtained allowed us to demonstrate that the approach adopted had a strong impact on our trainee teachers in terms of their involvement in the modelling processes and their use for teaching scientific concepts at their lowest level of formulation. Thus, our research has shown how modelling processes can give trainee teachers an active place in training, while at the same time encouraging them to design an analogue model, carry it out according to its details, use it to explain such a phenomenon or construct such a scientific concept in the learner. This research has also demonstrated how modelling can contribute to the acquisition of scientific concepts by trainee primary school teachers and to the design of simple but effective ways of communicating them to primary school pupils. The exchange of ideas, the sharing and discussion that takes place during the work in the workshops, as well as the back and forth between the models produced and the physical reality they represent, are all factors that allow the trainees to derive a lesson from them, to be at the heart of the training, and to contribute to filling the gaps they have in terms of basic scientific knowledge.

Three different aspects of the modelling process in teacher training are discussed here by establishing relationships between: scientific academic knowledge, the power of physical manipulation of scientific phenomena, and the ability to didactically translate scientific concepts for the benefit of primary school learners. The results of the operationalization of this approach in training show the difficulties that trainee teachers encounter in generating a modeling process that leads them to explain the behavior of different components of the model in any system studied in scientific awakening at primary school. As is the case with the concept of breathing; subject of this study.

These trainee teachers thus develop important knowledge through this practice, not only about the conceptual object of modelling, but also about how to simplify it in order to present it to learners in the primary cycle. It is therefore essential to link the understanding of the scientific model to be chosen, its uses, its limitations and the elements that make it up, with the process of analogue modelling itself, with the knowledge of the steps to be followed in the design of the model and the factors on which it depends (Justi & Gilbert, 2002; Justi & Driel, 2005).

The establishment of relationships between the concept of the modelling object and the chosen analogue model can improve the trainee's ability to search for information and to design the didactic tools necessary for teaching scientific concepts. The construction of these tools during the training of trainee teachers can provide a context conducive to reflection and encourage trainees to construct scientific arguments to justify their choices and objectives, and to do and think about science (Maia & Justi, 2009; Wilson et al., 2020).

Several lessons can be drawn from the use of this modelling approach in the training of trainee teachers, namely its positive effect on stimulating the imagination and the sense of observation and creativity of the trainees, and the assimilation of scientific concepts and the acquisition of motivation to reproduce this type of teaching activity. Therefore, the need to integrate this approach in a systemic way in their training, leading to a qualification in several sessions incorporating other scientific concepts (Dagnew & Endris, 2020).

The practical side of the workshop, the hands-on activity and the presentation of clear instructions tailored to each targeted group are the strength of this modelling approach initiated during the training. Moreover, the framework of the training is a necessary condition for the successful appropriation of the concept and the reproduction of the tool and its use in the classroom by the trainee teachers. It is therefore necessary to accompany and support these trainee teachers in their journey towards creativity. In this sense, the results obtained in this case study have allowed us to note that the guidelines for the creation and use of the requested model have been a valuable aid in the training of trainee teachers, allowing them to design and use this model to answer the questions asked and to give the necessary explanations. Therefore, it is necessary to support trainee teachers during their training in order to ensure the correct use of the different didactic resources that they will find in their future workplaces. In fact, the fact that teachers are provided with quality teaching tools and resources necessary for the act of teaching does not predict the use that will be made of them (Penneman et al., 2016).

The training environment and the discussions initiated during the various modelling activities played a decisive role in the success of these innovative practices. Thus, the assimilation of concepts by means of modelling proves to be very effective in a training environment that promotes discovery and integration into new experiences, where the heterogeneity of the trainees and their graduates is a richness and an asset that allows the different beneficiaries to exchange ideas, to explore and to share experiences.

The challenge is to apply this approach within the training center by creating the necessary conditions for the replication of these model activities. This requires:

- Firstly, an understanding of the role of models and modelling in science by encouraging trainees to understand their usefulness, the purpose of their use, their strengths and limitations (Abd-el-khalick et al., 2004). This in-depth mastery of modelling constitutes a kind of understanding of the nature of science (Lehrer & Schauble, 2007), and its application in teaching places high demands on future teachers to effectively engage their students in scientific modelling.
- Secondly, involving our trainee teachers in meaningful practices where scientific concepts are presented in a more attractive and innovative way. This involvement of trainees in modelling practices can help them to acquire expertise in the field and in the practices of constructing and evaluating scientific knowledge (Lehrer & Schauble, 2007; Schwarz & White, 2005). Attempts to inculcate model-based training practices in a highly heterogeneous classroom require a shift in the culture of the training classroom towards scientific practices, where the materials used and the approach chosen are confronted with the challenges posed by the trainees' conceptions and expectations of training and scientific material. This will foster not only the attitudes, expectations and beliefs that result, but also new understandings that emerge from disciplinary practice itself (Berland & Reiser, 2009; Hogan & Corey, 2001). We want learners to engage in meaningful practices where they understand and take ownership of the objectives. Such situations, in which learners experience the problems and the usefulness of different solutions, can be an important part of teaching.
- Thirdly, creating a training climate in which trainers have the opportunity to support beneficiaries, giving them the necessary support and time to reach their production from the planning, implementation and evaluation of model-based activities. This kind of teacher-learner support and collaborative work is fundamental to the spread of model-based teaching and can be a way of enhancing the role of teachers in supporting the development of students' modelling skills and knowledge (Justi, 2009; Werner et al., 2017).

The acquisition of this knowledge can only be improved by considering the scientific discipline in the context of answers to be discussed, as opposed to the acquisition of evidence-based knowledge derived from fixed answers to be learnt and reported (Schwarz et al., 2009).

5. Conclusion

This work has focused on the use of modelling as an approach to the training of trainee teachers in the primary cycle in order to develop their skills in teaching scientific concepts. This consists in organizing training sessions dedicated to the creation, manipulation and use of didactic tools using the scientific modelling approach. The main aim of these sessions is to enable trainee teachers to build up their knowledge and fill any gaps they may have in modelling scientific phenomena.

For this, we have developed with the trainee teachers several workshops dedicated to the creation of the didactic tools necessary for the teaching of scientific concepts related to the subject of "scientific activity" in primary schools. These workshops allowed the trainees to first assimilate the concepts and design simple ways to convey them to the students. In this sense, our vision is based on the fact that trainee teachers are entrusted with the acquisition of modelling skills that allow them to create a variety of analogue models and didactic models for the purpose of teaching concepts related to the scientific content programmed in the subject "scientific activity" in primary school.

At the end of this study, it appears that, according to the experiment carried out, modelling activities are an effective means for a good appropriation of the concepts and objects of modelling. They allowed us to overcome, during the training, the constraint linked to the heterogeneity of the trainees, through group work, the creation of a climate favorable to exchanges and the sharing of ideas. To achieve this, we have chosen to combine practical activities with theoretical knowledge in the training. This has led us to avoid training through classical and routine procedures and decontextualized understandings of science.

It is therefore necessary to break with frontal pedagogy and traditional training methods, mostly theoretical, based on lectures and note-taking by trainees, to initiate a new approach to professionalism among trainee teachers, focusing primarily on the interactions between them and the concerns and demands of the act of teaching science in the classroom. This can be achieved through creative, productive and reflective workshops. The new approaches to training must enable future teachers to overcome the obstacles of the didactic transposition of scientific concepts and to design their own teaching models based on their capacity for innovation and creativity.

The use of workshops for the creation of didactic tools by trainee teachers during their initial teacher training is a necessity, both to fill the disciplinary gaps among trainees and to make the material to be taught more meaningful and understandable to both teachers and learners.

The study has also highlighted the importance of integrating modelling as a key component of teacher training and professional development programs at the level of training center’s in order to promote the use of models in primary science education among teachers. Improving teachers' knowledge in this area could have a significant impact on students' science education.

To do this, it is very useful to think about the implementation of this modelling approach, which makes it possible to build scientific knowledge among trainee teachers. This is an approach that trainers and trainee teachers are expected to use. It will allow trainee teachers both to build the desired level of competence of the learner and to measure the degree of appropriation of the concepts. However, we recommend that you consider the following:

- Become aware of the importance of the appropriation of scientific concepts by future teachers during their qualifying training at the CRMEF;
- Use the results of the diagnostic assessment to plan and develop training activities to overcome the difficulties identified in the analysis of the results;
- Take into account the heterogeneity of the trainees in the management of the training activities Be aware that it is not enough to provide the trainee teachers with didactic tools, but to support them in using them;
- Integrate this approach into the skills training of future primary teachers.
- Consider this modelling approach as a training tool that meets trainees' expectations and encourages reflection on the profession.

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Acknowledgments

Our profound gratitude goes to the trainee teachers at the CRMETTH; Tetouan branch who participated in this case study by doing the didactic production workshops and agreed to evaluate this modeling process.

We would also like to thank Professor El Bouayadi Mohamed for his linguistic revision of this article.

Authors contributions

Authors contributed equally to the study.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Sciedu Press.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.