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SERVICE OF ICT INTEGRATION IN MATHEMATICS TRAINING BASED ON ADDIE MODEL

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Abstract- The main objective of pedagogical engineering is systematically associated with innovating pedagogical methods, adapting to the changes of our times, and maintaining the accessibility of learning. However, the question that arises is how to take advantage of pedagogical engineering, through the ADDIE model, to improve the teaching of mathematics and overcome the difficulties of secondary school learners, particularly those in the 1st year of secondary school [2]. To try to answer this question, we have developed a digital device for teaching relative decimal numbers, based on resources such as videos and interactive exercises using the "Hot Potatoes" tool and the ADDIE model. This research aims to support teachers in developing their digital skills and to ensure meaningful and motivating learning of mathematics. The system has been validated by experts and has been tested on a sample of learners in the first year of secondary school. To evaluate its impact on both learning outcomes and motivation of students, our study focused on 480 learners who were split into two distinct groups. The division was made by categorizing them into relatively similar subsets, determined through a statistically verified pre-test. The control group traditionally received the course, while the experimental group benefited from the same lesson but integrated the digital device designed based on pedagogical engineering and the ADDIE model. The outcomes of the post-test given to both sets of participants displayed significantly more favorable results for the experimental group when contrasted with the control group. This positive effect of integrating the digital device into the teaching-learning of relative decimal numbers was also apparent in terms of learner motivation, concentration, and the working atmosphere in the classroom.

Keywords: Educational Engineering, ADDIE, Mathematics, Secondary School, Relative Decimal Numbers.

1. INTRODUCTION

In Morocco, the concept of "Relative decimal numbers" is introduced in the first year of secondary school. This is the year that forms the interface between the primary cycle and the secondary cycle. The latter is characterized, among other things, by a gradual transition from learning based on concrete and observation in primary school to learning about abstraction, reasoning, and deduction. Teaching and learning this concept involve prerequisites relating to the comparison of positive numbers and the order of positive decimal numbers and fractions. However, research into pupils' difficulties and conceptions relating to the comparison of numbers and decimal numbers, as well as the processing of the latter, reveals that these learning difficulties are due to learners' misconceptions, calculation errors, and the didactic transposition of the concepts number, fraction and decimal number [7, 20, 25]. These constraints are compounded by the fact that mathematics is based on abstraction, reasoning, and deduction, which makes it difficult to teach this subject, particularly at the lower secondary level, since learners at the primary level are used to the concrete aspects of concepts.

Given this context and the heavy timetable that Moroccan mathematics teachers are complaining about, it is essential to try and find remedies to overcome these problems, and information and communication technologies could be a great help in this respect. Indeed, technology makes it possible to individualize learning by reaching a greater number of pupils with or without specific needs. Moreover, several studies have shown the value of integrating ICT into teaching and its role in motivating and improving learning [13, 15, 24]. To integrate ICT into mathematics teaching and develop a high-quality and appropriate digital training system, teachers must comply with pedagogical criteria and quality characteristics such as accessibility, sustainability, interoperability, reuse, adaptability, sharing and collaboration, pedagogical relevance, and recognition of intellectual property [5, 6]. Hence the importance of mastering and adopting an appropriate engineering model, especially with the trend towards distance learning, the digitization of educational pathways, the "adaptive learning" revolution, and the importance of emphasizing learner commitment, motivation, and autonomy, so that learners become active players in their learning.

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Based on the above context and requirements for the integration of ICT, this research focused on the development of a digital device for teaching and learning relative decimal numbers in the first year of secondary school, based on the ADDIE model. The choice of the mathematical concept 'relative decimal numbers' is mainly due to its fundamental role in the construction of other mathematical notions, the many difficulties encountered by learners in assimilating it because of its complexity, and the fact that they are studying it for the first time in the first year of secondary school when they have to make increasing use of reasoning and abstraction, something to which they are not accustomed. These findings, especially for a subject that learners consider difficult, are bound to demotivate them. The aim of this research is twofold. The aim is to make:

- The mathematics teacher is an educational engineer who supports the development of his or her digital skills as a designer and developer while complying with the required criteria and standards as well as ergonomics.
- Mathematical concepts more accessible to learners via a digital device likely to motivate them and help them overcome their difficulties and make them love mathematics through educational video since its use improves learners' motivation and makes them more active, which improves the quality of learning [10].

Through this study, we attempted to answer the following main research question: How can we take advantage of pedagogical engineering through the ADDIE model to overcome the learning difficulties of the target concept and motivate learners more?

2. THEORETICAL & CONCEPTUAL FRAMEWORK

Engineering is defined by "Le petit Robert" as "a concept covering the overall study of an industrial project at a technical, economic, financial and social level and coordinating the specific studies of several teams of specialists". It was integrated into educational practices to develop training systems that rely on a thorough examination of "incoming" information, encompassing accessible resources, learner characteristics, instructional goals, and more. The notion of instructional engineering is viewed as a supplementary approach for examining, creating, executing, and strategizing the utilization of educational systems [12]. This approach merges the notions, procedures, and fundamental principles of instructional design, software engineering, and cognitive engineering [17].

There are several instructional engineering models, such as SAT, MISA, ADDIE, MRK, SR, ASSURE, and others [16 and 19]. Some models are oriented towards the individual and enable the design of training tools, others are oriented towards the production of training material and finally, some generic models can all types of applications:

- United States Army (1975): SAT (Systemic Approach to Training)
- University of Florida (1975): ISD (Instructional Systems Development)
- ADDIE model (Analysis, Design, Development, Implementation and Evaluation)

In our study, we have adopted the ADDIE model because it is closer to the software engineering life cycle, and we are more familiar with it.

2.1. ADDIE Framework

This model presents a framework for crafting educational systems (inclusive of both in-person and remote learning) that suggests a sequence of five successive phases [8, 21]:

- Analysis: During this stage, the process involves recognizing, gathering, and evaluating all the components that will steer the system's design. This encompasses the training requirements, the attributes of the intended learners, the environment within which the training will occur, the preexisting resources that could be harnessed or customized for the educational system, as well as the temporal and financial limitations of the project.
- Design: During this phase, the learning engineers will specify the learning objectives, build the training architecture (order, content, and tools for each module), and define the overall training strategy (delivery method, for كexample) [1]. The design of the overall architecture of the training course is called macro-design, and the design of each tool and support contained in the training course is called micro-design. Development: This is the mediatization phase. It consists of building the tools and media defined in the previous phase.
- Implementation: This phase enables trainees to access the system they have created. In the case of a face-to-face system, we will talk about reserving a room, sending out a meeting, organizing the day, and so on. In the case of distance learning, we will talk about deployment, testing, launch, etc. [18].
- Evaluation: Finally, this phase consists of evaluating the system at 3 levels:

- What have the learners retained/learned/assimilated?
- How was the training perceived by the learners?
- What is the return on investment for the company?

The ADDIE model can be represented in different ways [4]:

2.1.1. Waterfall Representation

This representation has been criticized because each phase must be completed before the next begins. This can lead to a long delay in feedback, which increases the gap that occurs when changes are made.

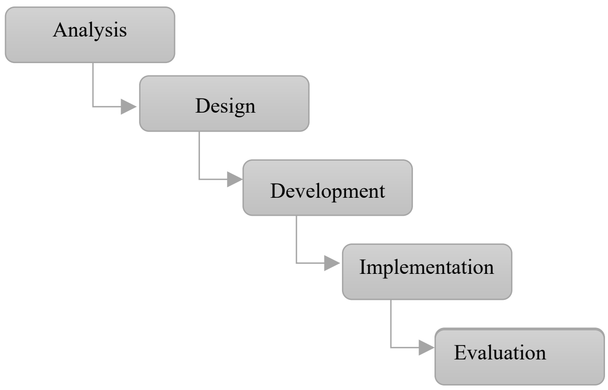

Figure 1. Representation of the ADDIE model in the form of a waterfall (redrawn from [4])

2.1.2. Cyclical Representation

The ADDIE model has undergone several attempts at representation (spirals, loops, etc.) to arrive at another representation proposed by Gustafson and Branch where the evaluation phase is central, reflecting its importance.

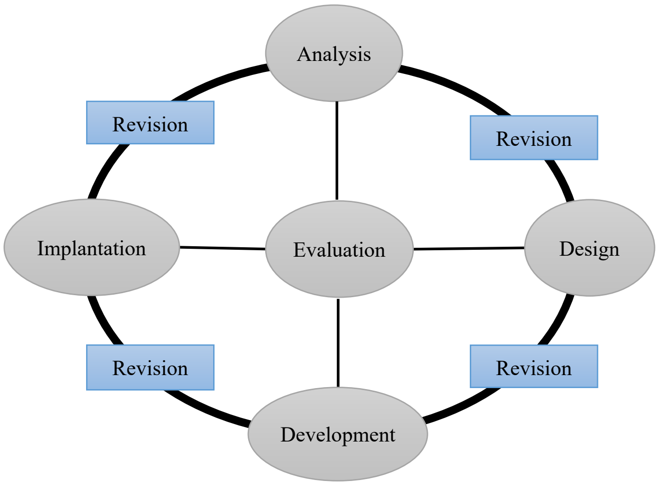

Figure 2. ADDIE model as represented by Gustafson and Branch [4]

2.2. Pedagogical Scenario

A classic definition is that of Paquette, Crevier, and Aubin [23]. These authors suggest considering an educational scenario as "the conjunction of a learning scenario and an associated training scenario, with the expression of the links that unite them". For teachers who want to plan a learning situation that incorporates ICT, the teaching scenario is a relevant tool for their practices. It is the outcome of the process of devising a learning endeavor within a specified timeframe, ultimately leading to the enactment of the scenario. Within this scenario, one encounters goals, the arrangement of learning tasks, a schedule, an elucidation of both students and assignments, as well as evaluation techniques. These elements are defined, structured, and coordinated throughout a pedagogical planning procedure [3].

2.3. Hot Potatoes

Hot Potatoes is free software that lets you intuitively create 5 different types of interactive exercises and then publish them in HTML format on the Internet (learner self-assessment, online exercises, etc.). It allows you to obtain different learning strategies and skills from the learner. No programming knowledge is required: whatever the exercise, you enter your data, text, questions, and answers, and the JavaScript-based software creates the HTML code. The 5 types of exercise are:

- JQuiz: allows you to design multiple-choice questionnaires (MCQs) with an unlimited number of questions and open-ended questionnaires.
- JMix: allows you to create single sentence reordering exercises.
- JCross: allows you to generate a crossword grid or enter a grid you have created yourself.
- JMatch: for matching exercises.
- JCloze: allows you to do exercises with gaps.

2.4. Educational Video

According to the Larousse online French dictionary, an "instructional video" is a video that allows a learner to access knowledge in a multimedia way: there may be images, slides, a person speaking, people acting, or text. A video clip is a video sequence, usually short and scripted, used to develop an idea, a concept, or a theme. It is used to explain, demonstrate, summarize, supplement, correct, and/or raise interest. It can take several forms. For example:

- A video sequence captured using a camera: reports, lectures, blackboard demonstrations, tabletop demonstrations, etc.
- A slide show with audio commentary.
- A recording of actions taking place on the screen or "Screencast".
- 2D or 3D animation produced frame by frame (stop-motion techniques).
- An interactive video enhanced by the integration of additional information that can be acted upon internet link, Twitter feed, additional videos, images, text, podcasts, etc.
- Moving text and still images with animated effects: writing, hand-drawing, etc.

These different types of vignettes can be combined to personalize your production [14].

Table 1. Teaching guidelines for the "relative decimal numbers" lesson [28]

Target skills	Teaching guidelines
Identify positive and relative positive decimal numbers. Write relative decimal numbers. Use relative numbers in situations. Classify relative numbers in order (ascending, descending). Determine the origin of the graduated line and the choice of unit. Graduate a line and show points on it. Add relative decimal numbers. Write a difference as a sum. Use of parentheses in numerical activities. Determining the result of multiplying two relative numbers. the result of multiplying several relative decimal numbers. Mastering the rules of signage Calculate the quotient of two relative numbers. Calculate the approximate value of a quotient of two relative numbers. Frame the quotient of two relative decimals. Recognize the power of a relative number. Use the properties of powers. Use the properties of powers. Recognize the power of 10 and its properties.	Introduce the concept of relative decimals through experiential activities tailored to the learner's background. Employ the graduated line and calculator as tools to acquaint learners with the concept of relative decimal numbers. Use of the term (relative whole number). Absolute value is considered to be outside the curriculum. After defining the difference between two relative decimal numbers, the rule $a-b=a+(-b)$ is introduced and used to solve exercises and study some applications of equality and sum, equality and difference, the aim of which is to prepare learners first for numerical and algebraic calculation, then for equations. Certain acquired techniques are used to organize the calculation of numerical sums (commutativity, associativity, opposite of a sum) without these properties being the objective of a theoretical study. Present the properties of multiplication using examples. After defining the inverse of a number and using the calculator, you can see that the quotient of two relative numbers is the product of the first multiplied by the inverse of the second. The division technique is used to determine default and excess values. The calculator is seen as a tool for dealing with the above concepts.

3. METHODOLOGY OF THE RESEARCH

In this modest work, we present the development process of a digital device designed using the ADDIE model and the results of its use in the teaching and learning of relative decimal numbers for pupils in the 1st year of secondary school. The choice of this concept is motivated by the fact that learners are discovering it for the first time at a level where they are also discovering abstraction, deduction, and reasoning. The planning of the course and the design of the digital device were carried out by the pedagogical guidelines set out in Table 1 relating to the development of the skills targeted, recognition, comparison, representation, and operations on relative decimal numbers in the 1st year of secondary school.

3.1. Target Audience

The digital device was tested with a sample of 480 secondary school learners divided into two homogeneous groups according to the results of a pre-test developed for this purpose. Each group was made up of 240 learners who were discovering the concept of "relative numbers" for the first time. A control group was given the same course without the integration of ICT, and an experimental group was given the same course but using a digital device based on pedagogical engineering.

3.2. Training System

The system consists of three educational videos and interactive exercises. The course materials were produced using Microsoft PowerPoint and the three videos were edited using Camtasia. The exercise software used in this study is Hot Potatoes. The system was evaluated and validated by trainers at the Moroccan Korean Information and Communication Technologies Training Centre in Rabat (CMCF). This center aims to make the integration of ICTs into Moroccan education more widespread and to enhance teachers' skills in this area by drawing on Korea's successful experience in this field. The aim is to reduce the digital divide between Morocco and developed countries [22].

3.3. Research Tools

Pre-test: This test consists of 16 items covering prerequisites such as decimal numbers, operations on integers and decimals, comparison, and number order. Each of these items contains 1 to 2 questions covering the different types of exercises possible with Hot Potatoes. Post-test: To gauge the impact of the system, a post-test was formulated and conducted with both the control and experimental groups upon the experiment's conclusion. This assessment comprised 20 questions that encompassed the learning objectives outlined in Table 1.

4. RESULTS AND DISCUSSION

The outcomes of this research center around the formulation of the slide utilizing the ADDIE model and its subsequent evaluation with the intended audience.

4.1. Design of the Device

4.1.1. Analysis Phase

This phase made it possible to identify the competencies of the teaching-learning process of relative decimals and to study all its characteristics in detail. The results are recorded in analysis sheet of Table 2.

Table 2. Analysis sheet

Teacher	Sounia El Bakkali
Subject	Mathematics
Target Group	Level: The 1st year of middle school Class: 1/9 and 1/10 Number of students: 96 students Competences: Students' knowledge is limited to social networks and video games
Objectives	Relative numbers: introduction, comparison, and operations
Duration	Preparation: 20 h Presentation: 20 min
Tools	Text, picture, sound
Environment	Class, Computer, Data show
Means	Windows, Mediator 9, Software for Treatment, Microsoft Power Point, Word

4.1.2. Design Phase

Figures 4 and 5 show the key design elements of our learning project, the main objective of which is to formalize and structure the project:

Table 3. Design Sheet

Structure	Scenario
Home page: $T1$	Picture, text, sound, button
Menu: M1 Recognize the name of each picture	Picture, text, sound, button
Summary: $S1$	Picture, text, sound, button
Exercises: E1: Operations on relative numbers E2: general information about relative numbers E3: Order of relative numbers E4: Opposite relative numbers	Picture, text, sound, button, interaction
Vocabulary	Picture, text, sound, button

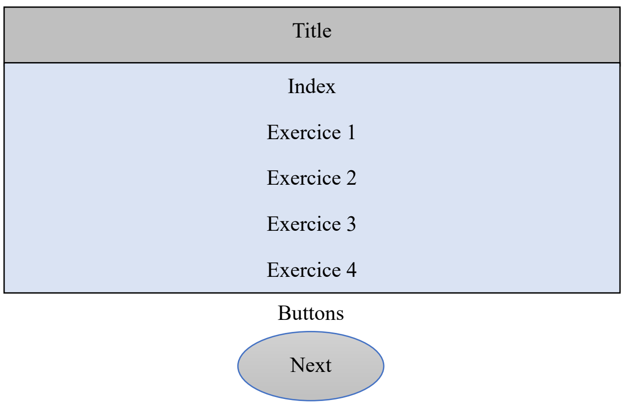

Figure 3. Story Bord

4.1.3. Development Phase

The digital system is based on the above sheets and the "Hot Potatoes" software, as illustrated in Figures 4 and 5.

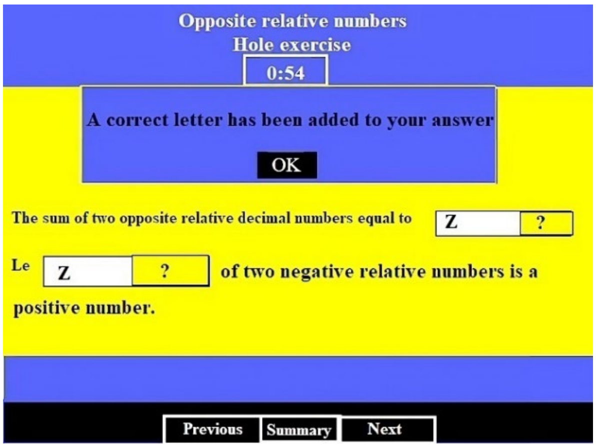

Figure 4. An example of a digital resource made by Hot Potatoes is designed according to the ADDIE model

We took the initiative of transforming the storyboard into software that could be used by the target audience.

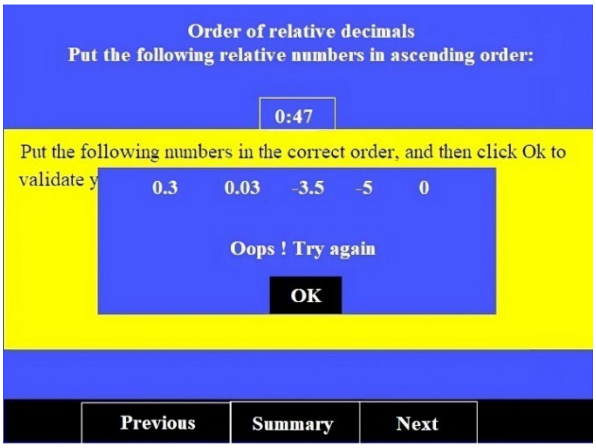

Figure 5. Example of interactive exercises developed by Hot Potatoes

4.1.4. Implementation Phase

The videos are shown to the students using a computer and a data show. The teacher then actively explains the lesson and allows the students to complete the exercises prepared by the ADDIE model.

4.1.5. Evaluation Phase

The evaluation was carried out progressively throughout the process, using digital resource analysis grids to validate the ergonomic aspect as well as pedagogical criteria such as orientation, compliance with the program, motivation, and scientific credibility [5, 6]. A second evaluation was carried out by the trainers, based on the degree of motivation of the learners and using an analysis grid [27].

4.2. Testing the System

4.2.1. Pre-Test Results

The results of the pre-test of the two groups, control and experimental, targeted by the experiment, are represented by the following diagram:

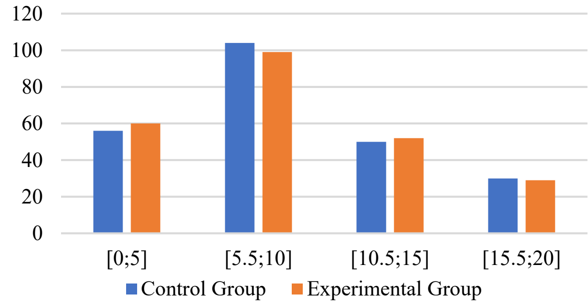

Figure 6. Pre-test results for control and experimental groups

Before commencing the experiment, we employed XLSTAT 2023 to verify the comparability of the two groups. This software serves the purpose of analyzing, visualizing, and modeling statistical data.

4.2.2. Study of the Normality of the Data

To identify a suitable statistical test for confirming our hypotheses, we need to initially examine the normal distribution of the collected data. In our case, the Shapiro-Wilk, Lilliefors, Anderson-Darling, and Jarque-Bera tests all give the same result. We present below the result of the Lilliefors test based on the following hypotheses:

- H0: The variable sampled adheres to a normal distribution.
- Ha: The variable from which the sample is derived does not exhibit a normal distribution.

Table 4. Lilliefors test for the control group in the pre-test

D	0.106
D (normalized)	1.646
Two-tailed *p*-value	<0.0001
Significance level (*alpha*)	0.05

Table 5. Lilliefors test for the experimental group in the pre-test

D	0.084
D (normalized)	1.299
Two-tailed *p*-value	0.000
Significance level (*alpha*)	0.05

Analysis of the tests: Since the computed *p*-value is lower than the predetermined significance level of *alpha*=0.05, we are inclined to reject the null hypothesis H0 and embrace the alternative hypothesis, Ha. Due to the absence of normal distribution in the data, we employed the Mann-Whitney test, and its outcomes are outlined below. The subsequent assumptions were considered:

- H0: The difference in the position of the samples is equal to 0.
- Ha: The difference between the positions of the samples is different from 0.

Table 6. Results of the Mann-Whitney test for the pre-test

U	29501
U (normalized)	0.623
Esperance	28560.500
Variance (*U*)	2278300.569
Two-tailed *p*-value	0.533
Significance level (*alpha*)	0.05

Analysis of the test: As the computed p-value surpasses the predetermined significance level of *alpha*=0.05, there isn't sufficient evidence to reject the null hypothesis H0. As the results in the tables below show, the control and experimental groups are relatively homogeneous.

4.2.3. Post-Test Results

The outcomes of the post-test administered after the system's assessment are displayed in Figure 7.

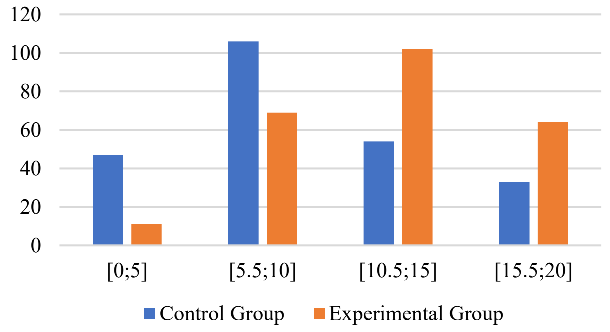

Figure 7. Post-test outcomes for both the control and experimental groups

The post-experiment evaluation of the experimental group measured the effect of the use of the device designed according to pedagogical engineering on the learners' learning.

4.2.4. Study of the Normality of the Data

Below, we provide the outcome of the Anderson-Darling test by the subsequent hypotheses:
- H0: The variable from which the sample is drawn adheres to a normal distribution.
- Ha: The variable from which the sample is drawn does not adhere to a normal distribution.

Table 7. Lilliefors test for the control group in the post-test

D	0.080
D (normalized)	1.236
Two-tailed *p*-value	0.001
Significance level (*alpha*)	0.05

Table 6. Lilliefors test for the experimental group in the post-test

D	0.082
D (normalized)	1.265
Two-tailed *p*-value	0.001
Significance level (*alpha*)	0.05

Interpretation of the test: Since the computed p-value is less than the predetermined significance level of *alpha*=0.05, it is advisable to reject the null hypothesis H0 and maintain Ha the alternative hypothesis.

4.2.5. Verification of Research Hypotheses: Mann-Whitney Test

Due to the lack of normality in the data, we applied the Mann-Whitney test, and its outcomes are displayed below. The following assumptions are made:
- H0: The difference in sample positions equals zero.
- Ha: The disparity between the positions of the samples is not equal to zero.

Table 7. Outcomes of the Mann-Whitney test for the post-test

U	18186.500
U (normalized)	-6.873
Esperance	28560.500
Variance (*U*)	2278040.400
Two-tailed *p*-value	<0.0001
Significance level (*alpha*)	0.05

Test analysis: Since the computed p-value is less than the predetermined significance level of *alpha*=0.05, it is appropriate to reject the null hypothesis H0 and maintain Ha the alternative hypothesis. These results are in favor of the positive effect of the use of the proposed system based on pedagogical engineering on the improvement of mathematics learning at the secondary level. For gauging the progress, we provide in this table the contrast between the outcomes of the experimental and control groups before and following the implementation of the system:

Table 8. Contrast between the outcomes of the pre-test and post-test for the control group

Type of test	Moyenne	Standard deviation
Pre-test	8.62	4.521
Post-test	9.20	4.16

Table 9. Evaluation of the pre-test and post-test outcomes for the experimental group

Type of test	Moyenne	Standard deviation	Coefficient of variation
Pre-test	8.51	4.521	64.99%
Post-test	12.49	2.03	15.80%

Based on the findings, there was a noteworthy disparity in the average arithmetic mean of the experimental group in comparison to the control group (an increase of four points). In addition, the standard deviation decreased by 2.491, indicating a reduction in dispersion and greater homogeneity in the experimental group. It is important to note that other factors may further promote the sustainability of these results and, consequently, improvements in mathematics teaching. The adoption of this method depends on didactic choices and the provision of schools with technological resources and teacher training. Consequently, these results support the idea of learner excellence following the adoption of pedagogical engineering in the teaching of mathematics.

5. CONCLUSIONS AND PROSPECTS

In this work, we first presented the ADDIE pedagogical engineering model that we adopted in the design and development of a digital device consisting of a PowerPoint presentation, 3 video clips edited by Camtasia, and interactive exercises designed using the Hot Potatoes exerciser. The aim was to learn about relative decimal numbers. Next, we presented the results of the experimentation of this device with a sample of learners in the 1st year of secondary school and the data was validated by statistical tests. The outcomes were highly promising regarding learner motivation and enhanced learning within the experimental group in contrast to the control group. We observed that the utilization of the digital device led to 100% of the learners being motivated and that the rate of comprehension improved, which encouraged us to repeat work with other classes & subsequently for other concepts and other school levels, using appropriate digital devices.

From the results of this study, we note other benefits of developing a digital device designed according to the ADDIE model and, consequently, the benefits of pedagogical engineering, such as [26]:

- Optimizing teacher performance: Pedagogical engineering makes it possible to set up appropriate learning devices to support teaching performance ambitions.
- Reducing costs: The pedagogical engineer will ensure that the learning methods chosen will enable teachers to reduce their efforts and time in the medium term, especially in the context of program overload.
- Improving the quality of life in the classroom: The learning engineer will consider the expectations of the learning community and propose a more appropriate and satisfying learning experience.

Employing pedagogical engineering in the instruction of secondary school mathematics yields a positive impact on devising and executing pedagogical systems tailored to a specific learner group while addressing distinct educational goals. This approach also results in time and effort savings. This would have a positive impact on learner motivation and commitment, and consequently on their understanding and development of the targeted skills [27]. We intend to take greater advantage of pedagogical engineering via the ADDIE model to design and model a digital curriculum that covers all the courses in the mathematics program for the first year of secondary school in Morocco, and why not extend it to cover all levels of secondary school.

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