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HYBRID TRAINING IN ROBOTICS AND THE DEVELOPMENT OF PROFESSIONAL TECHNOLOGY SKILLS FOR TEACHERS IN MOROCCO

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ABSTRACT

The hybrid training of teachers in Information and Communication Technology for Education (ICTE) gives rise to a new field of research in artificial intelligence for pedagogical purposes. With the rise of robotics, particularly in the field of education, its integration into teacher training appears necessary. This investigation aims to identify the impact of hybrid training in robotics through online institutional platforms on the professional skills development of teachers in the public primary education sector.Employing a quantitative approach to assess the impact of this robotics training on the development of teachers' skills in the public primary sector, using Generalized Linear Models (GLM), specifically the "logit" model, under the application of binary logistic regression. This analysis explicitly demonstrates that these training programs, such as humanoid robots, animal robots, robotic kits, and educational robots, have a significantly positive effect on improving teachers' skills.
Keywords: *ICTE, Humanoid Robot, Robotic Kit, Animat Robot, Educational Robot, Teacher Skills Development, Binary Logistic Regression*.

1. INTRODUCTION

Hybrid TICE training for teachers has become a crucial necessity for their professional development. It provides them with the necessary means for social interconnection and the sharing of their approaches through exchanges, coupled with increased interactivity (Peltier.C & Séguin 2020) [29]. The active involvement of TICE in the teaching-learning process enhances teachers' willingness to develop their digital skills (Caraban.A & al 2019) [9]. During TICE teacher training, the pedagogical framework of hybrid training poses a challenge for teachers in terms of interactivity and systematic, objective comparative evaluation (Soufiane.N & Rouggani.K 2022)[34].These training programs make effective Digital activities possible if the training plan takes into account the desired needs and expectations to motivate teachers and promote collaborative synergy (Peraya.D & al 2020) [31]. The potential of hybrid TICE training is observed in its effectiveness in instructor training (Zeitoun.S, Malek.R 2018) [39]. Thus, the relationship between hybrid TICE teacher training and their professional development presents a gray area that needs to be explained (Peraya.D, & Cerisier.JF 2022) [30].

At the beginning of this century, a technological shift becomes essential, what we call the era of robots.The frequent use of robotics is strongly recommended in many areas of daily life, especially in educational settings (Bonnel.B 2010) [6]. It is crucial to consider the promises of a potential revolution defined by the modernization of the technological sector; therefore, its constructive use and application must be clearly defined to integrate

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it into the field of education. Hence, the emergence of a specified field of study: "Educational Robotics (ER)". It aims to introduce a diverse series of technological knowledge in schools related to various artificial intelligence aspects (humanoid robots, animats, evolving robots, robotic kits). Its goal is to encourage and innovate the teaching/learning concept for both teachers and learners (Denis.B & Baron.G 1994) [12]. Aware of the importance of hybrid TICE training, the Moroccan Ministry of National Education created an entity linked to the National Center for Pedagogical Innovation and Experimentation (CNIPE) in 2002, specifically dedicated to online education. The objective of these projects is to meet the training needs of TICE teachers and promote their professional development. Numerous robotics training devices and platforms have been activated at various educational levels to improve teachers' skills and consolidate their techno-pedagogical capacities (El Anouar E. & al. 2022) [14].

In our article, we adopt a confirmatory approach to comprehend the mechanisms through which hybrid training in robotics fosters the development of skills among Moroccan teachers. In this context, the power of Educational Information and Communication Technologies (EICT) has brought about a significant transformation in teacher training methods. Hybrid training in robotics, combining elements of online and face-to-face learning, represents an innovative approach. In other words, we will attempt to assess the impact of this hybrid robotics training provided by online platforms on the professional development of teachers, specifically in the primary sector, with a view to addressing the growing needs for intelligent education in times of crises.

Through this study, we aim to measure the impact of each robotics training on the improvement of primary school teachers' skills, leveraging information technology tools IT.It is prudent to formulate a central question based on the aforementioned issue: To what extent do hybrid robotics training programs contribute to the professional development of teachers?This investigation focuses on the region of Fès-Meknès. It is essential to disintegrate our central question into an array of sub-research questions:

Sub-question 1: Does hybrid training in humanoid robots provided by online platforms have an impact on the professional development of teachers?

Sub-question 2: Does hybrid training in animatronic or animal robots provided by online platforms have an impact on the professional development of teachers?

Sub-question 3: Does hybrid training in robotic kits provided by online platforms have an impact on the professional development of teachers?

Sub-question 4: Does hybrid training in educational robots provided by online platforms have an impact on the professional development of teachers?

LITERATURE REVIEW

For several decades, hybrid ICT training has been a subject of research in educational technology, with a focus on organizational dimensions, the nature, and quality of learning in ICT training, capturing the attention of education researchers. According to the writings of (Darif el bouffy.H 2022)[11], specialized educators and pedagogical trainers are interested in the impact of technological evolution on education, the learner's behavior, and their emotional and physical reactions, aiming at lifelong use of ICT and the integration of digital technologies into teaching practices. Other researchers, such as (Alilouch.R & al 2020) [2], explore this theme and concentrate on the link between ICT teacher training and the development of teachers' skills. They mention that most teachers trained in ICT use them in their classes using computers, projectors, or interactive whiteboards, allowing trained teachers to benefit from a digital environment that offers a multitude of resources to leverage.

In a similar vein, (Basque.J. & Lundgren-Cayrol, K. 2007) [4]. note that teachers benefiting from training in the pedagogical integration of ICT simultaneously benefit from cross-cutting training based on ICT that can be widely used in the pedagogical process in all subjects. In other words, these training programs enable teachers to adapt to ICT pedagogies, aligning with learners' personal expectations, and learning to use tools and platforms that facilitate personalized teaching, thus contributing to improving students performance at various levels. Along this line, (Idrissi.N.A 2020) [19].confirms that acquiring digital tool skills under pedagogical supervision has a positive impact on teaching success. In other terms, ICT training allows teachers to acquire the necessary and required skills they need to effectively integrate ICT into their classrooms. This includes mastery of educational software, online course management, creation of

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digital materials, and solving common technological problems.

In the context of robotics, the learning of programming in schools is not new and has its roots in experiences that began in the 1980s with programmable robots using the LOGO language (Kalaš.I 2018) [20]. Following this logic, (Drot-Delange.B & al. 2021) [13].emphasize the importance of developing technical skills and knowledge in robotics for teachers, mastering programming languages such as C, C++, or Python, etc. Considering the development of robotics, a classification structure has been proposed describing types of robotics training, such as training in humanoid robots, animats, robotic kits, and educational robots (Nyangoma. E. N & al. 2017) [26].

Concerning hybrid robotics training, the concept of humanoid robots was introduced in the early 1970s to describe mobile robots with human-like characteristics, aiming to approach human motor performance as closely as possible (Gabriel. A & Yannick. A 2021) [17]. Building on this idea, (Bugmann.J & Karsenti .T 2018) [8].affirm that humanoid robots also resemble humans, having a head, two arms, two legs, two eyes, and a mouth, and even their "voice" can be modified and personalized. Thus, with the digital era and the importance of artificial intelligence, significant innovations in technological skills have introduced humanoid robots into the educational sphere (Spatola.N 2019) [35]. In a similar perspective, Gaudiello.I & Zibetti.E (2013, cited by Bugmann.J & Karsenti.T 2018) [8].mention that the advent of robotics in education holds promises of significant evolution, welcomed with both enthusiasm and skepticism.

The hardware/software ratio of the robot becomes the central axis around which learning provisions are articulated. Additionally, (Chang C. W. & al 2010, cited by Lapierre. HG 2021) [23]. confirm that technological innovations in robotics are becoming increasingly present in today's society and may continue to shape the educational world of tomorrow. Humanoid robot training has an educational objective to encourage recognition and cognitive interaction of knowledge that promotes learning through innovations.

Similarly,(Zimmermann.S&al.2019)[40].empha size other types of hybrid robotics training, such as Animats or animal-like robots, aiming to design simulated artificial systems or real robots inspired by animals. This training version generally presents interactive but "non-transparent" or "black box" technology (Koray. A & Duman. FG 2022) [21]. Another perspective from (Papadakis.S 2020) [27]. highlights the importance of hybrid training in robotic kits, identified as a means of knowledge transfer, as it combines the two previous types of technologies, making them easily customizable and responsive. This is achieved through a set of components offering the ability for rapid and intuitive construction. Learners are thus led to model the shape of their robot, then give it behaviors through programming using a computer or a smart brick.

Building on this reasoning, (Gaudiello.I & Zibetti.E 2013) [18]. state that this training allows a wide range of pedagogical activities due to its simultaneous use as both an object and a tool, allowing learning "on" and "through" the robot. It is a technological device offering a clear alternative to traditional lectures, in which learners use computers connected to the physical world and benefit from their specific interests developed through an educational process, enabling them to systematically solve problems and directly manipulate digital data (Raucci.R.2023) [32].

In line with this approach, (D'Amico .A & al. 2020) [10].argue that it is possible to develop learning through robotic kit training. Also, (Williams.D &al, 2007) [37].obtained positive results in learning Newton's three laws. Consequently, substantial progress was statistically observed in the same test conducted at the beginning and end of the camp. According to (Pache .A 2021) [28], the pedagogical potential of training in educational robots is closely linked to various ways of learning through a specific type of robot with three learning modes that can be identified during educational robotics training.

The first mode is defined by the modalities of learning robotics, in which the robot is used as an exercise platform for different spheres of knowledge (Alimisis.D 2019) [3]. The second involves learning with robots, including robot friends (e.g., the Roboovie robot). For example (Yoshida.E 2019) [38].mentions that the learner can interact with the robot and acquire new knowledge. The third involves learning through robotics, exemplified by teaching assistant robots (e.g., the Irobi robot) using projection devices, verbal interaction, etc. (Bresler.L & al 2020) [7]. During this literature review, we observed that robotics training develops teachers' professional skills. To initiate an understanding of its effects, our reflection poses the following four hypotheses:

$\boldsymbol{H_1}$: The training in humanoid robots provided by online platforms has an impact on the professional development of teachers.

$\boldsymbol{H_2}$: The training in animats, where animal robots are provided by online platforms, has an impact on the professional development of teachers.

$\boldsymbol{H_3}$: The training in robotic kits provided by online platforms has an impact on the professional development of teachers.

$\boldsymbol{H_4}$: The training in educational robots provided by online platforms has an impact on the professional development of teachers.

2. BINARY LOGISTIC REGRESSION [33].

We consider a population P subdivided into two groups of individuals $G_1$and G_2identifiable by an assortment of quantitative or qualitative explanatory variables $X_1, X_2, \dots X_p$ and let Y be a dichotomous qualitative variable to be predicted (explained variable), worth (1) if the individual belongs to the group G_1, and (0) if he/she comes from the groupG_2 . In this context, we wish to explain the binary variable Y from the variables $X_1, X_2, \dots X_p$.

3.1 Logit transformation

We have a sample of n independent observations of y_i, with i = 1, 2, ..., n. y_i denotes a dependent random variable presented as a column vector such that, $y_i = (y_1, y_2, \dots y_n)$ expressing the value of a qualitative variable known as a dichotomous outcome response, which means that the outcome variable y_i can take on two values 0 or 1, evoking respectively the absence or the presence of the studied characteristic. We also consider a set of p explanatory variables denoted by the design matrix (X) = $(X_1, X_2, \dots X_p)$ grouping the column vectors of the independent variables, of size (n × p) and rank (p), where (x_i) is the row vector of these explanatory variables associated with the observation (i) such that, i = 1, 2, …, n, and the column vector (β) of dimension p of the unknown parameters of the model, i.e. the unknown regression coefficients associated with the column vectors of the matrix (X). We consider that y_i (response variable) is a realization of a random variable y_i which can take the values 1 in the case of the termination of the car insurance contract or 0 in the case of the renewal of the car insurance contract with probabilities (π) and (1−π), respectively.

The distribution of the response variable y_i is called Bernoulli distribution with parameter (π). And we can write $y_i \sim$ B(1, π). Let the conditional probability that the outcome is absent be expressed by $P(y_i = 0|X) = 1 - \pi$ and present, denoted $P(y_i = 1|X) = \pi$, where X is the matrix of explanatory variables with p column vectors. The modeling of response variables that have only two possible outcomes, which are the "presence" and "absence" of the event under study, is usually done by logistic regression (Agresti, 1996) [1], which belongs to the large class of generalized linear models introduced by John Nelder and Robert Wedderburn (1972) [24]. The Logit of the logistic regression model is given by the equation:

$$\text{Logit}(\pi) = \ln\left(\frac{\pi}{1-\pi}\right) = \sum_{k=0}^{p} \beta_k \, x_{ik}, \text{ with } i = 1, \dots, n \quad (1)$$

By the Logit transformation, we obtain from equation (1) and equation (2):

$$\left(\frac{\pi}{1-\pi}\right) = \exp\left(\sum_{k=0}^{p} \beta_k \, x_{ik}\right)$$

We evaluate equation (2) to obtain π et $1 - \pi$ as:

$$\pi = \exp\left(\sum_{k=}^{p} \beta_k \, x_{ik},\right) - \pi \exp\left(\sum_{k=0}^{p} \beta_k \, x_{ik}\right)$$

$$\pi + \pi \exp\left(\sum_{k=0}^{p} \beta_k \, x_{ik},\right) = \exp\left(\sum_{k=0}^{p} \beta_k \, x_{ik}\right)$$

$$\pi \left(1 + \exp\left(\sum_{k=0}^{p} \beta_k \, x_{ik}\right)\right) = \exp\left(\sum_{k=0}^{p} \beta_k \, x_{ik}\right)$$

$$\pi = \left(\frac{\exp\left(\sum_{k=0}^{p} \beta_k x_{ik}\right)}{1+\exp\left(\sum_{k=0}^{p} \beta_k x_{ik}\right)}\right)$$

$$\pi = \left(\frac{1}{1+\exp\left(-\sum_{k=0}^{p} \beta_k x_{ik}\right)}\right) (2)$$

In the same way, we obtain $(1 - \pi)$:

$$1 - \pi = 1 - \left(\frac{1}{1+\exp\left(-\sum_{k=0}^{p} \beta_k x_{ik}\right)}\right)$$

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$$1 - \pi = \frac{\exp(-\sum_{k=0}^{p}\beta_k x_{ik})}{1+\exp(-\sum_{k=0}^{p}\beta_k x_{ik})} \quad (3)$$

3.2 Estimation of the β parameters of the nonlinear equations of the Bernoulli distribution using the maximum likelihood estimator (MLE).

If y_i takes strictly two values 0 or 1, the expression for π given in equation (7) provides the conditional probability that y_i is equal to 1 given X, and will be reported as $P(y_i = 0|X)$. And the quantity 1-π gives the conditional probability that y_i is equal to 0 given X, and this will be reported as $P(y_i = 0|X)$. Thus, for $y_i=1$, the contribution to the likelihood function is π, but when $y_i=0$, the contribution to this function is $1-\pi$. This contribution to the likelihood function will be expressed as follows:

$$\pi^{y_i}\,(1-\pi)^{1-y_i} \quad (4)$$

At this stage, we will estimate the P+1 unknown parameters β, using the maximum likelihood estimator (MLE) as follows:

$$L\,(y_1, y_2, \dots y_n,\ \pi) = \prod_{i=1}^{n} \pi^{y_i}\,(1-\pi)^{1-y_i} \quad (5)$$

Maximum likelihood is one of the most widely used estimation procedures for determining the values of the unknown β parameters that maximize the probability of obtaining an observed data set. In other words, the maximum likelihood function explains the probability of the observed data based on unknown regression parameters β. This method was developed by the British statistician Ronald Aylmer Fisher between (1912 - 1922) as it was assigned in John Aldrich's book "R. A. Fisher and the making of maximum likelihood 1912-1922 " published in (1997). This method aims to find estimates of the p explanatory variables to maximize the probability of observation of the response variable Y.

$$L\,(y_1, y_2, \dots y_n,\ \pi) = \prod_{i=1}^{n} \pi^{y_i}\,(1-\pi)^{1-y_i}$$

$$= \prod_{i=1}^{n}\left(\frac{\pi}{1-\pi}\right)^{y_i}(1-\pi)$$

Substituting equation (2) for the first term and equation (8) for the second term, we obtain:

$$L\,(y_1, y_2, \dots y_n,\ \beta_1, \beta_2, \dots \beta_p,\ ) = \prod_{i=1}^{n}\left(\exp\left(\sum_{k=0}^{p}\beta_k x_{ik},\right)\right)^{y_i}\left(1 - \frac{\exp(\sum_{k=0}^{p}\beta_k x_{ik})}{1+\exp(\sum_{k=0}^{p}\beta_k x_{ik})}\right)$$

So,

$$L\,(y_1, y_2, \dots y_n,\ \beta_1, \beta_2, \dots \beta_p) = \prod_{i=1}^{n}\left(\exp\left(y_i \sum_{k=0}^{p}\beta_k x_{ik},\right)\right)\ \left(1+\exp\left(\sum_{k=0}^{p}\beta_k x_{ik},\right)\right)^{-1}$$

For simplicity, we incorporate the Neperian logarithm into the above equation. Since the logarithm is a monotonic function, any maximum in the likelihood function will also be a maximum in the log-likelihood function and vice versa. Thus, considering the natural logarithm of this equation, we obtain the log-likelihood function ℓ expressed as follows:

$$\ln\,(L\,(y_1, y_2, \dots y_n,\ \beta_1, \beta_2, \dots \beta_p)) = \ln\left(\prod_{i=1}^{n}\left(\exp\left(y_i \sum_{k=0}^{p}\beta_k x_{ik}\right)\right)\ \left(1+\exp\left(\sum_{k=0}^{p}\beta_k x_{ik}\right)\right)^{-1}\right)$$

So,

$$\ell\,(y_1, y_2, \dots y_n,\ \beta_1, \beta_2, \dots \beta_p) = \sum_{i=1}^{n} y_i \left(\sum_{k=0}^{p}\beta_k x_{ik}\right) - \ln\left(1+\exp\left(\sum_{k=0}^{p}\beta_k x_{ik}\right)\right) (6)$$

Deriving the last natural logarithm equation of the likelihood function above, we should write:

$$\frac{\partial \ell(\beta)}{\partial \beta_k} = \sum_{i=1}^{n} y_i\, x_{ik} - \frac{1}{1+\exp(\sum_{k=0}^{p}\beta_k x_{ik})} \times \frac{\partial}{\partial \beta_k}\left(1+\exp\left(\sum_{k=0}^{p}\beta_k x_{ik}\right)\right)$$

$$\frac{\partial \ell(\beta)}{\partial \beta_k} = \sum_{i=1}^{n} y_i\, x_{ik} - \frac{1}{1+\exp(\sum_{k=0}^{p}\beta_k x_{ik})} \times \exp\left(\sum_{k=0}^{p}\beta_k x_{ik}\right) \times \frac{\partial}{\partial \beta_k}\sum_{k=0}^{p}\beta_k x_{ik}$$

$$\frac{\partial \ell(\beta)}{\partial \beta_k} = \sum_{i=1}^{n} y_i\, x_{ik} - \frac{x_{ik}}{1+\exp(\sum_{k=0}^{p}\beta_k x_{ik})} \times \exp\left(\sum_{k=0}^{p}\beta_k x_{ik}\right)$$

Knowing that:

$$\frac{\partial}{\partial \beta_k}\sum_{k=0}^{p}\beta_k x_{ik} = x_{ik}$$

So,

$$\frac{\partial \ell(\beta)}{\partial \beta_k} = \ell'_{\beta_k} = \sum_{i=1}^{n} y_i\, x_{ik} - \pi . x_{ik} (7)$$

Therefore, the estimation of the parameters $\hat{\beta} = (\widehat{\beta_0}, \widehat{\beta_1}, \cdots, \widehat{\beta_p})$ that maximize the log-likelihood function l can be determined by canceling each of the P +1 equations of ℓ' (gradient of ℓ) as mentioned in equation (12), and verify that its Hessian matrix (second derivative) is negative definite, i.e. that each element of the diagonal of this matrix is less than zero (Gene H. Golub and Charles F. Van Loan 1996). The Hessian matrix consists of the second derivative of equation (12). The general form of the second partial derivative matrix (Hessian matrix) can be written as follows:

$$\frac{\partial^2 \ell(\beta)}{\partial \beta_k \partial \beta_{k'}} = \frac{\partial}{\partial \beta_{k'}} \sum_{i=1}^{n} y_i \, x_{ik} - \pi . x_{ik}$$

$$\frac{\partial^2 \ell(\beta)}{\partial \beta_k \partial \beta_{k'}} = \frac{\partial}{\partial \beta_{k'}} (- \pi . x_{ik})$$

$$\frac{\partial^2 \ell(\beta)}{\partial \beta_k \partial \beta_{k'}} = - x_{ik} \frac{\partial}{\partial \beta_{k'}} \left(\frac{\exp(\sum_{k=0}^{p} \beta_k x_{ik})}{1+\exp(\sum_{k=0}^{p} \beta_k x_{ik})} \right)$$

$$\ell''_{\beta_{k\beta'_k}} = - x_{ik} \, \pi(1-\pi) \, x_{ik} (8)$$

To solve the (P +1) nonlinear β equations (12), we use the Newton-Raphson iterative optimization method, referring to the Hessian matrix. Using this method, the estimation of the β parameters starts with the first step of choosing a starting point $\beta^{\,0}$ or $\beta^{\,old}$. The second step consists in mentioning the way the method works by posing: $\beta^{\,k+1} = \beta^{\,k} + A_k \times \nabla L(\beta^{\,k})$, and finally stop when the condition $\beta^{\,k+1} \approx \beta^{\,k}$ or $\nabla L\beta^{\,k+1}) \approx \nabla L(\beta^{\,k})$ is realized. The result of this algorithm in matrix notation is:

$$\beta^{\,new} = \beta^{\,old} + [-\ell''(\beta^{\,old})]^{-1} \times \ell'(\beta^{\,old}) (9)$$

By putting $\hat{\beta} = (\widehat{\beta_0}, \widehat{\beta_1}, \cdots, \widehat{\beta_p})^t$, *we have :*

$$V(\hat{\beta}) = (-\frac{\partial^2}{\partial \beta^2} \ln L(\beta, Y))^{-1} \|_{\beta=\hat{\beta}} = (X^t W X)^{-1}$$

To simplify this equation above, we substitute the value of $\ell'(\beta)$, and $\ell''(\beta)$ with another matrix form in the following way:

$$\beta^{\,new} = \beta^{\,old} + (X^t W X)^{-1} \times (X^t Y - \mu)$$

$$\beta^{\,new} = (X^t W X)^{-1} \times X^t W (X\beta^{\,old} + W - 1(Y - \mu))$$

$$\beta^{\,new} = (X^t W X)^{-1} X^t W Z$$

Where, $Z = (X \beta^{\,old} + W^{-1} (Y - \mu))$

Where, $Z = (X\beta^{\,old} + W^{-1}(Y - \mu))$ is a vector, and W is the vector of weights of the values of the diagonal of the inputs $\widehat{\pi_\iota}(1 - \widehat{\pi_\iota})$. We can also write:

$$\beta^{\,new} = \beta^{\,old} + (X^t W X)^{-1} \times X^t (Y - \mu) (10)$$

With:

$$X = \begin{pmatrix} 1 & x_{1,1} & \cdots & x_{1,p} \\ 1 & x_{2,1} & \cdots & x_{2,p} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n,1} & \cdots & x_{n,p} \end{pmatrix}$$

$$\hat{V} = \begin{pmatrix} \widehat{\pi_1}(1 - \widehat{\pi_1}) & 0 & \cdots & 0 \\ 0 & \widehat{\pi_2}(1 - \widehat{\pi_2}) & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & \widehat{\pi_n}(1 - \widehat{\pi_n}) \end{pmatrix}$$

And:

$$W = \text{Diag } \widehat{\pi_1}(1 - \widehat{\pi_1}), \cdots, \widehat{\pi_n}(1 - \widehat{\pi_n}),$$

4. RESULTS AND DISCUSSIONS

4.1 Description, reliability, and dependence study of explanatory variables

In an effort to enhance the professional development skills of teachers, our study focused on analyzing the impact of hybrid robotics training on the professional development of teachers. Following an extensive literature review on the various determinants of robotics training, this theorization allowed us to outline the boundaries of the different explanatory variables for teachers' skills development. After selecting determinants with a significant impact on our response variable through a qualitative study, we then proceeded to develop an online questionnaire for teachers who underwent hybrid robotics training in the primary sector in the Fès-Meknès region. The objective is to collect their responses to explain the development process. The construction of the online questionnaire used in this article mainly covers two aspects. The first is dedicated to the personal information of teachers, while the second details the determinants of robotics training. It is important to note that the collected responses are confidential and will not be disclosed.

We used careful sampling to ensure representativeness, employing a simple random sample. This sample consists of 212, taking into account the size of the surveyed population. After deducting invalid questionnaires, a final sample of 200 valid questionnaires is obtained. The first part of the questionnaire is dedicated to the personal information of the respondents, while the second part focuses on multiple-choice responses, exploring the determinants of hybrid robotics training. In this section, we begin the reliability testing of explanatory determinants using the chi-square test and the Cramer's V test.

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4.2 Reliability test

In the context of assessing reliability and internal consistency among dimensions, authors typically compare the estimated Cronbach's alpha ($\hat{\alpha}$) to a conventional threshold set at 0.70 (Nunnally J. C. 1978) [25], such that ($\hat{\alpha}$) > 0.70.

Table1: Reliability Test

Cronbach's Alpha	Cronbach's Alpha based on standardized elements	Number of elements
0.822	**0,821**	**4**

Source: Author

According to the reliability test, we observe that the value of the coefficient ($\hat{\alpha}$) = 0.82 significantly exceeds the conventional minimum threshold of $\hat{\alpha}$ = 0.70 (Nunnally J. C. 1978) [25]. As (per Darren and Mallery 2008), this indicates that for this set composed of four elements, satisfactory internal consistency is achieved. Indeed, the Cronbach's Alpha coefficient ($\hat{\alpha}$) is an empirical construct resulting from a set of psychometric studies, more subjective than scientific, characterized by the absence of a precise distribution to conclusively accept or reject it (Evrard Y., Pras B., et Roux E. 1997) [15]. Furthermore, several works by theorists such as (Feldt L. S., Woodruff D. J., and Salih F.A. 1987) [16]., (Barnette J. J. 2005) [5], (Van Zyl M. J., Heinz N., and Nel D. G. 2000) [36], (Iacobucci D., and Duhachek A. 2003) [22], among others, have highlighted statistical procedures regarding the distribution of this coefficient and its confidence interval.

The construction of a confidence interval for the Cronbach's Alpha coefficient ($\hat{\alpha}$) requires rigor in statistical analyses and provides additional information for the research community. However, the works of (Feldt L. S., Woodruff D. J., and Salih F.A. 1987) [16], and those of (Iacobucci D. and Duhachek A. 2003) [22],, allowed the development of such an interval. In our study, we will exclusively rely on the approach of (Feldt, Woodruff, and Salih 1987) [16],Their writings demonstrated that the distribution of values of ($\hat{\alpha}$) follows the "Fisher" (F) distribution with degrees of freedom ddl_1 = (n-1), et ddl_2 = (n-1) (k-1),where n represents the sample size and k the number of variables used. However, for a sample of size (n), a scale consisting of (k) variables, an observed Cronbach's Alpha coefficient ($\hat{\alpha}$), and a level of significance (γ), the confidence interval bounds according to (Feldt et al. 1987) [16], can be determined as follows:

- $IC_{inf} = 1 - [(1-\hat{\alpha}) \times F_{(1-\gamma)/2}, ddl_1, ddl_2]$
- $IC_{sup} = 1 - [(1-\hat{\alpha}) \times F_{(\frac{\gamma}{2})}, ddl_1, ddl_2]$

Where F represents the Fisher statistical value for the percentiles γ/2 and (1 - γ)/2, respectively, with degrees of $ddl_1 = (n - 1)$, et $ddl_2 = (n - 1)(k - 1)$.

Table 2: Intra-Class Correlation Coefficient

Intra-Class Correlation		95% Confidence Interval		Fisher Test			
		Lower Bound	Upper Bound	Value	ddl_1	ddl_2	Sig.
Unique Measures	0.397	0.370	0.425	5.611	199	597	0.000
Mean Measures	0.822	0.804	0.838	5.611	199	597	0.000

Source: Author

Through the above table, it is observed that the observed Cronbach's Alpha coefficient ($\hat{\alpha}$) = with 0,822 ∈ $IC^{5\%}$= [0.838, 0.804], a sample size n = 200, an independent variable count k = 4 constituting the used scale, ddl_1 = (n - 1) = 199 et un ddl_2 = (n - 1) (k - 1) =597. It is also noted that the obtained values are highly significant with p = 0.000 < 0.05.

4.3 Chi-Square Test

The chi-square test, also known as the (χ^2),test, is a non-parametric test based on (χ^2),statistics introduced by the British mathematician Karl Pearson in 1900, as mentioned in Stephen Stigler's work "Karl Pearson's theoretical errors and the advances they inspired," published in 2008. These types of tests are applied exclusively to qualitative variables, whether nominal, ordinal, grouped into classes, or even binary. The(χ^2),tests primarily aim at comparing distributions among themselves. However, there are three categories of (χ^2),tests:the homogeneity(χ^2),test, the goodness-of-fit (χ^2),test, and the independence (χ^2),test. The latter will be used to demonstrate the statistical relationship between the explanatory variables used and the response variable on the same sample of size n. In other words, this test verifies the absence or presence of a statistical relationship between two qualitative variables X, assumed to be explanatory, and Y, to be explained. As a hypothesis test, let H_0be the null hypothesis describing independence between the distributions of the two variables. In terms of the p-value, the null hypothesis H_0 is generally rejected when p < 0.05.

. H_0 : The two variables X and Y are independent

Table 3: Chi-Square Test

Explanatory Variables	Pearson's Chi-Square Value	Likelihood Ratio	Linear-by-Linear Association	ddl	Asymptotic Significance (Two-Tailed)
X_1	13.341	12.291	8.001	3	0.000
X_2	11.209	11.376	11.501	3	0.000
X_3	8.129	8.673	6.242	3	0.000
X_4	12.304	12.479	11.112	3	0.000

Source: Author

According to the Chi-Square test, the association between the explanatory variables, namely training in humanoid robot (X_1), animat or animal robot (X_2),robotics kit(X_3),educational robot (X_4), and the response variable "development of teachers' professional skills" is highly significant, with an asymptotic significance (two-tailed) of p = 0.000 < 0.05. These results lead to the rejection of the null hypothesis H_0. In other words, the chosen explanatory variables in this study have a significant association with the response variable, indicating a substantial influence on the development of teachers' skills.

4.4 Cramer's Test

In addition to the Chi-Square test revealing whether variables are related, Cramer's test comes into play to measure the strength and intensity of this association. Let X and Y be two qualitative variables, $k_1$and k_2 their respective modalities, and n the size of the valid sample. The Cramer's V, based on the Pearson's χ^2test statistic, can be:

$$V=\sqrt{\frac{\chi^2}{n \times min\,(k_1-1,\ k_2-1)}}$$

Table 4 : Cramer's V Test

		Value	Approximate Significance
Cramer's V	X_1	0.490	0.000
	X_2	0.349	0.000
	X_3	0.320	0.000
	X_4	0.435	0.000

Source: Author

Table 5 : Interpretation Of Cramer's V

Absolute Value of Cramer's V	Strength of the Relationship Between Variables
Between0 and 0.10	Negligible Association
Between0.10 and 0.20	Very Weak Association
Between0.20 and 0.40	Moderate Association
Between0.40 and 0.60	Relatively Strong Association
Between0.60 and 0.80	Strong Association
Between0.80 and 1	Very Strong Association

Source: Developed by us, inspired by the works of Louis M. Rea and Richard A. Parker (1992)

The absolute value of |V| of Cramer varies within the [0,1] interval. In our case, it is evident that the explanatory variables have a strong impact on the variable to be explained**,** "The development of teachers' skills,**"** as indicated by the Cramer's test. The Cramer's V for the explanatory determinants, training in humanoid robot (X_1), training in animat robot (X_2), robot kit (X_3),educational robot(X_4),all

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exhibit a value exceeding 0.30, indicating a highly significant relationship.

Table 6 : Adjusted $\boldsymbol{R^2}$ *Test*

2 Log Likelihood	Cox and Snell R-Squared	Nagelkerke R-Squared	R-Squared (Sum of Squares)	Adjusted R-Squared (Sum of Squares) (R^2)
96.009	0.339	0.611	0.848	0.886

Source: Author

The model summary provides the values of (-2LL), Cox and Snell R-squared, and Nagelkerke R-squared for the complete model. The (-2LL) value for this model is 96.009. This value was compared to that of the base model using the chi-square test to reveal a highly significant decrease between the two ($p = 0.000 < 0.05$). This decline justifies that the new model is significantly more suitable than the null model. Additionally, the R-squared values approximately indicate how much variation in the outcome is explained by the model. The Cox and Snell R-squared of the complete model is 0.339, indicating that only 33.9% of the variation in the probability for a teacher to successfully develop their professional skills in robotics could be explained by the set of explanatory variables. Furthermore, the Nagelkerke R-squared, an adjusted version of Cox and Snell R-squared and therefore closer to reality, is 0.611. Therefore, it can be said that the explanatory variables contribute to explaining 61.1% of the variation in the probability for a teacher to successfully develop their professional skills in robotics in public primary schools. Moreover, a high value of the adjusted R^2coefficient, also called the adjusted determination coefficient, indicates a better fit of the model to the data used. In our case, the adjusted determination coefficient R^2adjusted = 0.886, meaning that 88.6% of the dispersion is explained by the binary logistic regression model. It is worth noting:

$$R^2 \text{ Adjusted} = R^2 - \frac{K(1-R^2)}{N-K-1}$$

Therefore,

- N : The sample size
- K: Number of explanatory variables
- R^2: Coefficient of determination

Table 7 : Equation Variables

	$\hat{\beta}$	E.S	Wald	ddl	Sig.	Exp ($\hat{\beta}$)	95% Confidence Interval for Exp ($\hat{\beta}$)	
							Inf.	Sup.
X_1	2.110	0.207	28.661	1	0.008	8.248	8.017	8.437
X_2	0.877	0.101	43.495	1	0.001	2.403	2.225	2.611
X_3	1.501	0.214	39.023	1	0.000	4.486	4.283	4.627
X_4	2.201	0.092	25.723	1	0.005	9.034	8.820	9.283
Constant	-4.298	0.771	71.097	1	0.030	0.000	-	-

Source: Author

This table provides the regression coefficients$\hat{\beta}$, the Wald statistic to test statistical significance, the odds ratio (exp ($\hat{\beta}$,)) for each explanatory variable, and finally the confidence interval for each odds ratio (OR). Examining the results, it is observed that there is a highly significant effect of all predictor variables on the response variable development of teachers professional skills. However, the asymptotic significance (two-tailed) *p*

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for the explanatory variable "training in humanoid robot (X_1) is 0.008 < 0.05, p for "training in animal robots (X_2) is 0.001 < 0.05, p for "training in robotic kit ((X_3)" is 0.000 < 0.05, and p for "training in educational robot is(X_4) 0.005 < 0.05.

However, interpreting the p-values is straightforward; nevertheless, the question that arises at this stage concerns how to interpret the regression coefficients$\hat{\beta}$. What does this coefficient correspond to, and how can it be interpreted? Nonetheless, the regression coefficient $\hat{\beta}$ can only elucidate the direction of fluctuation between the explanatory variable and the response variable. That is, a positive sign of the coefficient$\hat{\beta}$ indicates a change in the same direction between the predictor variable and the dependent variable, while a negative sign implies a change in opposite directions for the two variables. However, the coefficient $\hat{\beta}$ itself is not truly interpretable.

However, the exponential of "$\hat{\beta}$" (exp ($\hat{\beta}$))" assumes a meaning easily interpretable by statisticians. The "exp($\hat{\beta}$) also known as the odds ratio (OR), odds ratio, likelihood ratio, or relative risk ratio, is a statistical measure revealing the degree of dependence and the effect of an explanatory factor on the response variable.

The column exp$\hat{\beta}$) (Odds Ratio) indicates that the different explanatory variables each influence the predicted variable in a distinct way. In our case, we can claim that the determinant "training in Humanoid Robot (X_1) can generate eight times more chances (OR((X_1)) = 8248, 95% CI = [8.017, 8.437]) that teachers are likely to develop their skills through this training. Similarly, "training in Animal Robots (X_2) also allows for two times more chances (OR(X_2) = 2.403, 95% CI = [2.225, 2.611]) of skill development. Thus, "training in Robotic Kit (X_3)" presents four times more chances (OR(X_3) = 4.486, 95% CI = [4.283, 4.627]) of succeeding in the development of teachers' skills. Similarly, the determinant "educational robot (X_4)has a greater impact on improving teachers' skills, presenting nine times more chances (OR(X_4) = 9.034, 95% CI = [8.820, 9.283]) than expressing their refusals.

Previous research works, such as those conducted by (Afari E., Khine M. S. 2017)[2] and (Gaudiello.I&Zibetti.E.2013) [21] highlight the existence of positive connections between robotics training in the field of education and the development of teachers' skills. However, it is worth noting that there is a significant scarcity of empirical results in this research direction. Similarly, the writings of (Eleonora.A& al.2017) [15],discuss empirical outcomes on a limited sample, hindering result generalization. This article addresses this gap by empirically examining the impact of the four components of hybrid robotics training on the enhancement of primary school teachers' skills.

This inquiry underscores the importance of hybrid robotics training in the development of teachers' skills, also presenting positive effects on primary-level students. The significance of this type of training was particularly revealed during the Covid-19 pandemic, assisting teachers in delivering and monitoring their courses remotely without disruption and enhancing their skills through information technology tools IT, thereby not impeding the students learning process.

Every research endeavor has its limitations. However, the limitations of this article revolve around the restricted number of interviewed teachers, hampering result generalization, the existence of other unexplored robotics training in this investigation, and the possibility of analyzing responses using other econometric models such as neural networks, Probit model, Tobit model, etc

5. CONCLUSION

The literature review presented in this article highlights the numerous pedagogical advantages associated with teacher training in the field of robotics, including the use of humanoid robots, robotic kits, animation robots, and educational robots. These are not just programming teaching tools; they also serve as powerful means to enhance the overall educational experience. Beyond technical aspects, these training programs have had a profound impact on teachers' skill development. Robotics training enables teachers to acquire advanced technical skills in programming, design, and robot management. These skills enhance teaching pedagogies and facilitate the integration of emerging technologies into dedicated class settings. Moreover, utilizing robots in the classroom can encourage active teaching methods, engaging students in practical and collaborative activities. Robotics-trained teachers are thus better equipped and prepared to design courses that promote active learning, exploration, and problem-solving. Additionally, they can stimulate students' creativity by encouraging innovative thinking, creative problem-solving, and practical application of mathematical and scientific concepts.

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Building upon this literature review and employing a quantitative approach based on the Generalized Linear Model (GLM), our study aims to address the central question posed in the introduction:To what extent do hybrid robotics training programs contribute to the professional development of teachers?

The obtained results clearly indicate that the integration of hemorrhoid robot training significantly contributes to the professional skill development of teachers. Indeed, according to the findings, the likelihood of success in humanoid robot training on teachers' skill development can be multiplied by eight (OR(X_1) = 8248, 95% CI = [8.017, 8.437]). This training encourages teachers to create personalized pedagogical activities that can facilitate students' learning and enhance their skills.

Teachers can significantly enhance their career opportunities and broaden their expertise, paving the way for brighter career prospects in an increasingly technology-oriented world. Similarly, for the results obtained regarding animal robot training, teachers trained in animal robots are twice as likely to improve their professional prospects and deepen their skill sets (OR(X_2) = 2.403, 95% CI = [2.225, 2.611]).Trained teachers can develop more interactive and engaging teaching methods by utilizing robots as tools to reinforce pedagogical concepts. Additionally, animal robots can be employed to encourage student participation, thereby strengthening discipline and promoting a positive learning environment.

Additionally, teachers trained in robotic kits have four times the chances of improving their careers and pedagogical abilities (OR(X_3) = 4.486, 95% CI = [4.283, 4.627]).This training often provides the necessary flexibility to create various types of robots. Teachers can learn to customize kits to meet the specific learning objectives of their class, thereby developing the ability to personalize educational activities.While educational robot training has a more significant impact on improving teachers' skills, representing nine times more chances of generating skill improvement compared to maintaining the old intellectual level (OR(X_4) = 9.034, 95% CI = [8.820, 9.283]). Activities related to educational robots, as proposed by trained teachers, can generate strong interest among students, thereby reinforcing their motivation to learn

However, teacher training in robotics is not merely a pedagogical supplement but becomes a central and indispensable element of education. This development underscores the importance of integrating robotics into educational environments, transforming teaching methodologies, and providing students with decidedly innovative learning opportunities.

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