

Usage of digital technology by STEM teachers: An exploratory study

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ABSTRACT

The use of digital technology has become a mandatory requirement for modern teaching and is considered an essential professional competency for today's teachers. Extant research literature shows growing interest in how teachers use digital technology in their teaching and in the factors that facilitate or limit its integration into educational practice. For teachers of STEM subjects, the use of technology is particularly relevant, given the intrinsic link between technological progress and the specific content of these fields. Although the number of studies on the digitization of education is constantly growing, there is still a need for research that provides a clearer picture of the specific ways in which STEM teachers use digital technology in their day-to-day teaching. This research takes a formative measurement approach to explore the main factors influencing the use of digital technology in Romanian pre-university schools. A formative model has been specified and tested on a sample of 57 Romanian STEM teachers. Results show that usefulness for lesson preparation and the ease of integrating digital technology into teaching are the most important factors. Group analysis revealed differences related to teaching experience and gender.

AUTHOR KEYWORDS

Digital technology; pre-university education; formative measurement models; MIMIC models.

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INTRODUCTION

Usage of digital technology in education has become more and more widespread, challenging teachers to develop new skills and to adapt their teaching methods.

Digital technologies are changing the way students learn, facilitating interactive and collaborative educational experiences adapted to their individual needs [1, 2]. Rapid access to information, the use of simulations, interactive platforms, and educational apps offer new opportunities for developing critical thinking, creativity, problem-solving skills, the ability to analyze and interpret data, and more.

In the field of STEM disciplines, digital technologies facilitate the exploration of complex phenomena and the creation of authentic learning experiences closely aligned with real-world professional contexts. Digital technologies

are no longer merely auxiliary tools for teaching but essential components of the contemporary educational ecosystem. However, the mere presence of technology in the classroom does not automatically lead to improved learning [3]. Its effects depend on the pedagogical goal being pursued, the quality of the resources used, and the way in which the teacher integrates digital tools into the design and delivery of instructional activities.

In this context, teachers play an essential role in selecting, evaluating, and making pedagogical use of available technologies. Teachers' digital competencies involve not only the technical ability to use various applications, but also the ability to integrate them in a way that is consistent with learning objectives, content, and teaching strategies. Therefore, understanding how STEM teachers use digital technology is an important starting point for assessing current changes in educational practices and for designing appropriate professional development programs [4].

Recent years have shown an increasing interest among teachers in training programs oriented to digital pedagogy. Faced with the demands of a rapidly evolving educational landscape, teachers are progressively moving away from conventional methodologies in favor of technology-enhanced instruction. This shift reflects a broader systemic change in Romania, where digital literacy has transitioned from an optional asset to a foundational competency. Teachers are now actively embracing digital tools to foster student engagement and improve academic outcomes in response to evolving educational standards [5].

The relationship between the use of educational technologies and their factors has been extensively researched over the last decade, using various methodological approaches, such as the following models: TAM - *Technology Acceptance Model* [6], TPACK - *Technological Pedagogical Content Knowledge* [7, 8], UTAUT - *Unified Theory of Acceptance and Use of Technology* [9], and from different theoretical perspectives, such as technology acceptance, intention, and technology use behavior; teachers' technological and pedagogical competencies [6, 7, 10], organizational and institutional readiness [11], and the connectivist perspective [12].

Although the literature on the integration of technology in education has expanded considerably in recent years, research focusing on the specific practices of STEM teachers and how they use digital technologies in authentic teaching and learning contexts is less abundant.

In this context, the present study explores the main factors influencing the use of digital technology by STEM teachers in Romanian pre-university education. A formative measurement approach has been taken that proposes a focal construct relating formative indicators measuring the contribution of each factor and reflective indicators measuring the use. The model has been tested on a sample of 57 Romanian pre-university STEM teachers.

The next sections present some related work, the method, and the empirical study.

RELATED WORK

The digital transformation of education has led to a significant increase in researchers' interest in how digital technologies are integrated into teaching and learning processes. Early studies primarily addressed issues of access to technological infrastructure and the availability of equipment, but more recent research focuses on understanding the individual, pedagogical, and organizational factors that influence the effective use of technology in teaching. In education, teachers are central actors in digital transformation, and the way they perceive, accept, and use technology directly influences students' learning experiences.

The digital competencies required of teachers to use technology effectively in their professional practice, according to the European *DigCompEdu framework* [10], include areas such as professional engagement, the use of digital resources, teaching and learning, digital assessment, supporting students, and developing students' digital competencies. Thus, the integration of technology into the teaching process is not merely a matter of individual acceptance or use, but an essential component of contemporary teaching professionalism.

Blannin et al. [13] state that perceived digital literacy and prior experience with technology influence teachers' level of self-efficacy in teaching digital technologies.

Mena-Guacas et al. [2] suggest that emerging technologies have the potential to transform learning experiences significantly, but their effects depend largely on teachers' pedagogical and digital competencies and their ability to integrate technology into educationally relevant activities. Thus, teacher training is an essential prerequisite for the success of digital transformation.

The work of Drijvers and Sinclair [14] emphasized that digital technologies are used in mathematics instruction, but their integration into teaching practices varies considerably among teachers and across educational contexts, and their effectiveness depends on the pedagogical goals for which they are used.

The study conducted by Pangestu et al. [15] highlights a positive relationship between STEM integration and the TPACK model regarding student engagement in learning activities.

Research focused on STEM teachers indicates that digital competence is not uniform across all fields. Using the *DigCompEdu framework* and a sample of over 20,000 Portuguese teachers, Vieira et al. [16] identified significant differences in self-perceived digital competence among teachers of the following subjects: Mathematics and Natural

Sciences, Physics and Chemistry, Biology and Geology. Biology and Geology teachers scored higher on digital competence than teachers in the other groups, while Physics and Chemistry teachers scored higher than Mathematics and Natural Sciences teachers. Those findings suggest that STEM teachers should not be treated as a homogeneous professional group and that the disciplinary context should be taken into account when examining the integration of digital technology.

METHOD

Approach

A formative measurement approach has been taken to analyze the influence of factors on the usage of digital tools.

The measurement model describes the relationships between a latent variable (focal construct) and its measures. In formative measurement, the direction is from indicators to construct, and indicators may freely correlate and do not have an error term [17, 18, 19].

Given the small sample size, a MIMIC (Multiple Indicators Multiple Causes) model has been specified to capture the relationships between actual use and its influencing factors. MIMIC models have a single latent variable (focal construct) that connects formative indicators with reflective indicators [20].

The influence on actual use has been analyzed by checking the magnitude of formative indicators. Then, group differences by teaching experience and gender have been examined and discussed.

Research model and measures

To measure the influence on the usage of new technology, the following formative indicators have been specified as expected: basic knowledge about educational technology (previous experience), ease of learning a new technology and integrating it into teaching, collaborative development of digital materials, and usefulness of digital technologies.

Previous experience with digital technology refers to knowledge acquired through training programs (EXP1) and familiarity with the technology (EXP2). It is expected that both influence the actual use [9, 21].

Ease of learning new technologies (ELNT) and ease of integrating new technologies into teaching (EINT) are measures of the perceived ease of using digital technologies and, according to the technology acceptance theory, are also expected to influence actual use [6, 22].

Usefulness of digital technology refers to its usefulness for preparing the lesson (PULP). It is expected that the more useful a technology is perceived to be, the more it will be used. So, the usefulness for preparing the lesson is expected to positively influence the actual use of digital technology [6, 23].

The usage of educational technologies refers to actual use. In MIMIC models, it is both formative (the left part) and reflective (the right part).

As a reflective construct, it is measured with three reflective indicators: experimenting with digital technologies (UNT), using digital platforms (UEP), and integrating digital evaluation (UEV).

Evaluation Instrument

The evaluation instrument is presented in Table 1.

Table 1. Evaluation instrument

Item	Question
EXP1	How often do you participate in courses or training to improve your digital skills?
EXP2	How familiar are you with digital tools (e.g., word processing, spreadsheets, presentations)?
ELNT	How comfortable do you feel learning about new digital tools on your own (without external assistance)?
EINT	How easy do you find it to integrate technology into your teaching?
PULP	To what extent do you think digital technology would be useful for lesson preparation?
UNT	To what extent do you experiment with new educational applications or technologies?
UEP	How often do you use educational platforms in your teaching?
UEV	How often do you integrate digital assessments into the learning process?

Validation criteria

Model validation criteria for formative models are coverage of the domain of content, the sign and significance of the γ -coefficients measuring the contribution to the focal construct, and the significance of effect variables (λ -coefficients) [17, 18].

The reflective part should have convergent validity, which was checked by examining composite reliability (CR) and average variance extracted (AVE) [24].

Acceptable fit of the model with the data is also required [24], as proved by the goodness-of-fit indices: chi-square (χ^2), normed chi-square (χ^2/df), significance (p), comparative fit index (CFI), goodness-of-fit index (GFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA). The model has been estimated with LISREL 9.3 for Windows [25].

EMPIRICAL STUDY

Sample and data analysis

The evaluation instrument was administered in February-March 2026. Teachers were asked to answer some general questions, such as gender, teaching experience, discipline taught, educational tools used, and then to evaluate items on a 5-point Likert scale.

A total of 64 pre-university teachers (22 male, 42 female) participated in the study. Age varied from 22 to 66 years, with a mean of 50.5 (SD = 10.4). Teaching experience ranged from 1 to 40 years, with a mean of 24 (SD = 11.6).

Seven observations were excluded due to incomplete data, leaving a working sample of 57 observations (21M/ 36F).

Normality was assessed using skewness and kurtosis; all values were within the interval (-1, +1), indicating moderate deviations from normality [24].

Model estimation results

As regards the digital tools used, teachers mentioned a total of 133, out of which 34 (25.56%) are learning management systems (Google Classroom, Microsoft Teams, and Moodle), 24 (18.05%) platforms with gamification elements (Kahoot, Wordwall, etc.), 22 (16.5%) utility tools (Canva, Padlet), 14 (10.5%) authoring tools (LIVRESQ), 9 (6.8%) evaluation tools (Google Forms, Quizizz), 7 (5.3%) meeting platforms (Zoom, Google Meet), and 23 (17.3%) are other tools.

As regards the technologies they would like to get, 27 teachers didn't mention any, while 37 (58%) mentioned a total of 34. Most frequently mentioned were LIVRESQ (6, 17.65%), Canva (5, 14.71%), and educational applications (4, 11.76%). Overall, this suggests an acceptable level of dotation.

The descriptive statistics, λ -coefficients (factor loadings measuring the influence of the focal construct on the outcome variables, γ -coefficients, and their significance (p) are presented in Table 2.

The mean values are above the neutral value of 3.00, indicating a positive perception of all variables. The low mean value of EXP1 shows a relatively low level of training in using digital technologies for educational purposes. Also, the relatively low value of UEP suggests that integrating digital assessment is not a current practice.

Table 2. Descriptive statistics and loadings (N=57)

Value	M	SD	λ	γ	p
EXP1	3.44	0.87		0.19	.013
EXP2	4.18	0.80		0.19	.056
ELNT	3.79	1.05		0.20	.040
EINT	4.05	0.87		0.27	.029
PULP	4.04	0.87		0.31	.004
UNT	3.72	0.90	0.94		
UEP	3.89	0.99	0.67		
UEV	3.49	1.05	0.79		

The focal construct has good convergent validity, with a CR of 0.847 and an AVE of 0.652, both above the thresholds of 0.7 and 0.5, respectively.

Figure 1 presents the model estimation results. The nonsignificant p-value and the goodness-of-fit indices indicate an acceptable fit of the model with the data: $\chi^2 = 14.32$, DF = 10, p = 0.159, $\chi^2 / DF = 1.43$, CFI = 0.983, GFI = 0.945, SRMR = 0.038, RMSEA = 0.087.

Collinearity of indicators was checked by computing VIFs, which ranged from 1.14 to 2.94, below the recommended threshold of 3.

One formative indicator is marginally significant, EXP2 ($\gamma = 0.19$, p = .056). The remaining indicators are significant at the p < 0.05 level.

The indicators making the highest contribution to the usage are the ease of integrating digital technology into teaching, EINT ($\gamma = 0.27$, p = .029), and usefulness for lesson preparation, PULP ($\gamma = 0.31$, p = .004). The other three indicators have a similar contribution.

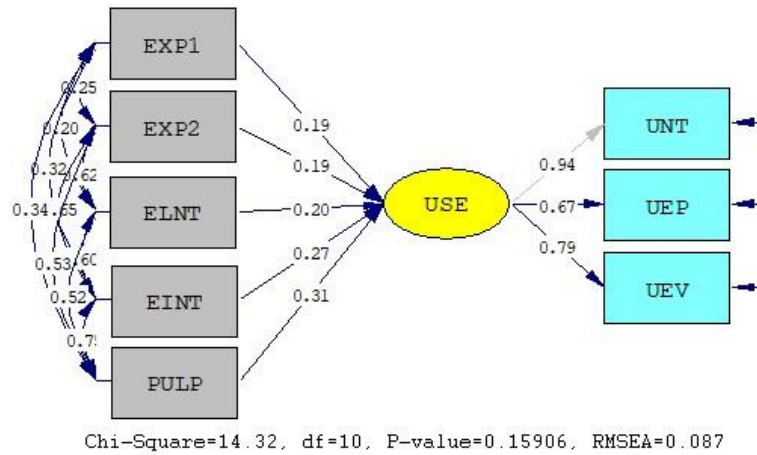


Figure 1. Model estimation results (N=57)

The model explains 81.4% of the variance in the focal construct, which proves a good coverage of the domain of content.

Differences by teaching experience

To analyze group differences by teaching experience, a comparison of mean values has been carried out, which is presented in Table 3. There are 28 teachers with 1-25 years of teaching experience and 29 with over 25 years.

Table 3. Differences by teaching experience (N=57)

Item	1-25 years		Over 25 years		Diff.
	M	SD	M	SD	
EXP1	3.18	0.98	3.69	0.66	-0.51
EXP2	4.25	0.89	4.10	0.72	0.15
ELNT	3.89	1.03	3.69	1.07	0.20
EINT	4.07	0.90	4.03	0.87	0.04
PULP	4.14	0.97	3.93	0.75	0.21
UNT	3.71	0.98	3.72	0.84	-0.01
UEP	3.82	1.12	3.97	0.87	-0.14
UEV	3.57	1.10	3.41	1.02	0.16

Except for three variables, teachers with less than 26 years of experience scored higher.

The differences are higher for participation in course or training programs (EXP1), ease of learning about new digital tools (ELNT), and usefulness for lesson preparation (PULP). This may be explained by the higher mean value of ELNT: teachers feeling comfortable learning about new technologies on their own are less interested in participating in training programs.

A one-way ANOVA (1,55) shows that only for participation in course or training programs is the difference statistically significant: EXP1 ($F = 5.342$, $p = .025$).

Gender differences

To analyze gender differences, a comparison of mean values between male and female teachers has been carried out, which is presented in Table 4.

Overall, with one exception, female teachers scored lower than male teachers. The differences are higher for integration of digital evaluations (UEV), participation in course or training programs (EXP1), ease of integrating digital tools (EINT), and usefulness for lesson preparation (PULP).

Table 4. Gender differences (N=57)

Item	Male		Female		Diff.
	M	SD	M	SD	
EXP1	3.16	0.83	3.58	0.86	-0.42
EXP2	4.32	0.82	4.16	0.79	0.16
ELNT	3.84	1.07	3.76	1.05	0.08
EINT	4.21	0.71	3.97	0.94	0.24
PULP	4.21	0.79	3.95	0.90	0.26
UNT	3.79	0.85	3.68	0.93	0.11
UEP	4.00	1.05	3.84	0.97	0.16
UEV	3.84	1.01	3.32	1.04	0.53

A one-way ANOVA (1,55) shows that for two variables, participation in course or training programs and integration of digital evaluations, gender differences are marginally significant: EXP1 ($F=3.104$, $p = .084$) and UEV ($F=2.286$, $p = .075$). Acknowledging those slight disparities is important for instructional designers and educational administrators aiming for true equity.

Discussion

This work contributes to a formative model addressing the factors influencing the use of digital technology in pre-university STEM disciplines. The advantage of this approach is a model that explains a lot of variability in the data with a small number of indicators. In this case, with only five formative indicators, the model explains 81.4% of the variance.

The results of this study show that the main factors influencing the usage are usefulness for lesson preparation and the ease of integrating digital technology into teaching.

These results are consistent with the Technology Acceptance Model, according to which perceived usefulness and perceived ease of use are important

predictors of technology acceptance and use [6]. Furthermore, the results are consistent with the UTAUT theory, which highlights the role of performance expectancy and effort expectancy in explaining technology usage behaviors [9].

The importance of usefulness for lesson preparation shows that STEM teachers tend to use technology when it offers concrete and immediate benefits for their professional work, such as organizing resources, preparing teaching materials, and designing learning activities. At the same time, the influence of the ease of integrating technology into the teaching process indicates that teachers are more likely to use digital tools when they can be integrated without major difficulties into existing teaching practices.

The results obtained are also consistent with the findings of the study by Mena-Guacas et al. [2], which emphasizes that the impact of emerging technologies on learning depends largely on teachers' pedagogical and digital competencies and on their ability to integrate technology into educationally relevant activities.

The low contribution (marginally significant) of EXP2 (familiarity with digital tools) suggests that this is a less relevant indicator for the usage of digital tools.

Analysis of teachers' perceptions shows a relatively low level of participation in training programs. Also, the relatively low value of UEP suggests that using educational platforms is not a current practice in teaching. These results are consistent with the literature, which highlights that the effective integration of digital platforms and tools depends not only on the availability of infrastructure but also on teachers' ongoing professional development and the existence of adequate institutional support [26, 27].

In terms of teaching experience, the differences seem to be important concerning participation in courses or continuous development programs, ease of learning related to new digital tools, and the perceived usefulness of those tools for lesson preparation. This pattern aligns with the *digital native* or *highly adaptive tech profile* often seen in the case of educators who entered the profession in the last two decades. Their higher scores in lesson preparation and tool mastery suggest a deeper, more organic integration of technology into their daily workflows.

Meanwhile, the marked disparity in training attendance implies that traditional professional development formats may not be adequately engaging or accessible for teachers with more than 26 years of experience, highlighting a critical area for systemic adjustment in digital pedagogy initiatives. Extensive research using frameworks like *DigCompEdu* consistently shows that younger teachers or those in the early-to-mid stages of their careers report higher levels of digital literacy and lower *resistance to change* [28].

Teachers with more than 26 years of experience likely completed their initial teacher training before or right at the dawn of the mainstream internet era (late 1990s / early 2000s). They are often classified in the literature as *digital immigrants*, whereas those with under 26 years of experience have spent their entire professional lives (and often personal lives) embedded in digital ecosystems [29].

There are inherent limitations of an exploratory study. The main limitations of the study are the relatively small sample size and the use of self-reported data. These factors limit the generalizability of the results. Furthermore, the study was conducted within a specific educational context and included a limited number of indicators, which may not fully reflect the complexity of integrating digital technology into STEM instruction.

CONCLUSION AND FUTURE WORK

The study highlights that STEM teachers' use of digital technology is primarily influenced by pedagogical and professional factors, rather than simply by familiarity with digital tools. The perceived usefulness of technology for lesson preparation and the ease of integrating it into teaching practices are the most important predictors of actual technology use. Those results suggest that teachers adopt technology to the extent that it offers concrete pedagogical benefits and can be integrated without major difficulties into existing teaching practices.

At the same time, the relatively low level of participation in training programs and the limited use of certain digital practices indicate the existence of underutilized professional development opportunities and highlight the importance of institutional support for strengthening the digital competencies of STEM teachers.

The findings support the idea that professional development strategies should go beyond approaches focused exclusively on technical skills and pay greater attention to the pedagogical dimensions of technology use, particularly how it can support the design, organization, and delivery of teaching and learning activities.

Overall, the study's findings provide insight into the factors associated with the use of digital technology in teaching STEM subjects and can serve as a starting point for developing strategies to support and train teachers.

Future work intentions include extending formative indicators to get better coverage and testing the model on a larger sample. Furthermore, future research should combine quantitative data with interviews, observations, or objective measures of technology use.

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