Moroccan pre-service elementary teachers: attitudes toward STEM education and mobile devices

Aziz Amaaz¹, Abderrahman Mouradi², Moahamed Erradi¹, Ali Allouch³

¹Computer Science and University Pedagogical Engineering Research Team, Higher Normal School, Abdelmalek Essaadi University, Tetouan, Morocco

²Energy, Materials and Computing Physics Research Team, Higher Normal School, Abdelmalek Essaadi University, Tetouan, Morocco ³Higher School of Education and Training, Ibn Tofail University, Kenitra, Morocco

Article Info

Article history:

Received Jul 30, 2023 Revised Mar 3, 2024 Accepted Mar 19, 2024

Keywords:

Attitudes Elementary school Integrated STEM education Mobile devices Pre-service teachers

ABSTRACT

The purpose of this study was to explore Moroccan pre-service elementary teachers' attitudes toward integrated science, technology, engineering, and mathematics (STEM) education and the use of mobile devices in integrated STEM education. The research sample was selected using convenience sampling. Data were collected from 226 pre-service teachers in the Bachelor of Education Elementary Specialty (BEES) using a 28-item questionnaire. The validity of the items was tested by factor analysis using the extraction method of principal component analysis with varimax rotation. Reliability tests for the different constructs were conducted by calculating Cronbach's alpha. Frequency, mean, standard deviation and Mann-Whitney tests were used to analyze the data. The results revealed that pre-service elementary teachers have generally neutral attitudes toward integrated STEM education, and they also showed that pre-service teachers' attitudes toward integrated STEM education do not depend on gender or grade level. However, these attitudes are dependent on pre-university studies. Pre-service teachers with a scientific background have significantly more positive attitudes toward integrated STEM education than their counterparts with a literary background. Furthermore, the results of this study also revealed that pre-service teachers have positive attitudes toward the use of mobile devices in integrated STEM education, and these attitudes are not dependent on gender, grade level, or pre-university studies.

This is an open access article under the <u>CC BY-SA</u> license.



Corresponding Author:

Aziz Amaaz Computer Science and University Pedagogical Engineering Research Team, Higher Normal School, Abdelmalek Essaadi University Sebta Avenue, Mhannech II, 93002 Tetouan, Morocco E-mail: aamaaz@uae.ac.ma

1. INTRODUCTION

The world we live in is constantly changing, and many of the problems we face in this world are interdisciplinary in nature, requiring the integration of a wide range of knowledge and practices from science, technology, engineering, and mathematics (STEM) subjects to solve them [1]. This integration is not an easy task because real-world problems are not compartmentalized in the same way that STEM subjects are taught in school [2]. The complexity of the problems and the difficulty students have in mobilizing their knowledge in separate STEM subjects to solve these problems have led many educational systems to adopt integrated STEM education.

Integrated STEM education is a curricular approach that combines the concepts of STEM in an interdisciplinary teaching approach [1], [3] that links these four fields so that learning becomes connected, focused, meaningful, and relevant to learners [4]. Thus, integrated STEM education creates a learning environment where students can understand the relationships between mathematics, science, engineering, and technology. The goal of the integrated STEM education approach is to change the way science is taught through the introduction of technology and engineering into student activities [3]. This introduction is likely to motivate students to learn science and mathematics and positively change their perceptions of technology and engineering [5], [6].

In spite of the fact that the concept of integrated STEM education has been considered in the United States beginning in the 1990s, how STEM is taught and the relationship between the four fields are still a matter of debate several decades later. Several models are proposed for implementing integrated STEM education. Each model may employ a combination of STEM fields, emphasize one field more than the others, take place in a formal or informal setting, and employ a variety of pedagogical choices [7]. Among the proposed models is one that suggests that integrated STEM education should use engineering and technical design activities as a context for students to make connections between content and practices in STEM fields [8]. In other words, engineering practices and technical design are an integrative component of the content to be learned in other STEM disciplines.

The implementation of integrated STEM education requires a change in instructional practices that cannot succeed without teacher preparation. This preparation depends on several specific elements, including the knowledge, attitudes, and skills needed to implement integrated STEM education [8]–[10]. Notably, teachers' attitudes and beliefs influence their teaching practices, which in turn influence their students' attitudes and beliefs [11], [12]. Thus, teachers can negatively affect their students' classroom activities and attitudes toward STEM, just as they can promote their students' interests and attitudes toward STEM [13], [14]. Teachers with positive attitudes toward STEM tend to enjoy implementing STEM activities in their classrooms, while teachers with negative attitudes tend to avoid STEM-related activities [15], [16]. Stohlmann *et al.* [4] reported that teachers' passion for STEM education influenced their confidence and comfort in adopting this approach.

Studies have shown that teachers are generally aware of the importance of integrated STEM education and believe it should be implemented in K–12 [17], [18]. Overall, teachers believe that the interdisciplinary nature of integrated STEM education and incorporating design activities are beneficial to students' learning and their futures [8], [17]. Teachers also believe that integrated STEM instruction motivates students and increases student engagement [8], [19].

The teaching of integrated STEM education is sometimes challenged not only by a lack of teaching materials, laboratories, and learner motivation but also by ineffective didactic choices implemented by teachers [20], [21]. The use of mobile devices has the potential to mitigate the impacts of these challenges by providing teachers with the ability to implement multiple pedagogical and didactic choices (e.g., educational games, quizzes, group work, individualized learning, situational learning, and out-of-class learning) [22], [23]. Mobile devices also enable anytime, anywhere access to learning and assessment materials [24], can have a positive impact on learners' motivation to learn [25], and allow visualization of scientific experiments, which can improve learners' understanding of scientific, mathematical, and technological concepts [26].

Although mobile devices can provide benefits to integrated STEM education, their availability does not guarantee their use in this education; therefore, it is important to assess teachers' readiness to use mobile devices [23], [27] by examining their attitudes toward this technology. Teachers' attitudes toward mobile devices are a key factor in understanding their motivation to use this technology in integrated STEM education. Examining these attitudes will help policymakers take initiatives to adopt mobile devices in integrated STEM education and to set up the appropriate infrastructure.

The concept of attitude has its origins in social psychology, where it has been a primary concern throughout most of the last century [28], [29]. Researchers have been interested in attitude to the extent that it can predict and affect the actions and behaviors of individuals. In social psychology, attitude refers to an evaluative judgment that integrates and summarizes a person's cognitive and affective reactions to an object/behavior [28], [30]. Thus, a person may have a negative, neutral, or positive attitude toward the object or behavior.

Attitudes are not directly observable; they are often inferred from indicators of three components: affective, behavioral, and cognitive [29]–[31]. The affective component consists of a person's sentiments and emotions toward the object of the attitude [30], [31]. The behavioral component includes the ways in which a person acts or behaves in relation to the object of their attitude [30], [31]. The cognitive component includes a person's knowledge and beliefs about the attitude object [31]. There is no consensus among researchers that the cognitive, affective, and behavioral components must be present for an attitude to emerge. An attitude may be formed primarily or exclusively by one of these three components, depending on the nature of the object of the attitude and the relationship the individual establishes with that object [31].

To examine teachers' attitudes toward the use of mobile devices and the factors that motivate their intentions to use or not use this technology, several studies have been conducted using models developed to explain technology acceptance. The technology acceptance model (TAM) is one of the most widely used models to explain user behavior across a wide range of computing technologies and users [32]. According to the TAM model, perceived usefulness and perceived ease of use are important determinants of technology acceptance behavior [33]–[35]. Perceived usefulness refers to an individual's belief in the technology's ability to improve their performance [33]. Conversely, ease of use refers to an individual's expectation that using the technology will require minimal effort [33]. In addition to the two core TAM constructs (perceived usefulness and perceived ease of use), studies [36], [37] have suggested adding perceived enjoyment as a strong construct to improve the TAM model's ability to explain people's technology adoption intentions. Intention to adopt technology is defined as the degree of willingness to use the technology on an ongoing basis [33], whereas perceived enjoyment refers to the extent to which the activity of using the technology is perceived as enjoyable in and of itself, regardless of any expected performance outcomes [38].

Morocco is a country that has just introduced integrated STEM education into its elementary science curriculum, following a revision of the elementary science curriculum in 2020. The purpose of introducing integrated STEM education is to promote the teaching of STEM subjects and enable Moroccan elementary school students to make sense of their learning in these subjects [39]. The STEM model adopted in the Moroccan elementary school curriculum focuses on engineering and technical design activities as contexts for students to apply and integrate their learning in science, technology, and mathematics to solve problems.

In order to improve learning in STEM subjects and increase the quality of STEM projects, the Moroccan elementary school curriculum recommends that teachers use information and communication technologies (ICT) in teaching and learning activities. Specifically, it is recommended that Moroccan teachers in elementary schools allow students to consult and use digital resources available through mobile devices (tablets and smartphones) inside or outside the classroom [39]. However, the innovations in the Moroccan elementary school curriculum, such as integrated STEM education and the use of mobile devices, cannot be effectively implemented in the classroom without in-service training programs for practicing teachers and pre-service training for future teachers. For these training programs to have a chance of success, they must take into account the recipients' beliefs and attitudes toward integrated STEM education and the use of mobile devices in STEM.

In an effort to improve the quality of primary teachers' initial training and promote their professionalization, Morocco launched a higher education program called the Bachelor of Education Elementary Specialty (BEES) at the beginning of the 2018-2019 academic year. Created as part of the 2015–2030 strategic vision launched by the Higher Council for Education, Training, and Scientific Research (HCETSR) in 2015, this program provides a long initial university education (3 years) leading to a Bachelor's degree in Education, which allows students to enter the Regional Centers for Careers in Education and Training (RCCET) through a competitive examination for a one-year professional training. This professional training leads to a certificate of pedagogical qualification for the elementary cycle, which allows its holder to work as a teacher in this cycle. The BEES allows students to benefit during their studies from training modules in languages, sciences, mathematics, educational sciences, ICT, and teaching methods of the different subjects taught in the elementary cycle [40].

In addition to providing future teachers with the theoretical, technical, and methodological foundations needed to teach in the elementary grades, the BEES training is expected to prepare these future teachers to implement the new pedagogical practices advocated by the new Moroccan elementary curriculum, such as integrated STEM education and the use of mobile devices in STEM education. The successful future implementation of these new practices depends heavily on the attitudes of these actors [41], [42]. Therefore, any improvement in these attitudes is likely to encourage future teachers to later implement integrated STEM education and the use of STEM in their classrooms [15], [16], [41], [43].

Although three years have passed since the implementation of the new Moroccan elementary education curriculum, almost nothing is known about the attitudes of pre-service elementary school teachers toward integrated STEM education and the use of mobile devices in this education. Likewise, little is known about the impact of pre-service training programs on the intentions of Moroccan elementary future teachers to implement integrated STEM education and to use mobile devices in that education. In this context, and to fill some of these knowledge gaps, this study focused on BEES students as pre-service teachers to examine their attitudes toward integrated STEM education and the use of mobile devices in education. Therefore, the current study attempts to provide sufficient answers to the following research questions: i) What are the attitudes of Moroccan BEES students toward integrated STEM education? Are there significant differences in their attitudes by gender, grade level, and pre-university studies? (RQ1); and ii) What are the attitudes of Moroccan BEES students toward the use of mobile devices in integrated STEM education? Are there significant differences in their attitudes toward the use of mobile devices in integrated STEM education? Are there significant differences in their attitudes by gender, grade level, and pre-university studies? (RQ1); and ii) What are the attitudes of Moroccan BEES students toward the use of mobile devices in integrated STEM education? Are there significant differences in their attitudes by gender, grade level, grade level, and pre-university studies? (RQ2).

2. METHOD

This exploratory study focused on Moroccan BEES students and their attitudes toward the implementation of integrated STEM education in the Moroccan elementary school cycle. It also examined these students' attitudes toward the use of mobile devices in STEM projects, as advocated by the curriculum for this cycle. A questionnaire was used to collect responses from participants, and descriptive statistics (means and standard deviations) and Mann-Whitney tests were used to analyze the attitude results. The population of the study was made up of Moroccan students in their second- and third-year (final year) of BEES. The first-year teacher students were excluded from the survey because they did not receive any training on teaching methods for the different subjects taught in the elementary cycle in the first year, which could bias the results of the survey, especially in the part measuring these teacher candidates' self-confidence in implementing integrated STEM education. In contrast, the second- and third-year teacher candidates received all the planned BEES training modules on the subjects taught in the Moroccan elementary cycle and on the methodologies for teaching these subjects [40].

The data were collected through a questionnaire. The study group included a total of 226 students in BEES at the Higher Normal School (HNS) of Tetouan of Abdelmalek Essaadi University and the Higher School of Education and Training (HSET) of Ibn Tofail University of Kenitra in Morocco. The convenience sampling method was used to select the research sample. This is a non-probability sample in which the authors of this study selected individuals who were both readily available and willing to participate in the study [44]. Students were informed in advance about the objectives of the study, how their data would be used, and the measures taken to ensure the confidentiality and anonymity of the data collected. They were then invited to participate in the research on a voluntary basis.

The questionnaire was made available online through an online survey platform set up by the authors of this study, and all responses collected were anonymized to protect the confidentiality and privacy of study participants. The questionnaire consisted of 3 sections and 28 items (questions). The first section contained 6 questions that collect personal and demographic information about BEES students. The second section contained 13 items to measure attitudes toward integrated STEM education. The third section included 9 items to measure attitudes toward the use of mobile devices in integrated STEM education. A five-point Likert scale with strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1) was used to measure the 22 attitude items toward integrated STEM education and the use of mobile devices in this education. Descriptive statistics (means and standard deviations) and Mann-Whitney tests were used to analyze the attitude results. The questionnaire was developed by the authors of this study. Some items used to measure BEES students' attitudes toward integrated STEM education were adopted from other studies [45], [46]. Some items used to measure BEES students' attitudes toward the use of mobile devices in integrated STEM education were adopted from several relevant studies [23], [33], [47], [48]. The questionnaire was submitted to two expert professors from Abdelmalek Essaadi University, Morocco, to check the clarity of the questions. After a thorough review, the experts concluded that the questions were appropriate for BEES students and addressed the intended research questions.

An exploratory factor analysis was conducted on items related to attitudes toward integrated STEM education and the use of mobile devices in integrated STEM education. The validity of the items was tested with a factor analysis conducted using the extraction method of principal component analysis with varimax rotation. Items measuring participants' attitudes toward integrated STEM education loaded into three factors: importance of integrated STEM education (between 0.752 and 0.926), enjoyment of implementing integrated STEM education (between 0.618 and 0.923), and self-confidence to implement integrated STEM education (between 0.707 and 0.835). Items measuring BEES students' attitudes toward the use of mobile devices in integrated STEM education were loaded as a single factor (between 0.614 and 0.864). Reliability tests were conducted for the different constructs by calculating Cronbach's alpha. The Cronbach's alpha values for the items in the different constructs were greater than 0.7, as shown in Table 1, which means that the items in these constructs had an acceptable level of internal consistency [49].

Table 1. Cronbach's alpha of the constructs

Constructions and dimensions	Cronbach-α
Attitude toward integrated STEM education	0.84
Importance of integrated STEM education	0.91
Enjoyment of implementing integrated STEM education	0.89
Self-confidence to implement integrated STEM education	0.78
Attitudes toward the use of mobile devices in integrated STEM education	0.91

The three constructs (dimensions) that grouped the items used to measure student attitudes toward integrated STEM education were used to assess the cognitive aspects (importance of STEM and self-confidence in implementing integrated STEM education) as well as the affective components (enjoyment of implementing integrated STEM education) of these attitudes. BEES students' attitudes toward integrated STEM education" (ISTEM) (measured by 4 items), "enjoyment of implementing integrated STEM education" (ISTEM) (measured by 5 items), and "self-confidence in implementing integrated STEM education" (SCSTEM) (measured by 4 items). The mean of each dimension was calculated by combining the items in that dimension, and the mean of attitudes toward STEM was calculated by combining the items in all three dimensions.

BEES students' attitudes toward the use of mobile devices in integrated STEM education were measured using 9 items. Of the 9 items used to measure each attitude, 3 items were used to measure perceived usefulness of mobile devices (PU), 2 items were used to measure perceived ease of use of mobile devices (PEU), 2 items were used to measure perceived enjoyment of using mobile devices (EU), and 2 items were used to measure intention to use mobile devices (IU). The mean of attitudes toward the use of mobile devices in integrated STEM education was calculated by combining the 9 items used to measure these attitudes.

Data analysis was performed using SPSS version 26. Means and standard deviations were used to analyze and interpret the attitude results. The scores used to interpret the attitude results were as follows: strongly disagree, 1.00-1.79; disagree, 1.80-2.59; have no idea, 2.60-3.39; agree, 3.40-4.19; strongly agree, 4.20-5.00. Mann-Whitney U tests were used to examine differences by gender, grade level, and pre-university studies between the mean scores of students' responses to items measuring different dimensions of attitudes toward integrated STEM education and the use of mobile devices in STEM education. The Mann-Whitney U test was preferred to the t-test because the data were not normally distributed. For each Mann-Whitney test, a difference was considered statistically significant if p<0.05. When significant differences were found by a Mann-Whitney test, the following intervals were used to define the effect size: r<0.3, small; $0.3 \le r<0.5$, medium; r ≥ 0.5 , large [50].

3. RESULTS AND DISCUSSION

3.1. Demographic data of the sample

Table 2 shows that the majority of students who participated in the survey were female, in their third year of BEES, were between the ages of 19 and 21 (mean age =20.38 years, SD=1.04), and all participants owned a mobile device. It is important to note that students who have access to BEES may have different pre-university educational backgrounds, including scientific, literary, or technological baccalaureate degrees. The diversity of the pre-university educational backgrounds of BEES students means that these students do not benefit equally from certain STEM subjects or the time envelopes of certain STEM subjects. A scientific baccalaureate allows students to benefit from larger time envelopes in mathematics and science compared to students with a literary baccalaureate. Some science pre-university backgrounds also allow students to benefit from technology and engineering courses or workshops, while other backgrounds do not allow students to benefit from such courses and workshops. Table 2 shows that the majority of students who participated in the survey had a scientific baccalaureate degree.

		n	Percentages (%)
Gender	Female	172	76.11
	Male	54	23.89
Age	18	3	1.33
	19	46	20.35
	20	72	31.86
	21	79	34.96
	22	19	8.41
	23	7	3.10
Grade level	Second year of BEES	81	35.84
	Third year of BEES	145	64.16
Type of baccalaureate	Scientific baccalaureate	174	76.99
	Literary baccalaureate	52	23.01
Mobile device ownership	-	226	100

3.2. Research question 1

3.2.1. Attitudes of Moroccan BEES students toward integrated STEM education

In analyzing the attitudes of Moroccan BEES students toward integrated STEM education, this study found that the students' responses to the items used in this study to measure these attitudes were generally neutral, meaning that these students' attitudes toward integrated STEM education were moderate as shown in Table 3. Participants' responses to items on the "importance of integrated STEM education" dimension were generally centered around the "agree" option, and responses to items on the "enjoyment of implementing integrated STEM education" dimension were generally centered around the "agree" option. And responses to items on the "enjoyment of implementing integrated STEM education" dimension were generally centered around the "no idea" option. In contrast, responses to items on the "confidence in implementing integrated STEM education" dimension were generally centered around the "disagree" option. Therefore, it can be inferred that BEES students believe that integrated STEM education is important, they are not sure that they will enjoy this education, and they are not confident in their ability to implement it. This result is consistent with the findings of Abdullah *et al.* [51] who reported high cognitive and moderate affective teacher readiness to implement integrated STEM education. This result is also consistent with the findings of the systematic review by Margot and Kettler [8], which showed that teachers are aware of the importance of STEM but are not confident in their ability to implement integrated STEM education. In addition, this finding is in line with other previous studies that reported teachers' unpreparedness to teach STEM [52] and lack of confidence in their ability to teach STEM in the classroom [53].

The present study's outcomes reveal substantial deficiencies in pedagogical training for BEES students' integrated STEM learning. In this context, the participants' responses to items in the 'self-confidence in implementing integrated STEM education' dimension indicate that they lacked sufficient pedagogical knowledge about integrated STEM education, felt inadequately prepared to implement it in an elementary classroom, were unable to answer elementary students' questions about STEM projects, and did not know how to assist these students in succeeding with their STEM projects. These findings are consistent with prior research, including the studies conducted by Margot and Kettler [8] and Pimthong and Williams [54], which uncovered inadequacies in integrated STEM pre-service teacher training. Similarly, these findings are consistent with the study by Susanti *et al.* [55] which reported that the majority of primary school teachers in one region of Indonesia had knowledge gaps in STEM and were inadequately prepared to teach in this area. In addition, these findings are in line with the findings of Kurup *et al.* [56] which indicated that pre-service elementary school teachers had limited understanding of STEM and limited confidence in teaching STEM due to their limited experience in teaching STEM during their university training and professional practice. Therefore, it can be concluded that BEES students' lack of knowledge about integrated STEM education affects their preparation [10] and may explain their lack of confidence in their ability to implement integrated STEM projects.

	Constructions and items	Ν	М	SD	Interpretation
Attitudes tov	vard integrated STEM education.	226	2.92	0.40	No idea
ISTEM	Importance of integrated STEM education	226	4.15	0.57	Agree
ISTEM1	I think that integrated STEM education will help elementary school students in	226	4.17	0.68	Agree
	their future work.				
ISTEM2	I think that integrated STEM education will help elementary students throughout	226	4.16	0.62	Agree
	their school careers.				
ISTEM3	Solving real-world problems in integrated STEM education increases elementary	226	4.08	0.66	Agree
	school students' interest in technology and engineering.				
ISTEM4	Solving real-world problems in integrated STEM education increases elementary	226	4.18	0.59	Agree
	school students' interest in science and mathematics.				
ESTEM	Enjoyment of implementing integrated STEM education	226	2.61	0.60	No idea
ESTEM1	I am interested in integrated STEM education at the elementary school.	226	2.35	0.75	Disagree
ESTEM2	As a teacher, I would like to engage elementary school students in STEM projects.	226	2.36	0.73	Disagree
ESTEM3	I would like to participate in training programs that help elementary school	226	3.36	0.65	Agree
	teachers implement STEM projects.				
ESTEM4	Primary students enjoy participating in STEM projects.	226	2.77	0.76	No idea
ESTEM5	As a teacher, I am sure I will be able to get elementary school students to	226	2.23	0.69	Disagree
	appreciate STEM projects.				
SCSTEM	Self-confidence to implement integrated STEM education	226	2.08	0.54	Disagree
SCSTEM1	I have sufficient pedagogical knowledge about integrated STEM education.	226	2.28	0.66	Disagree
SCSTEM2	I feel sufficiently prepared to implement integrated STEM education in an	226	2.03	0.76	Disagree
	elementary school classroom.				
SCSTEM3	In general, I think I can answer questions from elementary school students about	226	2.02	0.59	Disagree
	STEM projects.				
SCSTEM4	I know how to help elementary school students see their STEM projects through to	226	1.99	0.74	Disagree
	completion.				

Table 3. Means and standard deviations of items and dimensions of attitude toward integrated STEM education

3.2.2. Differences in Moroccan BEES students' attitudes toward integrated STEM education by gender, grade level, and pre-university studies

The Mann-Whitney U test used to examine the relationship between the gender of BEES students and their attitudes toward integrated STEM education, as shown in Table 4, revealed no significant differences between the mean scores of male and female students' responses to items measuring the dimensions: "importance of integrated STEM education," "enjoyment of implementing integrated STEM education," and "self-confidence in implementing integrated STEM education." This study also found that BEES students' attitudes toward integrated STEM education do not differ significantly by gender. This result corroborates other findings in the literature, which also indicated that gender does not affect pre-service teachers' attitudes toward integrated STEM education [11], [57]–[61]. Similarly, previous studies [53], [62] have found no significant relationship between elementary and secondary teachers' gender and their attitudes toward integrated STEM education and secondary teachers' attitudes toward integrated STEM education and secondary teachers' attitudes toward integrated STEM education. The lack of gender effect on BEES students' attitudes toward integrated STEM education are in the same university training and have undergone almost similar pre-university studies without gender differentiation.

Four Mann-Whitney U tests were conducted, as shown in Table 5, to examine the relationship between BEES students' grade level and their attitudes toward integrated STEM education. The first test indicated no statistically significant difference between the mean scores of the second- and third-year students' responses to all of the items used to measure attitudes toward integrated STEM education. The other three tests also indicated no significant differences between the mean scores of students' responses at the two levels to items measuring the dimensions of "importance of integrated STEM education," "enjoyment of implementing integrated STEM education," and "self-confidence to implement integrated STEM education."

Based on the previous tests, it can be concluded that there is no significant relationship between students' grade level and their attitudes toward integrated STEM education. In addition, there is no significant relationship between students' grade level and their responses to questions measuring the three dimensions of attitudes toward integrated STEM education. This finding is consistent with the results of the study by Haciömeroğlu [58], who found no significant differences in pre-service elementary teachers' knowledge, subjective norms, and attitudes toward integrated STEM education based on their grade level. Similarly, Temel [61] reported no significant relationship between pre-service elementary teachers' grade level and their attitudes toward STEM education. This finding is also consistent with the result of the study by Ateş and Gül [63], who found no significant relationship between pre-service teachers' educational level and their self-efficacy beliefs about STEM education. In contrast, this finding contradicts the result of the study by Kartal and Taşdemir [11], who showed that pre-service teachers' attitudes toward STEM tended to be more positive at higher levels of study than at lower levels because the knowledge and skills of the participants in this study improved as they progressed through the training programs. In the present study, the absence of an impact of BEES students' grade level on their attitudes toward integrated STEM education can be attributed to the fact that students do not receive any courses or workshops on integrated STEM education during their three years of training, which could potentially develop their attitudes toward this education.

The diversity of BEES students' pre-university backgrounds necessitates some interest in looking for possible relationships between these backgrounds and these students' attitudes toward integrated STEM education. As shown in Table 6, the Mann-Whitney U test used to compare the attitudes of BEES students with a scientific baccalaureate degree and those with a literary baccalaureate degree toward integrated STEM education revealed statistically significant differences between the means of the responses of these two groups of students to the items used to measure attitudes toward integrated STEM education. The mean response scores for students with a scientific baccalaureate degree are higher than those for students with a literary baccalaureate degree. The differences in attitudes toward integrated STEM education between scientific and literary baccalaureate students are moderate [50]. Furthermore, the other three Mann-Whitney U tests in Table 6, which were used to examine the differences between the mean scores of the responses of BEES students with a scientific baccalaureate and those of students with a literary baccalaureate to the items used to measure "importance of integrated STEM education," "enjoyment of implementing integrated STEM education," and "self-confidence in implementing integrated STEM education," revealed significant differences between the responses of the two groups. The mean response scores of students with a scientific bachelor's degree are higher than those of students with a literary bachelor's degree. The differences between the mean scores of the responses of the two groups of students to the items measuring "importance of integrated STEM education" and "self-confidence in implementing integrated STEM education" are moderate, while the differences between the mean scores of the responses of the two groups of students to the items measuring "enjoyment of implementing integrated STEM education" are small [50].

Table 6 results indicate that students with a scientific baccalaureate generally have more positive attitudes toward integrated STEM education than students with a literary baccalaureate. In addition, BEES students with a scientific baccalaureate are generally more aware of the importance of integrated STEM

education and more confident in their ability to implement it than their peers with a literary baccalaureate. This trend can be explained by the higher number of science and mathematics courses taken by students with a scientific baccalaureate during their pre-university studies compared to those with a literary baccalaureate. This increased exposure to STEM subjects enables them to acquire more knowledge in these fields, which could explain their more positive attitudes towards integrated STEM education. This finding is consistent with the study by Nadelson *et al.* [64] which found a positive correlation between teachers' knowledge of STEM subjects and their confidence in teaching STEM. Teachers with more knowledge in these subjects are generally more confident in their ability to teach STEM effectively [65]. Similarly, Margot and Kettler [8] found that teachers are more comfortable teaching STEM when they have taken more STEM-related courses. The results of this study are also supported by previous research [11], [66], which found significant differences in pre-service teachers' attitudes toward STEM in favor of those specializing in science.

Table 4. Results of Mann-Whitney tests examining relationships between gender and BEES students' attitudes toward integrated STEM education

attitudes toward integrated 51 EW education										
Attitudes and dimensions	BEES female students $(n-172)$			BEES male students $(n-54)$			Mann-Whitney U test			
Autudes and unitensions	(n=1/2)				(11-54)					
	М	SD	Mdn	М	SD	Mdn	U	Z	р	
Attitudes toward integrated STEM education.	2.92	0.42	2.96	2.91	0.37	2.94	4502.5	-0.338	0.735	
Importance of integrated STEM education	4.17	0.57	4.07	4.09	0.55	4.02	4288	-0.887	0.375	
Enjoyment of implementing integrated	2.60	0.60	2.62	2.66	0.61	2.82	4335	-0.743	0.457	
STEM education										
Self-confidence to implement integrated	2.09	0.56	2.11	2.06	0.46	2.03	4385.5	-0.624	0.533	
STEM education										

 Table 5. Results of Mann-Whitney tests examining the relationships between BEES students' educational level and their attitudes toward integrated STEM education

Attitudes and dimensions	Second year students (n=81)			Third year students (n=145)			Mann-Whitney U test			
Attitudes and unnensions	Μ	SD	Mdn	М	SD	Mdn	U	Z	р	
Attitudes toward integrated STEM	2.89	0.38	2.94	2.93	0.42	2.96	5416	-0.971	0.332	
education.										
Importance of integrated STEM education	4.11	0.55	4.07	4.17	0.58	4.05	5844	-0.063	0.950	
Enjoyment of implementing integrated	2.63	0.54	2.62	2.61	0.64	2.71	5798	-0.159	0.873	
STEM education										
Self-confidence to implement integrated	1.99	0.49	2.04	2.13	0.56	2.14	5088	-1.683	0.092	
STEM education										

 Table 6. Results of Mann-Whitney tests examining the relationships between pre-university studies and BEES students' attitudes toward integrated STEM education

	Students with a scientific baccalaureate degree (n=174)			Studen	ts with a l	iterary				
Attitude and dimensions				bacca	baccalaureate degree (n=52)			Mann-Whitney U test		
	Μ	SD	Mdn	М	SD	Mdn	U	z	р	r
Attitudes toward integrated	3.01	0.38	3.03	2.62	0.34	2.50	2009.5	-6.091	0.000*	0.39 ^b
STEM education.										
Importance of integrated STEM	4.24	0.58	4.14	3.83	0.38	3.84	2214.5	-5.831	0.000*	0.37 ^b
education										
Enjoyment of implementing	2.65	0.62	2.80	2.50	0.54	2.38	3649.5	-2.131	0.033**	0.14 ^c
integrated STEM education										
Self-confidence to implement	2.24	0.44	2.23	1.56	0.49	1.60	1501.5	-7.387	0.000*	0.47 ^b
integrated STEM education										

Note. a large effect size, b medium effect size, c small effect size, *p<0.001, **p<0.05

3.3. Research question 2

3.3.1. Attitudes of Moroccan BEES students toward the use of mobile devices in integrated STEM education

The analysis of BEES students' attitudes toward the use of mobile devices in integrated STEM education as seen in Table 7 revealed that these attitudes are generally positive, as the mean scores of the items used to measure these attitudes were centered on the "agree" option. Additionally, BEES students perceive the use of mobile devices as beneficial to the practice of integrated STEM education, motivating elementary students to engage in STEM projects, and improving the quality of these projects. BEES students also expressed comfort with the use of mobile devices in integrated STEM education and their intention to incorporate this technology into their teaching. However, the mean score of the responses to the PEU2 item

was generally centered on the "no idea" option, indicating that these BEES students are uncertain about the ability of elementary students to use mobile devices in STEM projects. The findings of this study regarding the attitudes of BEES students as future teachers toward the use of mobile devices in integrated STEM education are consistent with the findings of other studies in the literature that have reported positive attitudes of pre-service teachers toward the use of mobile devices in their future teaching practice [67]–[71].

This study found that BEES students have positive attitudes toward the use of mobile devices in integrated STEM education, even though they previously reported that they do not have enough pedagogical knowledge about integrated STEM education, do not feel prepared to implement integrated STEM education, are not able to answer students' questions about their STEM projects, and do not know how to help elementary students complete their STEM projects. BEES students' positive attitude toward the use of mobile devices in integrated STEM education, despite their reported lack of pedagogical knowledge about such education, indicates that these students view technological knowledge as distinct from pedagogical knowledge [72], which would enable them, as teachers, to effectively use mobile technology in integrated STEM education. This finding may be explained by the fact that in the first year of the BEES program, students receive general training modules in the use of ICT, and only in the second year do they receive training in pedagogical strategies for teaching different subjects. This sequence of training modules may not allow BEES students to establish connections between technological tools and the pedagogical strategies of the subjects in which these tools may be used.

Table 7. Means and standard deviations of items and attitudes toward the use of mobile devices in integrated STEM education

	Constructions and items	Ν	М	SD	Interpretation
Attitudes	226	3.91	0.63	Agree	
PU1	The use of mobile devices (tablets and smartphones) has a positive	226	3.78	0.88	Agree
	impact on integrated STEM education practices.				
PU2	Primary school students will be more motivated to engage in STEM	226	4.19	0.72	Agree
	projects if they use mobile devices (tablets and smartphones).				
PU3	The use of mobile devices (tablets and smartphones) improves the ability	226	3.80	0.92	Agree
	of elementary school students to work on STEM projects.				
PEU1	As an elementary school teacher, I will have no problem using mobile	226	4.23	0.60	Strongly agree
	devices (tablets and smartphones) to mentor students' STEM projects.				
PEU2	Primary school students have no problem using mobile devices (tablets	226	2.94	1.00	No idea
	and smartphones) to carry out their STEM projects.				
EU1	As an elementary school teacher, I would like to use mobile devices to	226	3.92	0.86	Agree
	mentor students on STEM projects.				
EU2	Primary school students like to use mobile devices (tablets and	226	3.96	0.81	Agree
	smartphones) when working on their STEM projects.				
IU1	As an elementary school teacher, if my school has mobile devices	226	4.27	0.77	Strongly agree
	(tablets and smartphones), I will have students use these devices to				
	develop their STEM projects.				
IU2	If an elementary school has mobile devices (tablets and smartphones), I	226	4.15	0.79	Agree
	recommend that teachers at that school use these mobile devices to help				
	their students develop STEM projects.				

3.3.2. Differences in Moroccan BEES students' attitudes toward the use of mobile devices in integrated STEM education by gender, grade level, and pre-university studies

Mann-Whitney U tests were used to examine differences in the attitudes of BEES students by gender, grade level, and pre-university studies toward the use of mobile devices in integrated STEM education. The test examining the relationship between the gender of BEES students and their attitudes toward the use of mobile devices in integrated STEM education revealed no statistically significant difference in attitudes between male and female BEES students (U=4442.5, Z=-0.484, p=0.628). Thus, it can be deduced that there is no relationship between the gender of BEES students and their attitudes toward the use of mobile devices in integrated STEM education. This finding corroborates other studies that have found no significant gender differences in preservice teachers' attitudes toward the use of mobile devices [68], [73]–[75]. The lack of effect of BEES students' gender on their attitudes toward the use of mobile devices in integrated STEM education may be due to the fact that all students own mobile devices, which has allowed them to become familiar with the use of these devices, and that they all received the same training in the use of ICT.

The test used to examine the relationship between BEES students' grade level and their attitudes toward the use of mobile devices in integrated STEM education showed no statistically significant

differences in the attitudes of second- and third-year students (U=5324, Z=-1.169, p=0.242). Therefore, it can be concluded that there is no relationship between the grade level of the BEES students and their attitudes toward the use of mobile devices in integrated STEM education. This result is consistent with the findings of other studies that found no significant differences in pre-service primary teachers' attitudes toward the use of mobile technologies based on their grade level [69], [70], [76]. The results of the present study can be attributed to the fact that all participants received two identical modules of information and communication technology training in the first year of the bachelor's degree. In addition, the third-year students did not receive additional training specific to the use of mobile devices in their future teaching practice compared to their second-year peers.

The Mann-Whitney test used to examine the relationship between students' pre-university studies and their attitudes toward the use of mobile devices in integrated STEM education revealed no significant difference in attitudes between students with a scientific baccalaureate and those with a literary baccalaureate (U=4256.5, Z=-0.650, p=0.516). Thus, it can be concluded that there is no relationship between BEES students' pre-university studies and their attitudes toward the use of mobile devices in integrated STEM education. This result may be due to the fact that none of the pre-university courses offer Moroccan students the opportunity to use mobile devices in their learning activities and the fact that all the students who participated in this survey own mobile devices, which would have given them sufficient experience in using these devices and, consequently, would have strengthened their positive attitudes toward the use of mobile devices in their future teaching practices [77].

The results of this study have several notable implications for the training of primary school teachers in Morocco to implement integrated STEM education and the use of mobile devices in this context. First, they highlight the imperative need to provide BEES students with theoretical courses on the content and pedagogical strategies of integrated STEM education, as well as practical workshops. This could improve their knowledge of integrated STEM education and increase their confidence in their ability to implement STEM projects in elementary schools [8], [78]. Second, given the significant differences in BEES students' attitudes toward integrated STEM education based on their pre-university studies, the study suggests that the BEES program should allow students with a literary baccalaureate to take more courses in STEM subjects. This is to close the gap created by their previous studies, which did not allow them to benefit from as many STEM courses as their peers with a scientific baccalaureate. Third, to prevent future teachers' uncertainty about elementary students' ability to use mobile devices from hindering the implementation of this technology, this study recommends that BEES training should prepare pre-service teachers to overcome the challenges that elementary students may face. Fourth, because BEES students do not perceive the relationship between content knowledge, pedagogical knowledge, and technological knowledge, this study recommends that BEES training should enable them to understand the interdependence of these three areas for the use of mobile devices in integrated STEM education through theoretical courses and practical workshops [72]. Finally, the lack of a significant effect of both gender and pre-university studies on attitudes toward mobile learning suggests that all BEES students could benefit from the previously recommended mobile learning training without the need to differentiate based on these two factors.

4. CONCLUSION

This study contributes to the understanding of pre-service elementary teachers' attitudes towards integrated STEM education and the use of mobile devices in Morocco. Although they recognize the importance of STEM, these pre-service teachers express a lack of confidence in their ability to provide effective STEM education. These concerns highlight the need to strengthen pre-service teacher education in the theoretical and practical areas of integrated STEM education. Notably, the study reveals significant differences in pre-service teachers' attitudes toward integrated STEM education based on their pre-university studies. This finding suggests the need to adapt the current BEES curriculum to address educational inequalities resulting from different pre-university pathways that do not provide equal access to STEM courses. In addition, although pre-service teachers are generally in favor of integrating mobile devices into STEM education, they have reservations about elementary students' ability to use these devices effectively in STEM projects and do not perceive the interrelationship between content knowledge, pedagogical strategies, and technological tools in the context of implementing mobile technology. These observations point to the need for targeted educational interventions to improve pre-service teachers' technical and pedagogical skills in using mobile technologies in STEM education. However, it is important to consider the limitations of this study. The data are self-reported and collected through an online questionnaire, which may introduce bias. Furthermore, the study is based on a sample limited to two Moroccan universities, which limits its generalizability. Therefore, future research should seek to replicate this study in several Moroccan universities with larger samples and using a variety of data collection methods such as interviews and focus groups to complement questionnaires.

REFERENCES

- H. Wang, T. J. Moore, G. H. Roehrig, and M. S. Park, "STEM integration: teacher perceptions and practice," *Journal of Pre-College Engineering Education Research (J-PEER)*, vol. 1, no. 2, pp. 1–13, 2011, doi: 10.5703/1288284314636.
- L. D. English, "STEM education K-12: perspectives on integration," *International Journal of STEM Education*, vol. 3, no. 1, pp. 1–8, 2016, doi: 10.1186/s40594-016-0036-1.
- [3] J. M. Breiner, S. S. Harkness, C. C. Johnson, and C. M. Koehler, "What is STEM? A discussion about conceptions of STEM in education and partnerships," *School Science and Mathematics*, vol. 112, no. 1, pp. 3–11, Jan. 2012, doi: 10.1111/j.1949-8594.2011.00109.x.
- [4] M. Stohlmann, T. Moore, and G. Roehrig, "Considerations for teaching integrated STEM education," Journal of Pre-College Engineering Education Research, vol. 2, no. 1, pp. 28–34, 2012, doi: 10.5703/1288284314653.
- [5] S. T. Hackman, D. Zhang, and J. He, "Secondary school science teachers' attitudes towards STEM education in Liberia," *International Journal of Science Education*, vol. 43, no. 2, pp. 223–246, 2021, doi: 10.1080/09500693.2020.1864837.
- [6] K. Hester and C. Cunningham, "Engineering is elementary: an engineering and technology curriculum for children," in 2007 Annual Conference & Exposition Proceedings, 2007, pp. 12.639.1-12.639.18, doi: 10.18260/1-2--1469.
- [7] M. A. Honey, G. Pearson, and H. Schweingruber, STEM integration in K-12 education. Washington, D.C.: National Academies Press, 2014, doi: 10.17226/18612.
- [8] K. C. Margot and T. Kettler, "Teachers' perception of STEM integration and education: a systematic literature review," *International Journal of STEM Education*, vol. 6, no. 1, p. 2, Dec. 2019, doi: 10.1186/s40594-018-0151-2.
- [9] A. L. Baylor and D. Ritchie, "What factors facilitate teacher skill, teacher morale, and perceived student learning in technologyusing classrooms?" *Computers and Education*, vol. 39, no. 4, pp. 395–414, 2002, doi: 10.1016/S0360-1315(02)00075-1.
- [10] K. McMullin and E. Reeve, "Identifying perceptions that contribute to the development of successful project lead the way preengineering programs in Utah," *Journal of Technology Education*, vol. 26, no. 1, pp. 22–46, 2014, doi: 10.21061/jte.v26i1.a.2.
- [11] B. Kartal and A. Taşdemir, "Pre-service teachers' attitudes towards STEM: differences based on multiple variables and the relationship with academic achievement," *International Journal of Technology in Education*, vol. 4, no. 2, pp. 200–228, 2021, doi: 10.46328/ijte.58.
- [12] S. Schwab and G. H. Alnahdi, "Do they practise what they preach? Factors associated with teachers' use of inclusive teaching practices among in-service teachers," *Journal of Research in Special Educational Needs*, vol. 20, no. 4, pp. 321–330, 2020, doi: 10.1111/1471-3802.12492.
- [13] R. Naziah, C. Caska, S. Nas, and H. Indrawati, "The effects of contextual learning and teacher's work spirit on learning motivation and its impact on affective learning outcomes," *Journal of Educational Sciences*, vol. 4, no. 1, pp. 30–43, 2020, doi: 10.31258/jes.4.1.p.30-43.
- [14] E. Regan and J. DeWitt, "Attitudes, interest and factors influencing STEM enrolment behaviour: an overview of relevant literature," in *Understanding Student Participation and Choice in Science and Technology Education*, E. K. Henriksen, J. Dillon, and J. Ryder, Eds., Dordrecht: Springer Netherlands, 2015, pp. 63–88, doi: 10.1007/978-94-007-7793-4_5.
- [15] M. K. A. Salami, C. J. Makela, and M. A. de Miranda, "Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching," *International Journal of Technology and Design Education*, vol. 27, no. 1, pp. 63–88, Mar. 2017, doi: 10.1007/s10798-015-9341-0.
- [16] L. Thibaut, H. Knipprath, W. Dehaene, and F. Depaepe, "The influence of teachers' attitudes and school context on instructional practices in integrated STEM education," *Teaching and Teacher Education*, vol. 71, pp. 190–205, Apr. 2018, doi: 10.1016/j.tate.2017.12.014.
- [17] K. L. Smith, J. Rayfield, and B. R. McKim, "Effective practices in STEM integration: describing teacher perceptions and instructional method use," *Journal of Agricultural Education*, vol. 56, no. 4, pp. 182–201, Dec. 2015, doi: 10.5032/jae.2015.04183.
- [18] N. T. T Khuyen, N. van Bien, P.-L. Lin, J. Lin, and C.-Y. Chang, "Measuring teachers' perceptions to sustain STEM education development," *Sustainability*, vol. 12, no. 4, p. 1531, Feb. 2020, doi: 10.3390/su12041531.
- [19] K. Lesseig, T. H. Nelson, D. Slavit, and R. A. Seidel, "Supporting middle school teachers' implementation of STEM design challenges," *School Science and Mathematics*, vol. 116, no. 4, pp. 177–188, Apr. 2016, doi: 10.1111/ssm.12172.
- [20] A. Bosman and S. Schulze, "Learning style preferences and mathematics achievement of secondary school learners," South African Journal of Education, vol. 38, no. 1, pp. 1–8, Feb. 2018, doi: 10.15700/saje.v38n1a1440.
- [21] M. Visser, A. Juan, and N. Feza, "Home and school resources as predictors of mathematics performance in South Africa," *South African Journal of Education*, vol. 35, no. 1, pp. 1–10, 2015, doi: 10.15700/201503062354.
- [22] N. Cavus, "Evaluation of MoblrN m-learning system: participants' attitudes and opinions," World Journal on Educational Technology: Current Issues, vol. 12, no. 3, pp. 150–164, 2020, doi: 10.18844/wjet.v12i3.4978.
- [23] J. Cheon, S. Lee, S. M. Crooks, and J. Song, "An investigation of mobile learning readiness in higher education based on the theory of planned behavior," *Computers and Education*, vol. 59, no. 3, pp. 1054–1064, 2012, doi: 10.1016/j.compedu.2012.04.015.
- [24] Y. Zhang, "Characteristics of mobile teaching and learning," in *Handbook of Mobile Teaching and Learning*, Y. (Aimee) Zhang and D. Cristol, Eds., Singapore: Springer Singapore, 2019, pp. 13–33, doi: 10.1007/978-981-13-2766-7_5.
- [25] S. A. Nikou and A. A. Economides, "A framework for mobile-assisted formative assessment to promote students' selfdetermination," *Future Internet*, vol. 13, no. 5, p. 116, Apr. 2021, doi: 10.3390/fi13050116.
- [26] D. Mutambara and A. Bayaga, "Determinants of mobile learning acceptance for STEM education in rural areas," *Computers & Education*, vol. 160, p. 104010, Jan. 2021, doi: 10.1016/j.compedu.2020.104010.
- [27] A. O. Insorio, "Technological and operational mobile learning readiness of secondary teachers," *International Journal of Pedagogical Development and Lifelong Learning*, vol. 2, no. 1, p. ep2103, Jan. 2021, doi: 10.30935/ijpdll/9362.
- [28] G. R. Maio, G. Haddock, and B. Verplanken, The psychology of attitudes and attitude change. Sage Publications Ltd., 2018.
- [29] D. G. Myers and J. M. Twenge, *Social psychology*, 14th ed. New York NY: McGraw Hill Education, 2022.
- [30] G. Haddock and G. R. Maio, "Inter-individual differences in attitude content: cognition, affect, and attitudes," in Advances in Experimental Social Psychology, vol. 59, 2019, pp. 53–102, doi: 10.1016/bs.aesp.2018.10.002.
- [31] A. H. Eagly and S. Chaiken, The psychology of attitudes. Fort Worth: Harcourt Brace Jovanovich College Publishers, 1993.
- [32] A. Granić and N. Marangunić, "Technology acceptance model in educational context: a systematic literature review," British Journal of Educational Technology, vol. 50, no. 5, pp. 2572–2593, 2019, doi: 10.1111/bjet.12864.
- [33] F. D. Davis, R. P. Bagozzi, and P. R. Warshaw, "User acceptance of computer technology: a comparison of two theoretical models," *Management Science*, vol. 35, no. 8, pp. 982–1003, 1989, doi: 10.1287/mnsc.35.8.982.

- [34] S. Isrososiawan, R. Hurriyati, and P. D. Dirgantari, "User mobile payment behavior using technology acceptance model (TAM): study of 'Dana' e-wallet users," *Jurnal Minds: Manajemen Ide dan Inspirasi*, vol. 6, no. 2, pp. 181–192, 2019, doi: 10.24252/minds.v6i2.11274.
- [35] A. Wicaksono and A. Maharani, "The effect of perceived usefulness and perceived ease of use on the technology acceptance model to use online travel agency," *Journal of Business Management Review*, vol. 1, no. 5, pp. 313–328, 2020, doi: 10.47153/jbmr15.502020.
- [36] J. Matute-Vallejo and I. Melero-Polo, "Understanding online business simulation games: the role of flow experience, perceived enjoyment and personal innovativeness," *Australasian Journal of Educational Technology*, vol. 35, no. 3, pp. 71–85, 2019, doi: 10.14742/ajet.3862.
- [37] J. H. Wu, Y. C. Chen, and L. M. Lin, "Empirical evaluation of the revised end user computing acceptance model," *Computers in Human Behavior*, vol. 23, no. 1, pp. 162–174, 2007, doi: 10.1016/j.chb.2004.04.003.
- [38] F. D. Davis, R. P. Bagozzi, and P. R. Warshaw, "Extrinsic and intrinsic motivation to use computers in the workplace," *Journal of applied social psychology*, vol. 22, no. 14, pp. 1111–1132, 1992, doi: 10.1111/j.1559-1816.1992.tb00945.x.
- [39] Curriculum Directorate, Official curriculum of the elementary education cycle: final version. Morocco: Ministry of National Education, Vocational Training, Higher Education, and Scientific Research [MNEVTHESR]. [Online]. Available: https://www.men.gov.ma/Ar/Documents/Curriculum%20_Primaire_2021%20Final%2028%20juillet.pdf
- [40] Ministry of National Education, Vocational Training, Higher Education, and Scientific Research (MNEVTHESR), University branches of education: Bachelor of Education (BE) Elementary Education Specialty. Morocco: Higher Normal School, Tetouan.
- [41] E. A. Dare, K. Keratithamkul, B. M. Hiwatig, and F. Li, "Beyond content: the role of stem disciplines, real-world problems, 21st century skills, and stem careers within science teachers' conceptions of integrated stem education," *Education Sciences*, vol. 11, no. 11, p. 737, 2021, doi: 10.3390/educsci11110737.
- [42] M. Kalogiannakis and S. Papadakis, "Evaluating pre-service kindergarten teachers' intention to adopt and use tablets into teaching practice for natural sciences," *International Journal of Mobile Learning and Organisation*, vol. 13, no. 1, pp. 113–127, 2019, doi: 10.1504/IJMLO.2019.096479.
- [43] M. Al-Emran, H. M. Elsherif, and K. Shaalan, "Investigating attitudes towards the use of mobile learning in higher education," *Computers in Human Behavior*, vol. 56, pp. 93–102, 2015, doi: 10.1016/j.chb.2015.11.033.
- [44] K. Zhao, "Sample representation in the social sciences," Synthese, vol. 198, no. 10, pp. 9097–9115, Oct. 2021, doi: 10.1007/s11229-020-02621-3.
- [45] M. Çengel, A. Alkan, and E. P. Yildiz, "Evaluate the attitudes of the pre-service teachers towards STEM and STEM's sub dimensions," *International Journal of Higher Education*, vol. 8, no. 3, pp. 257–267, 2019, doi: 10.5430/ijhe.v8n3p257.
 [46] M. Faber, A. Unfried, E. Wiebe, J. Corn, L. Townsend, and T. Collins, "Student attitudes toward stem: the development of upper
- [46] M. Faber, A. Unfried, E. Wiebe, J. Corn, L. Townsend, and T. Collins, "Student attitudes toward stem: the development of upper elementary school and middle/high school student surveys," in 2013 ASEE Annual Conference & Exposition Proceedings, 2013, pp. 23.1094.1-23.1094.26, doi: 10.18260/1-2--22479.
- [47] F. Moreira, C. S. Pereira, N. Durão, and M. J. Ferreira, "A comparative study about mobile learning in Iberian Peninsula Universities: are professors ready?" *Telematics and Informatics*, vol. 35, no. 4, pp. 979–992, Jul. 2018, doi: 10.1016/j.tele.2017.09.010.
- [48] T. Teo and J. Noyes, "An assessment of the influence of perceived enjoyment and attitude on the intention to use technology among pre-service teachers: a structural equation modeling approach," *Computers and Education*, vol. 57, no. 2, pp. 1645–1653, 2011, doi: 10.1016/j.compedu.2011.03.002.
- [49] S. T. Keith, "The use of Cronbach's alpha when developing and reporting Research instruments in science education," *Research in Science Education*, vol. 48, pp. 1273–1296, 2017, doi: 10.1007/s11165-016-9602-2.
- [50] C. O. Fritz, P. E. Morris, and J. J. Richler, "Effect size estimates: current use, calculations, and interpretation," *Journal of Experimental Psychology: General*, vol. 141, no. 1, pp. 2–18, 2012, doi: 10.1037/a0024338.
- [51] A. H. Abdullah, M. H. Hamzah, R. H. S. R. Hussin, U. H. A. Kohar, S. N. S. A. Rahman, and J. Junaidi, "Teachers' readiness in implementing science, technology, engineering and mathematics (STEM) education from the cognitive, affective and behavioural aspects," in *Proceedings of 2017 IEEE International Conference on Teaching, Assessment and Learning for Engineering, TALE* 2017, 2017, pp. 6–12, doi: 10.1109/TALE.2017.8252295.
- [52] J. Geng, M. S. Y. Jong, and C. S. Chai, "Hong Kong teachers' self-efficacy and concerns about STEM education," Asia-Pacific Education Researcher, vol. 28, no. 1, pp. 35–45, 2019, doi: 10.1007/s40299-018-0414-1.
- [53] W. K. Wei and S. M. Maat, "The attitude of primary school teachers towards STEM education," TEM Journal, vol. 9, no. 3, pp. 1243–1251, 2020, doi: 10.18421/TEM93-53.
- [54] P. Pimthong and J. Williams, "Preservice teachers' understanding of STEM education," Kasetsart Journal of Social Sciences, vol. 41, no. 2, pp. 289–295, 2020, doi: 10.1016/j.kjss.2018.07.017.
- [55] D. Susanti, Z. K. Prasetyo, and H. Retnawati, "Analysis of elementary school teachers' perspectives on stem implementation," *Jurnal Prima Edukasia*, vol. 8, no. 1, pp. 40–50, 2020, doi: 10.21831/jpe.v8i1.31262.
- [56] P. M. Kurup, X. Li, G. Powell, and M. Brown, "Building future primary teachers' capacity in STEM: based on a platform of beliefs, understandings and intentions," *International Journal of STEM Education*, vol. 6, no. 1, p. 10, Dec. 2019, doi: 10.1186/s40594-019-0164-5.
- [57] H. Bakirci and D. Karisan, "Investigating the preservice primary school, mathematics and science teachers' STEM awareness," *Journal of Education and Training Studies*, vol. 6, no. 1, pp. 32–42, 2018, doi:10.11114/jets.v6i1.2807.
- [58] G. Hactömeroğlu, "Examining elementary pre-service teachers' science, technology, engineering, and mathematics (STEM) Teaching Intention.," *International Online Journal of Educational Sciences*, vol. 10, no. 1, pp. 183–194, 2018, doi: 10.15345/iojes.2018.01.014.
- [59] K. Y. Lin and P. J. Williams, "Taiwanese preservice teachers' science, technology, engineering, and mathematics teaching intention," *International Journal of Science and Mathematics Education*, vol. 14, no. 6, pp. 1021–1036, 2016, doi: 10.1007/s10763-015-9645-2.
- [60] M. R. Saleh, B. Ibrahim, and E. Afari, "Exploring the relationship between attitudes of preservice primary science teachers toward integrated STEM teaching and their adaptive expertise in science teaching," *International Journal of Science and Mathematics Education*, vol. 21, no. S1, pp. 181–204, Jun. 2023, doi: 10.1007/s10763-023-10369-8.
- [61] H. Temel, "Investigation of the relationship between elementary school mathematics teacher candidates' attitudes towards STEM education and their proficiency perceptions of 21st century skills," *Uludağ Üniversitesi Eğitim Fakültesi Dergisi*, vol. 36, no. 1, pp. 150–173, 2023, doi: 10.19171/uefad.1147025.
- [62] M. Çevik and E. Özgünay, "STEM education through the perspectives of secondary schools teachers and school administrators in Turkey," Asian Journal of Education and Training, vol. 4, no. 2, pp. 91–101, 2018, doi: 10.20448/journal.522.2018.42.91.101.

- [63] H. Ateş and K. S. Gül, "Investigation of self-efficacy and concern levels of pre-service teachers about STEM education (in Turkish)," *Türk Eğitim Bilimleri Dergisi*, vol. 21, no. 1, pp. 478–504, Apr. 2023, doi: 10.37217/tebd.1211730.
- [64] L. S. Nadelson, J. Callahan, P. Pyke, A. Hay, M. Dance, and J. Pfiester, "Teacher STEM perception and preparation: inquirybased STEM professional development for elementary teachers," *The Journal of Educational Research*, vol. 106, no. 2, pp. 157– 168, Feb. 2013, doi: 10.1080/00220671.2012.667014.
- [65] R. E. Bleicher, "Nurturing confidence in preservice elementary science teachers," *Journal of Science Teacher Education*, vol. 17, no. 2, pp. 165–187, 2006, doi: 10.1007/s10972-006-9016-5.
- [66] E. P. Yildiz, A. Alkan, and M. Cengel, "Teacher candidates attitudes towards the stem and sub-dimensions of STEM," *Cypriot Journal of Educational Sciences*, vol. 14, no. 2, pp. 322–344, 2019, doi: 10.18844/cjes.v14i2.4144.
- [67] J. W. Hur, Y. W. Shen, U. Kale, and T. A. Cullen, "An exploration of pre-service teachers' intention to use mobile devices for teaching," *International Journal of Mobile and Blended Learning (IJMBL)*, vol. 7, no. 3, pp. 1–17, 2015, doi: 10.4018/IJMBL.2015070101.
- [68] S. Papadakis, "Evaluating pre-service teachers' acceptance of mobile devices with regards to their age and gender: a case study in Greece," *International Journal of Mobile Learning and Organisation*, vol. 12, no. 4, pp. 336–352, 2018, doi: 10.1504/ijmlo.2018.10013372.
- [69] J. C. S. Prieto, S. O. Migueláñez, and F. J. García-Peñalvo, "Mobile acceptance among pre-service teachers," in *Proceedings of the 3rd International Conference on Technological Ecosystems for Enhancing Multiculturality*, Oct. 2015, pp. 131–137, doi: 10.1145/2808580.2808601.
- [70] J. C. Sánchez-Prieto, S. O. Migueláñez, and F. J. García-Peñalvo, "Enjoyment, resistance to change and mlearning acceptance among pre-service teachers," in *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality*, Nov. 2016, pp. 691–697, doi: 10.1145/3012430.3012594.
- [71] A. Zhumabayeva, S. Nurshanova, Z. Zhumabayeva, Y. Ospankulov, R. Bazarbekova, and A. Stambekova, "Analysis of prospective primary school teachers' attitudes towards mobile learning tools and acceptance of mobile learning," *International Journal of Education in Mathematics, Science and Technology*, vol. 11, no. 3, pp. 728–743, Apr. 2023, doi: 10.46328/ijemst.3322.
- [72] D. Stoilescu and D. McDougall, "Technological pedagogical content knowledge: a framework for teacher knowledge," *Teachers College Record*, vol. 108, no. 6, pp. 722–727, 2009, doi: 10.1111/j.1467-9620.2006.00684.x.
- [73] K. Nikolopoulou, V. Gialamas, and K. Lavidas, "Acceptance of mobile phone by university students for their studies: an investigation applying UTAUT2 model," *Education and Information Technologies*, vol. 25, no. 5, pp. 4139–4155, 2020, doi: 10.1007/s10639-020-10157-9.
- [74] B. W. O'Bannon and K. M. Thomas, "Mobile phones in the classroom: Preservice teachers answer the call," *Computers and Education*, vol. 85, pp. 110–122, 2015, doi: 10.1016/j.compedu.2015.02.010.
- [75] Z. Walker, H. H. Kho, D. Tan, and N. Lim, "Practicum teachers' use of mobile technology as measured by the technology acceptance model," *Asia Pacific Journal of Education*, vol. 40, no. 2, pp. 230–246, 2020, doi: 10.1080/02188791.2019.1671808.
 [76] J. C. Sánchez-Prieto, S. Olmos-Migueláñez, and F. J. García-Peñalvo, "MLearning and pre-service teachers: an assessment of the
- [76] J. C. Sánchez-Prieto, S. Olmos-Migueláñez, and F. J. García-Peñalvo, "MLearning and pre-service teachers: an assessment of the behavioral intention using an expanded TAM model," *Computers in Human Behavior*, vol. 72, pp. 644–654, 2017, doi: 10.1016/j.chb.2016.09.061.
- [77] J. M. Romero-Rodríguez, I. Aznar-Díaz, J. M. Trujillo-Torres, and A. J. Moreno-Guerrero, "Best practices in the use of mobile learning by university teachers of didactics language-literature," *Revista Conhecimento Online*, vol. 3, pp. 6–25, 2021, doi: 10.25112/RCO.V3.2772.
- [78] T. Sydon and S. Phuntsho, "Highlighting the importance of STEM education in early childhood through play-based learning: a Literature Review," *RABSEL*, vol. 22, no. 1, Sep. 2022, doi: 10.17102/rabsel.22.1.3.

BIOGRAPHIES OF AUTHORS



Aziz Amaaz **b** As worked as a secondary school technology teacher and is currently a technology educational inspector. He is currently pursuing a Ph.D. in physics education at the Faculty of Science, Abdelmalek Essaadi University. He is a member of the "Computer Science and University Pedagogical Engineering" research team. His research interests include physics education, integrated STEM education, the integration of information and communication technologies in STEM education, and the design and development of digital resources for mobile learning. He can be contacted at email: aamaaz@uae.ac.ma.



Abderrahman Mouradi key source of higher education in physics and science didactics at the Higher Normal School of Abdelmalek Essaâdi University, Morocco. He teaches physics and science didactic modules for future physics and primary school teachers. He also conducts research on wind energy and physics education, with a focus on STEM, the integration of new technologies in physics teaching and learning, and the use of augmented reality in physics education. He is active in editing and publishing scientific journals and has currently published 7 articles in indexed journals and presented over 15 papers at international conferences. He can be contacted at email: abderrahman.mouradi@uae.ac.ma.



Essaadi University, Morocco. He teaches science didactics and multimedia pedagogical engineering. He is the director of the "Computer Science and University Pedagogical Engineering" research team at Higher Normal School of Abdelmalek Essaadi University and a member of the "Laboratory of Operational Research, Computing, and Applied Statistics" (LIROSA) at the Faculty of Science, Abdelmalek Essaadi University. He is also the Head of the Department of Mathematics, Physics and Computer Science at the Higher Normal School, Abdelmalek Essaadi University. His research interests include physics education, science didactics, multimedia pedagogical engineering, integration of information and communication technologies in science teaching and learning, and adaptive learning. He can be contacted at email: m.erradi@uae.ac.ma.

Moahamed Erradi 💿 🔀 🖾 🗘 is a professor at the Higher Normal School of Abdelmalek



Ali Allouch **(D) (S) (S) (S)** is professor of higher education in physical sciences and didactics of physics and chemistry at the Higher School of Education and Training, Ibn Tofail University, Kenitra, Morocco. This school is dedicated to the training of primary and secondary school teachers in Morocco. He is working on an innovative design project in collaboration with the "Mechanical and Integrated Engineering Team M21" laboratory at the National Higher School of Arts and Crafts (ENSAM), Moulay Ismail University, Meknes, Morocco. His research also focuses on physics education and integrated STEM education. He has participated as a reviewer at several international STEM conferences. He is working as a USAID expert on redesigning science curricula with a STEM approach at the Ministry of National Education in Morocco. He can be contacted at email: ali.allouch@uit.ac.ma.