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Attitudes of Ecuadorian Secondary School Teaching Staff towards Online STEM Development in 2022

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Abstract. Ecuadorian teachers lack experience in the process of teaching and learning science, technology, engineering and mathematics online (STEML). These limitations are evident in the low grades of students in the general unified baccalaureate (GUB) and in the low application of STEM majors in Ecuador. The study aims to describe, elucidate and understand the attitudes of Ecuadorian teachers towards STEM education in GUB using a multi-method or mixed-method approach study. The design was the DEXPLIS sequential explanatory type. The questionnaire was administered to 194 participants and ten teachers who responded to a semi-structured interview. The sampling technique was non-probabilistic participatory sampling. The student's t-test and ANOVA analysis were used for quantitative data analysis and the triangulation technique for qualitative data. Results showed the lack of materials and technological support hinders online activities. Significant differences were found in the attitudes between the teaching staff of

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public and private institutions and between the different levels of the GUB. Statistical analyses showed that administrative support, professional support, STEML training, teaching and learning time positively influenced the attitudes of STEML teachers.

Keywords: Ecuador; education; multi-method research; science teachers; STEML; teacher′ attitude

1. Introduction

The growing need for nations to remain globally viable and competitive depends on the availability of education and on having a qualified Teaching Staff of Science (TSS), specifically a teaching staff who possess the STEML (Science, Technology, Engineering and Mathematics Online) competencies. The impact of not having a STEML-trained teacher was experienced during the COVID-19 pandemic crisis in Ecuador and many other countries (Navarro et al., 2021).

Virtual assessments showed that more than 60% of Ecuadorian students failed or had their lowest scores in biology, chemistry, physics, and mathematics (Calle, 2022). Consequently, students have little preparation or motivation to pursue STEML-related careers in Ecuadorian universities. Yet, STEML education has been recognised as an effective approach to increase students' motivation and interest in learning the four STEM disciplines (Mulisa, 2019) of science, technology, engineering and mathematics which are connected in real-world problems (Hebebci, et al., 2020). STEML education is a pedagogy as well as a curriculum based on an instructional approach that improves performance in science-related subjects, facilitating student motivation to pursue STEML-related careers at university.

The STEML educational concept involves the integration of subjects in a constructivist environment. Since 2017, Ecuador has adopted UNESCO regulations to ensure the smooth transition of integrating science subjects into the curriculum. The burden of implementing STEML education has been placed on baccalaureate science teachers (biology, chemistry, integrated science, and physics). Although STEML subjects are taught individually according to the Ecuadorian curriculum, the teachers have been given the task of aligning their subject content. Based on the above, according to Kara, (2019) and Zuljan et al., (2021), consolidating science subjects with other subjects is recommended to create a constructivist environment.

The Ecuadorian Ministry of Education is committed to motivating students to learn STEML-related topics and has put extreme pressure on teachers in Ecuador (Ministry of Higher Education, 2018). However, the Ecuadorian teachers have limited experience and nominal efficiency in teaching STEM-related subjects online, and it has become increasingly important to develop the STEML capacity of the teachers. Many studies have shown that hands-on training and creative problem-solving remain imperative in the educational process (Ching & Fernandez, 2020).

Some research indicates that the lack of values and attitudes towards STEML education in Latin countries contributes to underachievement (Blackburn & Heppler, 2019); in consequence, the Ecuadorian government has emphasised professional development programmes that adequately train and equip teachers. Existing studies have suggested a link between teachers' attitudes, motivation and student performance within the same area (Ciftci, et al., 2020; Gok, 2021). When teachers develop progressive attitudes towards collaboration with other teachers, they cultivate a more positive approach to teaching in an interdisciplinary way, and they become more receptive to the idea that STEML students' attitudes, beliefs and enthusiasm can be improved (Ha et al., 2020; Altan, et al., 2018). Understanding STEML teachers' attitudes is therefore critical to successful implementation and is necessary to foster the advancement of teachers' STEML professional development.

In the Ecuadorian context, studies on how science teachers perceive STEML education are scarce, and research on factors that can predict teachers' attitudes towards STEML teaching is limited. The limited evidence that is available is mostly qualitative in nature (Thibaut, et al., 2018; Altan, et al., 2018). This study describes a novel investigation into the attitudes of Ecuadorian teachers to STEML. The research seeks to examine current teachers' STEML attitudes and their fundamental interdisciplinary nature. When the attitudes of Ecuadorian teachers to STEML are known and understood, effective intervention strategies can be developed to support and assist teachers and STEML. As Ecuador prepares to promote science education in the wake of the COVID-19 pandemic, it is imperative to explore the attitudes of teachers to STEML to identify the influencing factors.

In summary, the research focuses on the attitudes of STEM teachers towards teaching in Ecuadorian education. The study analyses and determines the barriers that impede the progressive implementation of the STEML curriculum within the classroom and analyses the factors affecting teachers' attitudes. The research focuses on the following questions:
(1) What are the attitudes of Ecuadorian teachers towards STEML education?
(2) What factors influence the attitudes of Ecuadorian teachers towards STEML education?
(3) What is needed to help teachers implement STEML education?

2. Theoretical foundations

2.1 Attitudes of STEML teaching staff

Attitudes towards STEML education refer to a teacher's views, state of mind or feelings towards the integration of science, technology, engineering and mathematics. In STEML education, students are exposed to specific learning content and intentional instruction derived from interconnected disciplines (Thi et al., 2020; Thibaut et al., 2018). STEML education also includes the use of the engineering design process which involves a cyclical process of students evaluating their solutions and then working to improve them. The implementation of STEML education depends critically on the attitudes of the teachers. However, primary teachers feel that they are not sufficiently equipped to provide science education (Lam et al., 2021). According to Ramli and Awang (2020), primary teachers find students' questions problematic, and they mostly conclude their lessons with standard textbooks or exercises.

In Ecuador, Levels 1, 2 and 3 of the general unified baccalaureates (GUB) offer STEML classes (see Table 1) and since 2018, this new training has been promoted through actions and programmes that raise awareness in the community, generate alliances, and support improvements in the educational process. The Ecuadorian Ministry of Education emphasises the upgrading the teachers and improving attitudes through curricular teacher updating. In this way, students will be the leaders, innovators, scientists, researchers, engineers and technologists of tomorrow (Ministry of Higher Education, 2018).

Table 1: The educational levels of education in Ecuador

Definition	Level	Age
General Unified Baccalaureate (GUB)	1, 2 y 3	From 15 to 17
Higher Basic	8, 9 y 10	From 12 to 14
Middle Basic	5, 6 y 7	9 to 11 years old
Basic elementary	2, 3 y 4	6 to 8 years old
Preparatory	1	5 years old
Initial	Unnumbered	3 to 4 years old

Attitude is a key factor in accepting pedagogical practices or the actual use of STEML education (Wong & Maat, 2020) and teachers’ attitudes are challenging agents in their understanding and interpretation (Tai, et al., 2022). A change in the attitude of the teachers towards STEM education determines the level at which their educational practice changes (Arnado et al., 2022). These implementation agents facilitate new instructional practices such as teaching STEML in a more integrated way. Teachers with positive attitudes towards STEML tend to enjoy teaching in an integrated way; teachers with negative perceptions tend to avoid interdisciplinary teaching (Cennet et al., 2021; Holmes et al., 2021). Margot and Kettler (2019) reported lower STEML attitude scores for mathematics teachers than for engineering/technology teachers because of their resistance to change. It can be conjectured that general student attitudes towards STEML originate from and are enhanced by the teacher’s own attitude (Tardy et al., 2021).

Valid measurement of teachers’ attitudes towards STEML teaching has proven to be a challenge over the years (Potgieter & Potgieter, 2021). Attitude is not a stand-alone concept, but rather a construct comprising multiple dimensions and sub-components. Attitude is addressed in a framework that provides a highly validated and widely applicable instrument for measuring STEML baccalaureate teachers’ attitudes (Tunc & Bagceci, 2021) and consists of three dimensions: cognition, affect and perceived control. These dimensions comprise sub-components that represent a variety of thoughts, beliefs and/or feelings towards STEML teaching (Wahono & Chang, 2019). The cognitive dimension comprises the relevance and relative difficulty associated with STEML teaching. The affective dimension comprises perceived enjoyment of and anxiety towards STEML teaching. The final dimension, perceived control, refers to the amount of control and ability the teachers perceive as having over STEML teaching (Tai et al., 2022; Lam et al., 2021).

2.2 Factors affecting teachers' attitudes towards STEML education

Teachers’ attitudes are fundamental to the efficient implementation of STEML. These attitudes could be shaped by gender, education, training and profession, religious convictions, individual characteristics, personality, and even relationships with others (Toma & Greca, 2018). According to Bronfenbrenner's bioecological model, the four-layered factors of the environment interact in a complex way and all affect the development of individuals (Bronfenbrenner & Ceci, 1994). The ecosystem comprises the larger social system and includes the media, politics and communication of the teachers. Similarly, each of the environments, or system layers, within the STEML education ecosystem has an impact or influence on teachers’ attitudes. This impact is underpinned by the microsystem (immediate environment and social aspects of schooling, such as resources, classroom routines, physical spaces, curriculum, and pedagogy). The mesosystem consists of the administrative, support and school climate indicators. The macrosystem comprises the learning institution, such as the education system and the STEML curriculum (Wolfe & Riggs, 2017). Bronfenbrenner's model recognizes the relationships and inflections between factors, both within and between systems. In this way they are not seen or measured in isolation. The present study employs a bioecological model to systematise factors that may influence teachers’ attitudes towards STEML.

Systematisation allows for the discovery of processes and conditions that ensure or impede the successful implementation of STEML education. Therefore, in this study, the relationship between teachers’ attitudes and the Ecuadorian educational context will be investigated. Despite the lack of consensus among researchers regarding the factors that influence teachers' attitudes, several factors have been identified (Wiebe et al., 2018). Some researchers emphasise the role of teachers’ professional development and training programmes in shaping attitudes (Mendoza et al., 2019; Kaleva et al., 2019), others maintain that teachers’ attitudes are based on personal characteristics and teacher education experiences (Shojaee et al., 2019).

2.3 Personal characteristics

Teachers’ attitudes towards STEML education are influenced by personal characteristics and teachers’ experiences (Terzi & Kirilmazkaya, 2020). For example, some studies report no significant differences in teachers’ attitudes based on gender and age (Vennix et al., 2018) while others claim that men have more positive attitudes towards science and STEML than women do. Shojaee et al. (2019) conducted a study on how school-related and contextual factors affect teachers’ attitudes towards STEML teaching. In that study, teaching background (age, gender, STEML teaching experience, previous education, professional development attendance) and personal attitudes (personal relevance to STEML subjects) were found to be influential factors.

Consistent results were also observed in other, different studies which showed that teachers with a postgraduate degree had more positive attitudes towards

STEML education than undergraduate teachers (Mendoza et al., 2019; Thibaut et al., 2018). Teachers with a bachelor's degree were more confident in their science and technology education than their counterparts without a bachelor's degree. Multiple claims by various researchers argue that many teachers have low scientific literacy and have mostly negative perceptions of science. These are common characteristics that hinder motivation to implement science (Kubat, 2018).

2.4 Training and professional development

The professional development of teachers in education has received much attention by critical stakeholders in STEML education reforms (Madani, 2020; Changtong et al., 2020). Teachers tend to have greater efficiency, confidence and pleasure in teaching STEM when they have had prior STEML content knowledge (Margot & Kettler, 2019). On the other hand, Vongai (2019) and Holmes et al., (2021) argue that involving teachers in professional development is much more effective in changing attitudes than merely participating in science teaching.

Training, as existing research finds, is essential to provide the necessary support for teachers. Thibaut et al. (2018) assert that attitudes are affected by teachers' experiences in subjects from teaching tasks and teaching situations. Attitudes are shaped by the nature of the subject matter a teacher teaches. Tunc and Bagceci (2021) found that teachers were positive about science teaching, but their research indicated that teachers with little or no prior training experienced difficulty and anxiety in education. In contrast, teachers trained with postgraduate degrees showed less anxiety when explaining science and technology concepts (Widya & Rahmi, 2019).

The present study seeks to investigate the perception of teachers towards STEML integration. It also seeks to analyse the factors affecting their attitudes. It is thus theoretically based on the conceptualisation of teachers' attitudes towards science and STEML. Table 2 shows the three dimensions of attitudes (cognition, affect and perceived control) towards STEML education that were investigated.

This research is also complemented by the bioecological model of Bronfenbrenner and Ceci (1994) which was used to establish the relationship between attitude and environment. The bioecological model argues that different environments exist throughout life and that these models can influence behaviour to varying degrees (Kurniati et al., 2022). It suggests that both the person and the environment are mutually reinforcing bidirectionally. Mulisa (2019) refers to the bioecological model as a systems theory in which exist systems of complexities, relationships and multi-level interactions that influence the person and the environment. Individual and collective interactions between variables contribute dynamically to the outcomes of attitudes towards STEML. As shown in Table 2, five factor categories, including demographics, were investigated.

Table 2. Theoretical framework for attitudes of science teaching staff towards STEML.

Categories		Dimensions
Demographic features	Attitudes of science teaching staff towards STEM education	Cognition
STEML education		
Professional and administrative support		Affect
Access to STEML resources		Perceived control
Availability of time		

A three-step hierarchical multiple regression model was used to investigate the predictive power of independent variables, such as demographic information and STEML training, on different dimensions of science teachers' attitudes towards STEML education.

3. Method

3.1. Research strategy and design

The study focuses on the multi-method or mixed-method research paradigm. The research design was sequential explanatory, according to Hernández et al. (2014). In the first stage, quantitative data are collected and analysed, followed by another phase in which qualitative data are collected and evaluated. The DEXPLIS design occurs when the initial quantitative results support the qualitative phase. Quantitative data were used to answer the first and second questions, responses to which were initially collected through questionnaires. Semi-structured follow-up interviews were then conducted to answer the third research question. These interviews were instrumental in understanding and elaborating the key factors that help in shaping the teachers' perceptions of STEML education.

3.2. Research setting and participants

The research was conducted in the city of Quito, Republic of Ecuador, which has a population of approximately 2.11 million people. The target population of the study comprised 194 teachers and was sampled using a nonprobalistic-participatory technique. The letter-questionnaire was sent to the email addresses of the institutions working at the baccalaureate to participate in this study. Of the 510 institutions (public and private) contacted, a total of 45 educational institutions agreed to participate.

The schools were selected based on convenience and ease of access. Teachers who teach biology, chemistry, physics and mathematics responded to the questionnaire. After the questionnaire, participants were given the opportunity of an interview. A stratified purposive sampling technique based on specific demographic characteristics was used to select the interview participants. The researchers sought as representative a sample of participants as possible. Of the 10 participants, half (50%) were from public schools, the other half (50%) were from public schools. The male-to-female gender ratio was also 1:1. Descriptive statistics of the participants are given in Tables 3 and 4.

Table 3. Demographic information of the sample.

Characteristic	N	%
Gender		
Female	90	46,4
Male	104	53,6
Type of school		
Private (Private)	84	43,3
Fiscal (Public)	110	56,7
Age group		
under 25 years old	23	11,9
26-35	112	57,7
36-45	30	15,5
46-55	19	9,8
56 years and older	10	5,2
Grade (GUB)		
1	69	35,6
2	60	30,9
3	65	33,5
Teaching experience		
less than 3 years	20	10,3
4-9	112	57,7
10-15	47	24,2
16 and above	15	7,7
Educational level		
Bachelor's degree (Graduate)	152	78,4
Postgraduate	42	21,6

Table 4. Characteristics of interview informants

Informant	Gender	Age	Experience Docent	Formation	Type of school	STEML training
T.1	Female	39	12 years	Postgraduate	Public	No training
T.2	Female	28	2 years	Bachelor's degree	Private	No training
T.3	Female	25	1 year	Undergraduate	Public	Training
T.4	Female	30	5 years	Postgraduate	Private	Training
T.5	Female	29	4 years	Undergraduate	Public	Training
T.6	Male	37	12 years	Bachelor's Degree	Private individual	No training
T.7	Male	29	5 years	Undergraduate	Public Prosecutor	Training
T.8	Male	40	19 years	Postgraduate	Private individual	Training
T.9	Male	42	20 years	Undergraduate	Public Prosecutor	No training
T.10	Male	38	14 years	Postgraduate	Private Individual	Training

3.3. Data collection instruments

To assess attitudes towards STEML Education, three instruments were applied. Two questionnaires were applied in the quantitative phase and an interview in the qualitative phase. The first was the Dimension of Attitude towards Science (DAS) Instrument, designed by Van Aalderen et al. (2011). The second instrument was the Teachers' Attitudes towards STEML questionnaire, designed by Thibaut et al. (2017). The instruments were adapted, combined, and modified. For the purposes of this research the following steps were taken: first, permission was obtained from the competent authorities to use these instruments; second, the language of the items was simplified; third, the items relevant to the research questions were combined from both sources. The final instrument had a total of 26 items which were divided into three dimensions: the cognitive judgement dimension of STEML, the affective perception of STEML, and perceived control of STEML teaching behaviours.

In the cognitive judgement dimension, the teachers reported on the perceived relevance of STEML and their perceived difficulty in teaching STEML. In the affective perception dimension, teachers' enjoyment and anxiety were measured.

The response options were set by a five-choice Likert scale: ranging through "Never" (1 point), "Hardly Ever" (2), "Sometimes" (3), "Almost Always" (4) to "Always" (5).

Table 5. Reliability results of the instruments applied to teachers (N=194)

Case Processing Summary			
Scale	**Subscale**	**Items**	**Reliability Cronbach's α**
Attitude	Perceived difficulty	6	0.794
	Perceived relevance	4	0.702
	Anxiety	4	0.899
	Enjoyment	5	0.850
	Perceived control of teaching behaviours	7	0.758
Factors	Professional and administrative support	5	0.854
	Access to STEM resources	5	0.755
	STEM training	5	0.798

To establish the reliability of the questionnaire, a pilot test was applied to five participants and Statistical Package for the Social Sciences (SPSS) was used to calculate Cronbach's alpha coefficient for each subscale. In the pilot test the results were greater than 0.700, indicating reliability. (Ponce, et al., 2021). As a third instrument, the semi-structured questionnaire was used. This research employed a semi-structured interview for its flexibility (see Table 6). The development of the interview protocol was based on both the theoretical framework and the results of the questions from the quantitative phase.

Table 6. Script of questions applied to the key informants of the research

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Date: ___/___/___	Informant:	________________
Semi-structured interview		
Items		
1	What kind of resources do you apply in STEML teaching?	
2	How capable do you feel of teaching and integrating the different aspects of STEML into your lessons, and why?	
3	What other things do you think can help you be effective in implementing STEML education?	

Key words were explained within the questions contained in the interview guide. Interviews were conducted using an interview protocol with the researcher following a script. The interviews were conducted virtually using the GoToMeeting application (Cavus & Sekyere, 2021) and were recorded and transcribed. In this way, researchers could gain an in-depth understanding of the participant's opinion regarding the factors that they believe can improve their attitudes towards STEML education.

3.4. Data analysis

Each subscale of the questionnaire was considered as an analysis group. These groups were compared and analysed quantitatively using Student's t-tests and ANOVA. The results were developed with the SPSS version 25. These methods facilitated the comparison of attitude scores between the groups. Correlation and regression analysis was used to determine the relationship and was also applied to establish the predictive value of factors such as demographic information, training, support and time on the attitude subscales. In the qualitative phase, interpretive analysis was used to analyse the information with respect to the interview and the technique of contrasting the information was applied (Feria et al., 2019).

A hierarchical multiple regression model consisting of three steps was used to investigate the predictive power of the independent variables. Analysis of predictions of the different dimensions of teachers' perceptions of STEML education was chosen, based on Bronfenbrenner's model. Predictors were included sequentially in the models as follows: all demographic predictors were included in Model 1 as controlled variables. In Model 2, all other factors were added. In Model 3, potential interactions between factors were added to investigate moderating effects. Non-significant variables were removed from the final model, which comprised only the significant predictors of the outcome variables.

At the conclusion of the statistical analyses, the researchers cross-checked the results with interview feedback, improving clarity, providing a deeper understanding and ensuring easy categorization of the data using structural networks from which the respective themes for further interpretation were derived.

4. Results

The quantitative and qualitative results were contrasted using triangulation. In this way, the questions posed were answered.

4.1 Question 1: What are the attitudes of Ecuadorian science teachers towards STEML education?

Table 7 shows no significant differences between male and female teachers with respect to their overall attitude scores (t = -.974, p=.331). Similar trends were also observed for age (F=1.273, p=.282) and teaching experience (F=1.259, p=.290). However, a significant difference in overall attitude scores was observed between private and public school teachers (t=2.202, p=.029).

Table 7. Differences between groups in terms of overall attitudes towards STEML

Variable	N	M	SD	t/F (*p*)
Gender				
Male	104	3.41	.16	−.974(.331)
Female	90	3.37	.19	
School Type				
Private	84	3.39	.16	−2.202(.029)
Fiscal (public)	110	3.36	.20	
Grade				
1	69	3.39	.20	1.751(.057)
2	60	3.36	.17	
3	65	3.35	.16	
Education level				
Bachelor's degree	152	3.54	.22	−.783(.435)
Postgraduate or Master's degree	42	3.51	.23	
Age				
Under 25	23	3.43	.13	1.273(.282)
26-35	112	3.53	.24	
36-45	30	3.56	.22	
46-55	19	3.56	.14	
56 and above	10	3.50	.31	
Teaching Experience				
Under 3	20	3.44	.24	1.259(.290)
4-9	112	3.53	.22	
10-15	47	3.53	.22	
16 and above	15	3.56	.19	

4.2. Question 2: What factors influence teachers' attitudes towards STEML education?

The results of the first step of the regression model (Table 8), the demographic predictors "Type of school" and "Grade taught" collectively accounted for 5.1% of the variance in the outcome variable. These results indicated that teachers teaching higher grade levels had more positive attitudes towards STEML education than teachers teaching lower grades. Similarly, teachers in public schools had more positive attitudes towards STEML than those teaching in public schools. The results of the second step of the regression model showed that the interactive effects of the variables included in this model accounted for 31.8% of the variance in the outcome variable. Type of school (β = .029), STEML training (β=.325), level of support (β=.296), sufficient time to prepare (β=.202) and insufficient time to use the STEML approach (β=.104, p=-.147) contributed tentatively to the model. This generally indicates that teachers who have less training in STEML and less support from school administration are likely to have negative attitudes towards STEML.

Table 8. Results of hierarchical multiple regression of factors influencing teachers' attitudes towards STEML education.

	Model 1		Model 2	
Variable	**B (*p*)**	**β**	**B (*p*)**	**β**
(Constant)	3.338		2.998	
School type	.084(.011)	.190	.061	.029
Grade taught	.084(.019)	.175	.040	.032
STEML training			.142	.296
Insufficient time to teach			−.047	−.147
Sufficient time to prepare			.041	.202
R^2	.051	.318		
F	4.946	13.917		
ΔR^2	.051	.267		
ΔF	4.946	17.510		

4.3. Question 3: What is needed to help teachers to implement STEML teaching?
When teachers were asked what was needed to effectively implement or teach their instructional topics using the STEML approach, three recurring themes emerged: the first was training and professional development; the second theme was peer collaboration and administrative support, and the third was the availability of resources such as computers and software.

4.4. Training and professional development in STEML are the most important factors
All 10 participants interviewed highlighted the importance of training in STEML. Constant training implements successful STEML education in a more meaningful and integrated way. The majority (8 out of 10) of the participants highlighted their ability to successfully align other STEML subjects with their instructional subjects and attributed their ability to prior STEML training, either in the form of professional development or during their pre-service teacher education programme. In contrast, one participant expressed a generally negative level of ability on account of the lack of training and professional development opportunities within his school. Participant T.9, a 42-year-old GUB teacher, expressed his dissatisfaction in these words:

> *"I don't feel able to teach and integrate other aspects of STEML. To be frank with you, the pandemic made me very unhappy. The reason is that I don't have any knowledge to explain STEML. Also, I have no training to teach STEM with computers. The training can help me to be effective in integrating STEM education virtually."*

The participant clearly felt anxious and unhappy owing to the lack of STEML training available.

Participant T.4 expressed their ability to teach their subject alone, but attributed their lack of confidence in aligning other STEM subjects to the lack of STEML training. All teachers interviewed alluded to the need for professional development opportunities in the form of workshops, short training programmes, seminars, and opportunities to study abroad. They also felt that STEML is dynamic and requires constant training to be implemented effectively. They said that the quality of their delivery within the classroom depended to a large extent on improving its quality through professional development. In addition to professional development, seven participants (Participants T.1, T.2, T.4, T.7, T.8, T.9, T.10) mentioned that local and international experts should be invited to share their knowledge. Technical advice on evaluation and mentoring would help them enormously and they believed that continuous technical support from these STEML experts would help them to become more professional. Participant T.5 said:

> *I have little educational experience, I need STEML experts. The experts can provide me technical support with additional knowledge.*

4.5. Availability of resources improves teachers' attitudes.

The general availability or absence of digital resources was the most frequent theme in the interview transcripts. In general, the teachers expressed a lack of support from educational institutions, which generated distress about the absence of adequate resources within their schools during the COVID-19 pandemic. Participant T.2 voiced this concern:

> *I have a very limited computer[access]. My access to the internet has really affected the teaching in my subject. Worse using the STEML approach. Realistically speaking, most of the materials I use are mine. If I were given the technological equipment, everything would be better. I am required to use technology, but the payments do not solve the problem.*

Participants stated that STEML was a complex construction involving many things. As such, it was right to have access to STEML resources to make it more meaningful, interesting, and less stressful. Participant T.6, a teacher from a public school said:

> *Because STEML involves more than one subject, it will require four times more activities. Therefore, it is expected that the materials needed to teach it will be more. For me, if one is to conduct a full STEML instruction, one will need a well-equipped laboratory; a fast and efficient computer, a projector and other STEML-related teaching materials. These things will make STEML instruction very easy. Without these things, teaching STEML is stressful and difficult.*

The resources they mentioned during the interviews included a well-equipped modern lab, science kits, current digital PDF books, fast internet, modern computers, and budget support. Despite these school-related challenges, some of the teachers were quite optimistic and resourceful. Participant T.5, a public-school teacher, articulated her resourcefulness amidst the lack of resources:

> *I don't really have adequate resources for the full STEML presentation. But I have tried my best over the years, using my training knowledge in these areas to teach.*

However, because of the passion I have for STEML, most of the time I use my salary to get teaching materials to teach.

4.6. Teachers need peer-to-peer collaboration and administrative support to teach STEML

Collaboration was a theme that was related to other themes found in the interview. The essential nature of collaboration between the teachers and administrators was obvious throughout the interview process. Participants T.2, T.3, T.4, T.5, T.6, T.7 and T.10 considered peer evaluation as well as collaboration between teachers of different STEML subjects, partner teaching, provision of necessary resources. Participants T.1, T.2 T.3, T.4, T.5, T.6, T9 and T.10 felt that peer collaboration was a form of professional development that made STEML teaching easier and more enjoyable. An analysis of the transcripts revealed that all participants believed that school administrators had a key role in providing STEML resources to implement it successfully. Interviewees emphasized the need for administrators to be proactive in establishing meaningful internal and external collaboration among participants. Participant T.8 expressed his thoughts on this issue by saying:

> *Educational administration has a role to play in helping us teach STEML. The administration should supervise my work and provide me with what I need to teach well. My colleagues should work as a team for lesson planning. When everyone collaborates, it saves planning time and makes teaching easy and enjoyable.*

The teachers indicated that the STEML approach is highly integrated and collaborative, and this collaboration should be evident in its implementation. Five of the ten participants voiced the importance of the role of school principals, who had a duty to create an enabling environment for teachers to work in. Teamwork as well as an environment for student achievement in science and STEML-related subjects was essential for success. The teachers reiterated the massive failure of students in STEML-related subjects in mid-term and termly examinations in which the blame for low grades is always placed on the teachers. Participant T.1, a 39-year-old woman with 12 years of teaching experience said:

> *We cannot work alone. We try, but it is difficult. If you are passionate about what you do and you have all the knowledge in the world, being in a school where there is no support is difficult. The school environment and the administration can help us fail or succeed, so they are very important, if they weren't, I would just stay at home. If not, then I would offer tutorials at home for students.*

5. Discussion

In the Republic of Ecuador, the COVID-19 pandemic forced an unexpected turn on education. Moving from face-to-face to virtual education was difficult. The education system demanded the implementation of STEML as a strategic plan, but it did not take into account the need for teachers or the problems of low performance of students in STEML subjects at GUB level and lack of preparedness of students. As Ramli and Awang (2020) pointed out, there has been a growing decline in student interest in science, engineering, mathematics, and technology in Latin America owing to the lack of trained STEML instructors. In this context, the Ecuadorian Ministry of Education is promoting the development of courses and research. The present study contributes to the description and interpretation in the following ways.

Firstly, the current study demonstrates the attitudes and lack of understanding of teachers towards STEML teaching. It also demonstrates relevant influential factors in the Ecuadorian educational context and highlights the importance of teachers' attitudes towards STEML teaching from three dimensions. The study examines the factors affecting teachers' attitudes and investigates their views on what is necessary to implement STEML in the Ecuadorian context.

Secondly, the study is important for strengthening the capacities of the teachers because it provides relevant recommendations that will help the STEML education division within the Ministry of Education. When the attitudes of the teachers are known and understood, effective programmes can be developed to support and assist the science educator. Specifically, the study will help policy makers in Ecuador more aware of teachers' attitudes towards STEML and the factors that influence their attitudes (Ching & Fernandez, 2020). It will ensure that STEML career development programmes are more efficient and responsive to science needs in Ecuador in order to increase student achievement, interest and motivation in STEML careers.

Thirdly, this research provides a rationale for an intervention to reform STEML education.

5.1. What are the attitudes of Ecuadorian science TEACHERS towards STEML education?

The first research question examined the attitudes of teachers towards online STEM education. The results suggest that GUB teachers have a positive outlook towards STEML education although they differed in attitudes, based on school type and grade levels. However, there were no significant differences between genders. With regard to the need for serious economic development, the teachers alluded to the importance of STEML education for the development of the country.

Teachers in private schools showed a more positive attitude towards STEML education than those in public schools. The main reason for this difference could be that private schools provide resources and, by maintaining better services, they attract more students (in most cases, they have a higher socio-economic status than those in public schools). In this context, most private schools in Quito, Ecuador, tend to invest in scientific equipment. These schools have teaching resources and look for better qualified teachers.

Secondly, the environment of private schools is more favourable. The rectorate or principals tend to be more involved in the teaching process. They also tend to participate in many STEML activities (such as virtual science presentations and robotics competitions). In the case of public schools, obtaining resources for such activities is very cumbersome and bureaucratic.

Finally, public schools are overcrowded. As a result, teachers must deal with two or more very large classes with an average of 45 pupils per class. The large class sizes make STEML teaching difficult and frustrating for teachers.

Based on the three Grade levels, teachers teaching at Grade Levels 1 and 2 generally have less experience in teaching STEML. They have access to fewer professional development opportunities and are often less qualified than teachers working at Level 3. GUB teachers rarely have graduate or Master's degrees; they are usually Bachelor graduates. Those GUB teachers teaching at Level 1 generally have larger classes whereas teachers at Levels 2 and 3 teach smaller classes. This factor is consistent with Simpson and Bouhafa (2020) who argue that most Level 1 teachers have a low level of scientific literacy. These teachers also demonstrate mostly negative attitudes towards science. The GUB Level 1 teachers also feel more confused about STEML, unlike the Level 3 teachers, who enjoyed teaching STEML more. This difference is possibly a result of the teachers' belief that they are adequately qualified to teach STEM with technology. To obtain a science degree (biology, chemistry, engineering, physics) in Ecuador, you must study some aspect of STEML courses for at least two semesters (technology education is not available at some universities). All this previous experience with more science and mathematics courses stimulates the teachers to be more aware and positive, as described by Thibaut et al. (2017). These results align with other research that claims that perception might be affected by the subject experiences of the teachers (Ugras, 2018; Kurniati, et al., 2022).

5.2. What factors influence the perception of the TEACHERS towards STEML education and why?

Alangari, (2022) and Selco and Habbak, (2021) emphasize that individual and contextual factors shape perceptions and attitudes of teachers. Therefore, this study specifically examined the relationship between teachers' demographic characteristics, school environment variables and their attitudes towards STEML teaching.

The main recurring inflection factors found in the regression analysis showed that professional development, sufficient preparation time and administrative support positively influence STEML attitudes, whereas insufficient class time (actual teaching time) negatively influenced attitudes. This factor is consistent with research by Roberts et al. (2018) and Asgari et al. (2021). The cited authors suggest that, in the context of STEML education, teachers are forced out of their comfort zone. Therefore, in addition to providing time for collaboration and planning, the presence of a strong support system, STEML training opportunities, sufficient preparation time and the virtual classroom greatly reduce anxiety, and would have a greater influence on attitudes as well as reduce teachers' levels of difficulty towards STEML teaching.

In this study, teacher training had the strongest positive correlations with STEML attitudes. Similarly, a study by Nurtanto et al. (2020) indicated that in-service STEML teachers had significantly higher self-efficacy scores for instruction. According to the authors, the higher levels arose from completing a two-year professional development programme.

5.3. What is needed to help Ecuadorian teachers implement STEML instruction?
This study found that access to STEM technology resources, support, and the need for STEML training surfaced most frequently in the qualitative data. The Ecuadorian teachers saw the main obstacles to STEML implementation as the lack of support, technological resources, and training. Professional and administrative support helps the teachers to constantly improve their teaching practice as well as facilitate the development of students' interests. However, a teacher working in a solo environment is bound to feel unsupported and overburdened.

The lack of resources, support and training made the teachers feel apprehensive and unhappy about STEML teaching practice. These components are consistent with many studies that allude to the importance of these factors in implementing STEML education (Muenks et al., 2020). For example, research by Ha et al. (2020) identified the following factors as likely to make STEML teaching easier or more difficult: collegial and social support, professional development, collaboration, lack of resources (materials and money), time allocated to science in the curriculum, and time to prepare science lessons.

6. Conclusion and implications

Three main findings surfaced in the research. First, GUB teachers of science have a positive outlook towards STEML education although teachers' attitudes differed, based on school type and grade levels. Private school teachers have more positive STEML attitudes than their public-school counterparts. Secondly, the study revealed that professional development, sufficient teaching hours, preparation time and administrative support positively influence teachers' attitudes. Finally, teachers need STEML professional development. They require peer collaboration, administrative support, and STEM resources to successfully implement STEML. Based on the findings, there is a need to provide additional support to the GUB teachers. It is recommended that STEML professional learning communities should be established, and attitude-focused STEML training programmes should be designed. These actions will reasonably drive the effective implementation of STEML education in Ecuador.

The implications for future research based on this research are numerous. First, this study has implications not only for Ecuador, but also for nations around the world. Although the factors here were drawn from a sample from the province of Pichicnha, Quito, Ecuador, the results are consistent with other cultures (Zeidler, 2016). For example, both groups of teachers may recognise the importance of STEML education, but it was also found that teachers from different contexts face similar challenges. These challenges are insufficient support (Thibaut et al., 2018b), limited teaching resources (Li et al., 2020) and lack of training (Mendoza et al., 2019). For example, Kelley et al. (2020) noted that, in the United States, teachers could potentially limit their students' exposure to the totality of STEML knowledge by limiting themselves owing to their own loss of teaching skills. Li et al. (2020) noted that the professional growth of STEM teachers depends on policy support at the bureaucratic level. These factors imply that the development of STEML education is not an easy task for any country. As such, more connection, more technology, more communication, more exchange, and more teamwork will benefit us all.

Secondly, the factors based on this study will also help future research by facilitating other studies to design context-based strategies to improve STEML education. Based on the quantitative and qualitative data, STEML professional development training was identified as one of the influential factors. This influencing factor was always related to teachers' attitudes. Therefore, future research could analyse existing STEML professional development programmes and analyse the key content and strategies that shape attitudes to see if they have been addressed. In addition, given that teachers are concerned about insufficient support, future research could explore how support could be provided efficiently, especially within the school context.

Thirdly, as a pioneering research work in Ecuador, this study intends to provide important information on the current situation in STEML education and information based on quantitative and qualitative paradigms or methodologies. Although it focuses only on the teachers in the province of Pichincha, Ecuador, the factors could also be generalized to other provinces in Ecuador (there may be slight contextual differences) and even to other South American nations owing to similarities in contexts and challenges. Martinez et al. (2019) have pointed out that Ecuador faces a severe skills shortage in STEML areas owing to challenges such as poor resources and infrastructure. There are also the limitations of inappropriate and deficient curricula, and the absence of assessment practices which result in teachers with inadequate pedagogical and subject knowledge and, consequently, disengaged and unenthusiastic students. This situation points to the need for better teaching and STEML interventions all aimed at improving the pedagogical practices of Ecuadorian teachers in STEM subjects (Ching & Fernández, 2020).

7. Limitations

The limitations of the current study need to be addressed in future research. Firstly, only a limited number of influencing factors were investigated; there are many complex contextual factors that may influence STEML perception, and more studies are needed to further investigate the bigger picture and provide a broader view of the Ecuadorian educational context. Future research could also examine each factor in more depth to provide a clearer picture of the extent to which a specific factor affects STEML attitudes of the teachers.

Secondly, the factors are based on teachers’ self-reports which, although it is a common methodology for measuring implicit perception, could elicit socially undesirable responses (Thibaut et al., 2018). Unfortunately, implicit measures of ability beliefs (such as implicit association tests) are currently absent. However, the results of this study are significant owing to the limited empirical research on the relationship between STEML attitudes and attitude-shaping factors. The former open the door to examine new approaches to stimulating teachers' attitudes towards STEML education.

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