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STEAM conceptions, competencies and attitudes in higher education: a pilot study

Concepciones, competencias y actitudes STEAM en la educación superior: un estudio piloto

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Abstract

The rapid development of the STEAM disciplines (science, technology, engineering, art and mathematics) has allowed education based on this approach to be considered as a key and essential component for 21st century education, where students are required to have a range of science and technology skills, skills and knowledge, in addition to providing them with a range of tools to cope with the various situations that arise, many of them complex and challenging; the objective of this paper is to show the preliminary results of a pilot study that was carried out to validate two instruments that were designed in order to evaluate the competences and attitudes in STEAM education of students and university teachers. To meet this objective, four stages were implemented that included the following moments: Phase 1. Estimation of the distribution of data, Phase 2. Pilot study, Phase 3. Estimation of reliability and internal consistency. Phase 4. Preliminary results. The main results show favorable indicators in understanding, relevance and satisfaction of the items and an adequate internal consistency around the values of reliability and validity.

STEAM education, knowledge Socioformation and knowledge society, interdisciplinary approach, pilot study

Resumen

El desarrollo vertiginoso de las disciplinas STEAM (ciencia, tecnología, ingeniería, arte y matemáticas) ha permitido que la educación basada en este enfoque sea considerada como un componente clave y esencial para la educación del XXI, donde se le exige al estudiantado una serie de habilidades, destrezas y conocimientos de ciencia y tecnología, además de otorgarles una serie de herramientas para hacer frente a las diversas situaciones que se le presentan, muchas de ellas, complejas y desafiantes; el objetivo del presente trabajo es la de mostrar los resultados preliminares de un estudio piloto que se realizó para validar dos instrumentos que se diseñaron con el fin de evaluar las competencias y actitudes en la educación STEAM de estudiantes y docentes universitarios. Para cumplir con este objetivo se implementaron cuatro etapas que comprendieron los siguientes momentos: Fase 1. Estimación de la distribución de los datos, Fase 2. Estudio piloto, Fase 3. Estimación de la confiabilidad y la consistencia interna. Fase 4. Resultados preliminares. Los resultados obtenidos muestran indicadores favorables en comprensión, pertinencia y satisfacción de los ítems, así como una adecuada consistencia interna en torno a los valores de confiabilidad y validez.

Educación STEAM, Socioformación y sociedad del conocimiento, enfoque interdisciplinario, estudio piloto

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Introduction

The concept of university education in the 21st century has evolved from the conceptualisation of the information society to the knowledge society, where students are expected to be competent problem solvers with a collaborative, systemic and ethical approach (Salazar-Gómez and Tobón, (2018). This is why there is a need to redefine and innovate teaching and learning models that allow students to develop the skills and abilities associated with creativity, communication, problem solving, and technical-scientific knowledge and competences to deal with the various complex and challenging situations of today's world (Toh, Causo et al. 2016).

According to Santillán, et al. (2019), education with STEM (Science, Technology, Engineering, and Mathematics) methodology is a proposal that allows us to respond to these new requirements of the knowledge society.

The term STEAM was introduced in 1990 by the National Science Foundation (2020) to describe the set of disciplines that will have the purpose of forming new skills and abilities in young people in the United States, with the aim of responding to the needs that were envisaged from the technological revolution and industry 4.0 (Jiménez-León, Et al., 2021); from this, changes were made in educational policies that in the short term were adopted by other countries such as the United Kingdom, Taiwan, Japan, China and Korea, who developed educational methods and systems that give importance to science and technology.

Mexico also adopted the STEM approach, emphasising the linkage that should exist between business and higher education institutions, which has led to significant progress in the development and practical application of real and innovative projects (Peña and Bermúdez, 2016; Jung, 2019).

After more than 30 years of the formulation of the term STEM, and the educational evolution in the teaching of science and technology that this entails, the STEM approach becomes relevant and is transformed to incorporate the arts, modifying its acronym to STEAM (Science, Technology, Engineering, Arts and Mathematics), with the aim of considering aspects such as creativity, ethics, aesthetics and innovation in academic work (Cilleruelo & Zubiaga, 2014). STEAM allows higher education institutions to formulate an educational ecosystem, allowing equal access to young people, regardless of their background, race, ethnicity, gender, religion or income (UNESCO, 2017).

By implementing the STEAM methodology at the university, students develop scientific and technological knowledge and skills through a series of academic practices framed in the context of the real world, promoting problem solving in a creative, collaborative and innovative way, in order to provide students with the necessary tools and a solid professional training, which promotes the social and economic progress of society (Levinson & Parrise Consortium, 2014; European Commission, 2014; Couso, 2017).

An educational proposal is considered a STEAM methodology when classrooms become a learning community, and the process for acquiring knowledge is student-centred, considering that it is the student who constructs it, with a focus on solving problems of daily life, with collaborative and interdisciplinary components, and its objects of study or phenomena are in the domain of the disciplines of the hard sciences (Pelajero, 2018).

ISSN 2524-2075

December 2022, Vol.6 No.11 6-20

The implementation of pedagogical practices and strategies to achieve STEAM objectives in the university classroom should be based on active didactics such as those presented below: Problem-Based Learning (PBLm), Cooperative Learning (CL), Project-Based Learning (PBLt) and Challenge-Based Learning (CBL). In general, the purpose of the four strategies previously mentioned, will allow students trained in STEAM to acquire scientific-technological knowledge; communication skills, creativity, useful search and treatment of information; attitudes such as commitment and responsibility; social competences reflected in project work, evaluation of processes, problem solving, implementing solutions, personal motivation, teamwork, interpersonal relationships, social relations, collaborative work, among others (Usache, 2019; Jiménez-León, et al, 2019); thus achieving the purpose that characterises STEAM: to connect students' learning with their reality and with the world of work, to generate practical learning and with a clear relationship between what they learn and what is expected of them in the future (Vo et al., 2017; Casado & Checa-Romero, 2020)

The four active strategies for the implementation of STEAM projects are described below, all of which are based on having a stimulus, be it a project, problem or challenge, with the aim of producing a specific response: outcome, resolution or solution:

Problem-Based Learning (PBL) is a student-centred method, it is based on the application of acquired knowledge and the development of skills, abilities and competences, teachers are facilitators in the learning process and students actively participate in the search for the solution (Diego-Mantecon, et al., 2021). Cooperative Learning (CL) is a strategy that is used with small groups of 5 or 6 students with the aim of maximising their own and their peers' learning, favours the development of social competence and inclusion (Thibaut et al., 2018). With the CA methodology, the working team is aware that the cooperation and participation of each of the members is required to achieve the common goal, therefore, the achievement obtained belongs to all.

Project Based Learning (PBL) is a strategy that gives importance to the students' ability to organise the work and activities for the development of the project, students start from a set of tasks and actions assigned among themselves in order to solve a real life problem; it focuses on the application of the knowledge acquired in the classroom. In Challenge-Based Learning (RBL), a practical solution to a problem is sought using technology for this purpose, its purpose is to produce a real impact on the community, it focuses on the acquisition of new knowledge that arises from the need to solve the challenge and on the development of skills and Soft Skills competences (Diego-Mantecon, et al., 2021).

An important element according to Gisbert, González & Esteve (2016), is the figure of university teachers in STEAM education, who have a key and leading role, so it is necessary to provide clear and explicit pedagogical guidelines, which in turn allows them to implement pedagogical practices in the classroom that promote scientific and technological education, with a character of innovation, using information technologies and the diversification of collaborative learning environments (Dijk, et al., 2020; Lioum & Daly, 2020). For Jho, Hong & Song (2016), designing classrooms with a STEAM approach leads to teacher open-mindedness and self-innovation.

Teachers must bear in mind that their goal is to train a generation of interested, skilled students with a set of skills and knowledge that will enable them to solve complex problems collaboratively, with an integrative approach, using technology, making use of critical, logical-mathematical and analytical thinking, with motivation, initiative, innovation, creativity, originality and mental flexibility, using assertive communication, leadership, ethics, social influence and stress tolerance, emphasising active participation in their future profession and society (Kurup, Li, Powell, & Brown, 2019; Pantoja Et al. , 2020).

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A relevant aspect within STEAM learning that is important to keep in mind is the promotion of gender equity in this knowledge ecosystem (UNESCO, 2017), in which the participation of girls, adolescents and young people from different educational levels in the different existing areas of science is encouraged, providing an important boost in scientific vocations (Fernández, Schaaper and Bello, 2016; Ortiz-Revilla et al.,2020); to achieve this, a joint effort by teachers, institutions and families is required to eliminate the prejudices associated with the study of hard areas, which are traditionally considered as complex areas mainly intended for the male gender (Penuel, Clark, and Bevan, (2016); another relevant point is the issue of motivation from childhood to the university stage, for which it is necessary to highlight the skills that girls and young women have and encourage the development of curiosity in science (Simarro, C., Couso, D. 2021).

To achieve gender equity in STEAM, Rahm (2016) mentions five principles to keep in mind when designing learning activities, namely: (1) Leveraging values and practices to articulate shared learning goals; (2) Engaging stakeholders in co-design; (3) Making connections between settings; (4) Naming young people as contributors; and (5) Intentional learning from intermediaries in different settings.

Due to the importance of STEAM in education, a pilot test of two instruments was carried out in order to investigate the conceptions, competences and attitudes around the STEAM educational approach at university level, in teachers and students, the purposes of the study were: 1) to analyse the degree of understanding, wording, relevance and general satisfaction of the participants with respect to the instructions, items and descriptors of the instruments; 2) to estimate the reliability and internal consistency of the constructs and 3) to determine the level of development of STEAM conceptions, competences and attitudes.

Methodology

Type of study

This research was conducted with a quantitative, predominantly instrumental approach, whose methodological basis consists of administering the instruments to a small sample of cases to test their relevance and effectiveness (including the understanding of the instructions), as well as the conditions of the application and the procedures involved. Based on this test, the reliability and initial validity of the instrument is calculated (Soriano, 2014; Ventura-León & Caycho-Rodríguez, 2017).

Participants

In total, 253 university students answered the Scale for University Students on STEAM Education in Mexico (ESTEAM-34), of which 51% were female and 48.6% male, with an average age between 15 and 26 years old (97.2%), coming mostly from public universities in the country (95.7%) and enrolled in different semesters (from first to twelfth). Furthermore, as can be seen in Table 1, at least 44.7% of the participants have received recognition for their academic performance, 88.5% stated that they had not failed any subject in the previous semester, and only 10.8% confirmed that they had dropped out of the course once or twice at some point.

Variable	Category	Frequency	Percentage
Sex	Male	123	48.60%
	Woman	129	51%
	I prefer not to say	1	0.40%
Age range	15-20	108	42.70%
	21-26	138	54.50%
	27-32	4	1.60%
	33-38	2	0.80%
	43-48	0	0%
	More of 48	1	0.40%
Type of university	Public	242	95.70%
	Private	11	4.30%
Semester/ semester term you are currently studying	First	65	25.70%
	Second	2	0.80%
	Third	4	1.60%
	Fourth	49	19.40%
	Fifth	3	1.20%
	Sixth	3	1.20%
	Seventh	45	17.80%
	Eighth	2	0.80%
	Ninth	1	0.40%
	Tenth	60	23.70%
	Eleventh	10	4.00%
	Twelfth	9	3.60%
Number of times he/she has been recognised for academic performance	None	107	42.30%
	One	40	15.80%
	Two	33	13%
	Three	28	11.10%
	Four	6	2.40%
	Five	6	2.4
	More than five	33	13%
Number of	None	224	88.50%

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subjects failed in the last semester	One	9	3.60%
	Two	11	4.30%
	Three	2	0.80%
	Four	3	1.20%
	Five	0	0%
	More than five	4	1.60%
Number of times he/she has withdrawn from the race	None	227	89%
	One	24	9.50%
	Two	2	0.80%

Table 1 Sociodemographic and academic characteristics of the students who participated in the study

On the other hand, we had the collaboration of 21 university teachers who responded to the scale for teachers on STEAM education in Mexico (DSTEAM-36). Of these, 61.9% were men and 38.1% were women, aged between 36 and 57 years (76.1%). These teachers claimed to have an average of 15 (± 10) years of teaching experience, 81% had a postgraduate degree in some area and 61.9% worked in public universities. They also described that they participated as speakers in scientific events more than once (61.8%), 51.6% published at least one scientific article and 23.8% published between 1 and 5 books.

Variable	Category	Frequency	Percentage
Sex	Woman	8	38.10%
	Men	13	61.90%
Age range	18-23	1	4.80%
	24-29	4	19.00%
	30-35	0	0%
	36-41	7	33.30%
	42-47	2	9.50%
	48-50	4	19%
	51-57	3	14.30%
Last degree obtained	Bachelor's degree	4	19%
	Master's degree	11	52.40%
	Doctorate	6	28.60%
Type of university where you work	Public	13	61.90%
	Private	8	38.10%
Number of scientific articles published so far	None	10	47.6
	01-may	4	19%
	06-nov	5	23%
	dic-17	1	4.80%
	18-23	0	0%
	24-30	1	4.80%
Number of times he/she has participated as a speaker at scientific events	None	8	38.10%
	01-may	7	33.30%
	06-nov	4	19%
	dic-17	2	9.50%
Number of books published so far	None	16	76.20%
	01-may	5	23.80%

Table 2 Socio-demographic and professional characteristics of the teachers who participated in the study

Procedure

After having validated the content of the two questionnaires, a pilot test was carried out with a group of 21 students and 21 teachers, who participated by answering a questionnaire of satisfaction with the instruments.

Through this procedure, the degree of satisfaction of the respondents was sought, the reliability of the instrument was evaluated and some preliminary results were reported. The collection of information was carried out through a form elaborated in the Google forms tool and the invitation was sent to the participants by e-mail.

Instruments

The scale for students on STEAM education in Mexico (ESTEAM-33) consists of a Likert-type scale, which has criterion validity by a group of judges, who evaluated in a satisfactory way the comprehension, wording and relevance to the totality of the proposed items (Aiken's V > 0.80). After considering some recommendations and making adjustments based on the judges' opinions, the final scale consisted of 33 questions, with five response options ranging from very low (1.0) to very high (5.0), other options are nominal and some have open answers. The instrument was provisionally distributed into five dimensions, which can be seen in table 3, and allows us to inquire about some STEAM conceptions, competences and attitudes in higher education students.

Dimensions	Items	V de Aiken	
		Relevance	Writing and comprehension
I. Pedagogical conceptions about the STEAM educational approach	1. Level of knowledge of the STEAM educational approach.	0.939	0.909
	2. Level at which teachers design their classes using the STEAM approach.	1	1
	3. Degree of importance of STEAM education at any educational level.	0.848	0.758
	4. Importance of STEAM education for professional and personal futures.	0.818	0.727
	5. Importance of applying STEAM knowledge and skills in everyday life.	0.939	0.788
	6. Sufficiency of time devoted to STEAM subjects in the school timetable.	0.848	0.727
	7. Importance of time allocated by the university for STEAM education.	0.939	0.818
	8. Sufficiency of the resources and spaces in the institution to work in STEAM areas.	0.909	0.848
	9. Resources and spaces that are still lacking to work on STEAM in your university (open response).	0.879	0.909
	10. Quality of STEAM teaching at the university.	0.939	0.879
	11. Quality of STEAM teaching in Mexico.	0.97	0.909

II. Self-efficacy, cognitive concept and STEAM competences	12. Understanding of concepts, purposes and challenges of STEAM education.	0.909	0.909
	13. Level of theoretical knowledge and STEAM competences.	0.818	0.788
	14. Level at which he/she seeks to learn about STEAM education.	0.758	0.697
	15. Level of teacher training in STEAM teaching strategies and techniques.	0.848	0.818
	16. Teachers' strengths in STEAM teaching (nominal).	0.909	0.848
	17. Ability to solve scientific problems through technology.	0.879	0.848
	18. Ability to solve problems with engineering.	0.97	0.879
	19. Ability to make use of logical-mathematical thinking.	0.939	0.909
	20. Ability to integrate technology, engineering and logical-mathematical thinking.	0.97	0.939
III. Affective attitudes towards STEM learning	21. Willingness to participate in classes with a STEAM approach.	1	1
	22. Motivation to practise acquired knowledge.	0.939	0.939
	23. Level of enjoyment when taking STEAM subjects.	1	0.97
	24. Level of motivation in the face of achievements.	0.879	0.879
IV. Need for STEAM education	24. The training received will allow him/her to work in STEAM areas in the future.	0.939	0.879
	25. Level of current training in STEAM areas.	0.879	0.848
	26. Level at which you would like to receive more STEAM training.	0.939	0.939
	27. Aspects in which you would like to receive more STEAM training (nominal).	0.97	0.879
	28. Most developed generic competence under this approach (nominal).	0.818	0.818
V. Conceptions of STEAM competences	29. Ability to identify challenges and propose solutions.	0.879	0.848
	30. Ability to solve problems creatively.	0.848	0.788
	31. Ability to identify the components and processes of the projects in which he/she participates.	0.909	0.788
	32. Ability to work collaboratively.	0.939	0.879
	33. Ability to identify problems, generate questions and issue hypotheses.	1	0.879

Table 3 ESTEAM-33 instrument

The scale for teachers on STEAM education in Mexico (DSTEAM-36) is a Likert-type scale with five response options, where some are ordinal and measure the variables by levels ranging from very low to very high, others list nominal options and some open questions are also included. The content of both the questions and the descriptors has been validated through the Aiken V and the instrument is made up of 36 items distributed in 5 dimensions (Table 4).

Dimensions	Ítems	V de Aiken	
		Relevance	Writing and comprehension
I. Pedagogical conceptions of STEAM education	1. Level of knowledge of the STEAM educational approach.	0.956	0.889
	2. Level at which you design your lessons with a STEAM approach.	0.933	0.956
	3. Importance of STEAM education at any level of education.	0.889	1
	4. Importance of STEAM subjects for students' professional and personal futures.	0.933	0.889
	5. Importance of applying STEAM knowledge and skills in everyday life.	0.889	0.867
	6. Sufficiency of time devoted to STEAM subjects.	0.911	0.8
	7. Level at which they teach STEAM subjects in an innovative, creative and motivating way.	0.956	0.933
	8. Main strategy used in STEAM teaching (open question).	0.911	0.933
	9. Adequacy of resources and spaces for STEAM teaching.	0.911	0.911
	10. Resources and spaces that are still missing for STEAM teaching at your university (Open question).	0.889	0.911
	11. Quality of STEAM teaching at university.	0.978	0.911
	12. Quality of STEAM education in Mexico.	1	0.956
II. Self-efficacy, cognitive concept and competences in STEAM education.	13. Understanding of concepts, purposes and challenges of STEAM education.	0.956	0.978
	14. Level of theoretical knowledge and competences for STEAM teaching.	0.933	0.889
	15. Level at which he/she seeks further training in STEAM education.	0.978	0.933
	16. Strengths of their teaching with the STEAM approach (nominal).	0.8	0.844
	17. Ability to solve scientific problems using technology.	0.933	0.911
	18. Ability to integrate engineering into teaching and learning activities.	0.822	0.822
	19. Ability to use logical-mathematical thinking in problem solving.	0.844	0.911
	20. Ability to integrate technology, engineering and logical-mathematical thinking in scientific problem solving.	0.978	0.911
III. Affective attitudes towards STEM education.	21. Willingness to teach using the STEAM approach.	0.978	0.978
	22. Motivation to put STEAM teaching into practice.	1	0.978
	23. Level of enjoyment for teaching with STEAM methodology.	0.844	0.822
	24. Level of	0.978	0.978

	motivation in the face of student achievement.		
IV. Professional development in STEAM.	25. The training received so far allows you to work with STEAM subjects.	0.978	0.956
	26. Level of education that you consider you still need to work with STEAM subjects.	0.889	0.933
	27. Level at which you would like to receive further training in STEAM.	0.978	0.978
	28. Aspects that you would like to improve in STEM education training (nominal).	1	0.956
	29. Level at which you would like to be part of the country's STEAM leadership team.	0.933	0.956
V. Conceptions of competences and attitudes in STEAM education .	30. Generic competence most developed in students under this approach (nominal).	0.933	0.8
	31. Ability of students to identify challenges and propose solutions.	1	0.956
	32. Ability to identify problems, generate questions and issue hypotheses by students who are trained through the STEAM approach.	0.956	0.844
	33. Students' ability to manage their own knowledge.	0.889	0.933
	34. Students' ability to work collaboratively.	0.978	0.978
	35. Motivation level of students to work with STEAM approach.	0.978	0.978
	36. Level of students' interest in developing STEAM competences.	0.978	0.978

Table 4 Dimensions and questions that make up the DSTEAM-36 instrument

Questionnaire of Sociodemographic and Professional Factors

This instrument was constructed for the present study and comprises a series of questions that inquire about the following aspects: age range, sex, last academic degree obtained, type of university where they work, number of scientific articles published so far, number of times they have participated as speakers in scientific events, number of books they have published so far, etc.

Data analysis

The statistical analyses of the present study were carried out in IBM SPSS v.26 and JASP v.0.12.2.0, based on the following phases:

Phase 1. Estimation of the distribution of the data. A Kolmogorov-Smirnov test with Lilliefors correction (K-S-L) was performed on the data obtained from the students' responses ($n > 50$), and the Shapiro Wilk test for the teachers' responses ($n < 50$). In the case of both tests, p-values > 0.05 indicate that the data have a normal distribution, while lower values show non-normality (Campo-Arias & Oviedo, 2008).

Phase 2. Pilot study. The degree of comprehension, wording, relevance and general satisfaction with the instructions, items and descriptors of the scales to the instruments was determined. For this purpose, responses were randomly taken from 21 participants for each instrument and percentages were calculated for each of the variables mentioned. In this study, the highest percentages are expected to be between medium, high and very high, indicating that the proposed construct is clear, adequately worded and the items are relevant to the study. Additionally, the average time needed to answer both questionnaires was estimated.

Phase 3. Estimation of reliability and internal consistency. Reliability is understood as the property of a test that has an important impact on the accuracy of the results obtained. Among the most widely used methods for estimating reliability is 1) Cronbach's Alpha, which is recommended for continuous variables, unidimensional constructs and with at least five response alternatives and, 2) the McDonald's Omega coefficient ideal for binary or ordinal variables with five or fewer response options (Ventura-León & Chaycho-Rodríguez, 2017). For both coefficients, values greater than 0.80 are expected, which indicates a good level of reliability of the scale (Campo-Arias & Oviedo, 2008; Cronbach, 1951).

Phase 4. Preliminary results. During this phase, we sought to determine whether a population mean is statistically different from a known or hypothetical value (Cressie, 1980; Box 2018; Mandeville, 2013). For each variable, the value assessed was 3.0, as it represents the theoretically accepted mean (or minimum expected value) in this study, and statistically significant differences were confirmed when p-values < 0.05 were obtained (Altman, 1991).

Since the values obtained from the student instrument (ESTEAM-33) had a normal distribution, a one-sample t-test was performed. Whereas the data obtained from the construct for teachers (DSTEAM-36) did not present a normal distribution, hence, they do not satisfy the conditions necessary to perform a parametric test, and that is why a Wilcoxon test was performed (Wilcox 2003). It should be noted that in this analysis only ordinal variables measured on the same scale were evaluated and nominal or other variables were excluded.

Variable	Category	Percentage of students	Percentage of teachers
Degree of understanding of instructions	Very low	4.76%	-
	Low	4.76%	4.76%
	Medium	38.10%	23.81%
	High	28.58%	28.58%
	Very high	23.80%	42.85%
Degree of comprehension and wording of all questions in the instrument	Low level of understanding	-	-
	Acceptable level of understanding	61.90%	47.62%
	High level of understanding	38.10%	52.38%
Degree of relevance of all questions in the instrument	Not relevant	-	-
	Low level	4.76%	14.28%
	Acceptable	42.85%	38.10%
	High level	52.39%	47.62%
Overall satisfaction with the instrument	Very low	-	-
	Low	-	4.76%
	Medium	23.80%	23.81 5
	High	33.34%	28.58%
	Very high	42.85%	42.85%

Table 5 Percentages of students' (n=21) and teachers' (n=21) understanding, wording and relevance of the instructions and the proposed items.
Source: Own elaboration

Results

Understanding, relevance and satisfaction with the instruments

From the questionnaire on satisfaction with the instruments, favourable results were found in terms of comprehension, relevance and satisfaction (Table 5). Here, the degree of understanding of the instructions showed higher scores at the medium and high level according to the point of view of the students (90.48%) and teachers (95.24%). Also, 100% of the participants indicated that the understanding and wording of all the questions in the instrument was good and, the proposed questions were relevant according to 96.24% of the students and 85.72% of the teachers.

Furthermore, 76.19% of the students and 71.43% of the teachers indicated high and very high levels of satisfaction with each of the proposed instruments and, finally, it was estimated that, on average, students required at least 10.67 (SD ± 6) minutes to answer the questionnaire and teachers 10.29 (SD ± 6) minutes.

Reliability and internal consistency

Using the same sample, the reliability of the two questionnaires was estimated and optimal values for internal consistency were found, as they showed reliability values for both Cronbach's Alpha and McDonald's Omega above 0.80.

Instrument	Cronbach's alpha	McDonald's Omega
Students	0.851	0.896
Teachers	0.896	0.933

Table 6 Reliability
Source: Own elaboration

STEAM conceptions, competences and attitudes

Preliminary results obtained from the single-sample t-test indicated firstly that, although students have some mastery of the STEAM educational approach, the topic still needs further work to reach the minimum expected level ($p > 0.05$). Students indicated that their teachers tend to plan their classes under this approach at a higher level than expected ($M=3.38$, $p < 0.05$), and reported that the time dedicated in the school timetable (M= 3.25), the resources available (M= 3.56) and the quality of STEAM teaching at the university (M= 3.57) have satisfactory levels above 3.0. Likewise, high levels (scores ≥ 4.0) were evident in terms of the importance of: STEAM training at any educational level, STEAM training for professional and personal futures, and the time allocated at the curricular level to the subjects involved.

In terms of self-efficacy, cognitive concept and STEAM competences, students stated that they understand the general concepts, purposes and challenges of STEAM education (M=3.41), consider that they have been prepared with STEAM knowledge, competences and skills (M=3.42) and seek to learn about STEAM at a higher level than theoretically accepted (M=3.29).

They also reported confidence in: solving scientific problems using technology (M= 3.53), solving problems using engineering (M= 3.26), using mathematical logical thinking to represent data or solve scientific problems (M= 3.60) and integrating the use of technology, engineering design and mathematical thinking in problem solving (M=3.55).

Regarding affective attitudes, they expressed a high level of willingness to participate in classes that implement STEAM methodology (M=4.26), to put acquired knowledge into practice (M= 4.11) and a high degree of enjoyment towards STEAM-based classes (M= 4.22). Similarly, they indicated that the training they have received so far will allow them to work in STEAM areas in the future (M= 3.74) and to develop professionally in the subject (M= 3.69), although they would like to continue strengthening their training in this global trend (M= 4.17).

Similarly, students consider that those trained under this approach are able to: identify challenges and propose solutions (M= 3.93), use creativity to solve problems (M= 3.81), recognise the components and processes of the projects they carry out (M= 3.93), work collaboratively (M= 4.01) and identify problems, generate questions and issue hypotheses (M= 4.04) at high levels. Finally, Cohen's d indicates that large (d= 0.80), medium (d= 0.50) and small (d= 0.20) effect sizes were found in these observations, thus providing an estimate of the extent of these findings.

Table 7 Differences of students' STEAM skills and attitudes with respect to the minimum accepted value (3.0) and their effect size (n= 253)

Note: Student's t-test determines the existence of statistically significant differences with $p < 0.05$

Regarding the teachers' responses, they stated that they know the approach (M=3.52) and design their classes based on STEAM education strategies (M= 3.52) at a higher level than expected. They also stated that STEAM education is important at any educational level (M= 4.57), has an important impact on students' professional and personal lives (M= 4.85), and is highly applicable in everyday life (M= 4.81). They also mentioned that the time devoted to STEAM subjects (M=3.28; p= 0.271) and its innovative and motivating teaching (M= 3.33; p= 0.183) are acceptable in the university context. Whereas, the adequacy of resources and spaces and the quality of STEAM teaching at university and national level are below the minimum accepted level.

In relation to the cognitive concept, self-efficacy and STEAM competences, it was found that teachers have a good understanding of the concepts, purposes and challenges of STEAM education (3.85), they consider that they have the theoretical knowledge and competences necessary for teaching STEAM (3.61) and that they receive acceptable training in the subject (M=3.33; p= 0.183). Despite this, they claim to have a good ability to solve scientific problems using technology, to include engineering in teaching and learning activities, to integrate technology, engineering and mathematical logical thinking in problem solving and to make use of mathematical logical thinking.

Similarly, teachers' affective attitudes towards STEAM teaching showed very positive scores, as they indicated high levels of willingness (M= 4.47), motivation (M= 4.28) and enjoyment (M= 4.61) towards STEAM teaching and reported being highly motivated by their students' achievements (M= 4.66). At the same time, they indicated that the training received so far allows them to work in STEAM areas at a level above acceptable (M= 3.52), that they would like to receive more training in the subject (M= 4.52) and that they would like to be part of the STEAM leaders in the country (M= 4.52).

Finally, they consider that students who are trained in STEAM have a good ability to identify challenges and propose solutions (M= 3.85), identify problems, generate questions and issue hypotheses (M= 3.76), manage their own knowledge (M= 3.76) and work collaboratively (M= 4.2). In addition, teachers perceive that the level of motivation (M= 3.95) and interest (M= 4.23) of students is higher when working under this approach.

Ítems	Media	DE	t	p	Cohen's d
1	2.941	1.062	-0.888	0.375	0.056
2	3.387	0.96	6.421	< .001	0.404
3	4.282	0.83	24.509	< .001	1.544
4	4.423	0.75	30.178	< .001	1.897
6	3.253	1.019	3.948	< .001	0.248
7	4.209	0.84	22.897	< .001	1.44
8	3.565	0.918	9.798	< .001	0.616
10	3.577	0.908	10.109	< .001	0.636
11	3.055	0.941	0.935	0.351	0.059
12	3.415	0.844	7.823	< .001	0.492
13	3.237	0.854	4.417	< .001	0.278
14	3.292	0.905	5.141	< .001	0.323
15	3.565	0.984	9.133	< .001	0.574
17	3.534	0.857	9.907	< .001	0.623
18	3.261	0.961	4.317	< .001	0.271
19	3.601	0.892	10.709	< .001	0.673
20	3.557	0.892	9.94	< .001	0.625
21	4.269	0.877	23.017	< .001	1.447
22	4.111	0.884	19.986	< .001	1.256
23	4.221	0.816	23.821	< .001	1.498
24	3.747	0.89	13.344	< .001	0.839
25	3.696	0.876	12.625	< .001	0.794
26	4.178	0.838	22.355	< .001	1.405
29	3.937	0.784	18.999	< .001	1.194
30	3.818	0.811	16.052	< .001	1.009
31	3.933	0.806	18.4	< .001	1.157
32	4.016	0.84	19.228	< .001	1.209
33	4.047	0.849	19.635	< .001	1.234

Table 8 Differences of teachers' STEAM competences and attitudes with respect to the minimum accepted value (3.0) and their effect sizes.
Note: Wilcoxon signed-rank test determines the existence of statistically significant differences at $p < 0.05$

Discussion

There has been little progress in the development of valid and reliable instruments to probe conceptions, self-efficacy and need for STEAM training so far. The scales that have been presented (Çevik & Sıtkı, 2019; Korkmaz et al., 2020), generally focus on inquiring about STEAM knowledge, students' attitudes towards STEAM and basic skills that can be acquired through STEM training and are targeted only at students.

Thus, the constructs proposed in this paper arise from the need to strengthen STEAM education in Mexico (Rojas and Segura, 2019; UNESCO, 2019). Studies related to this purpose have focused on investigating the reasons why students choose STEM careers (Oliveros-Ruiz, 2019); designing didactic strategies to incorporate STEAM models in the education system (Castellanos, 2020; Escobar and Ramírez, 2021; Fuentes et al., 2019; Juvera and Hernández, 2021) and critically analysing the implementation of STEAM education in the Mexican national territory (Diehl et al., 2020).

However, so far, no research has been conducted on the ideas, notions and mental elaborations of educational actors about the approach; neither has the self-efficacy of teachers and students regarding STEAM core competences been addressed, nor has the affective attitudes of the participants towards this approach, particularly in higher education, been questioned.

Thus, a pilot study was conducted to test methodological, logistical and feasibility aspects in order to carry out a larger scale and more complex investigation using the ESTEM-33 and DESTEM-36 instruments. In this way, the adequacy of the methods and processes was evaluated, in order to have greater knowledge or certainty about the functioning of the research and thus reduce possible biases and errors in obtaining the data (Abeille et al., 2015; Díaz-Muñoz, 2020). Casas et al., (2003) state that this phase makes it possible to determine whether the questions have been correctly understood by all subjects, whether they have produced fatigue or rejection, whether the duration has been excessive or any other deficiency; and that these deficiencies will be reflected in the data obtained. Based on this, the results presented here suggest that both instruments are understandable, relevant and generate high satisfaction among participants. Similarly, Cronbach's Alpha and McDonald's Omega coefficients indicated that each instrument consistently measures a sample of the population and represent valid constructs (Campo-Arias & Oviedo, 2008; Cronbach, 1951; Domínguez-Lara & Merino-Soto, 2015; Muñiz, 2010).

Preliminary results show that, in general, students have positive conceptions of STEAM education at their university. According to them, the lesson plans, the time devoted, the resources available and the quality of STEAM education have satisfactory scores. They also indicated that receiving STEAM education is important at any level of education and has an important effect on professional and personal futures. In this respect, authors such as Arabit and Prendes (2020) reported similar results, where, students shared positive views regarding the STEAM education received in the country.

The teachers' perspective on this point is different in some respects, as they point out that resources and spaces are not sufficient for effective STEAM teaching. This same need has been reported by other authors (Adams et al., 2022; Catterall, 2017; Malecha, 2020), who state that the lack of materials means that STEAM education is not as immersed in institutions as we would like it to be. Furthermore, from the teachers' point of view, the quality of STEAM education is below the acceptable level, which coincides with the view of other teachers regarding the quality of STEAM education in Mexico.

Now, speaking in terms of self-efficacy, both teachers and students stated that, thanks to the training received so far, they have a good ability to solve problems through engineering, make use of logical mathematical thinking to represent data or solve scientific problems by integrating the use of technology, engineering design and mathematical thinking. This belief of both actors in their own ability is critical to the success of educational activities, leading to better teaching and learning outcomes (Ahmad & Safaria, 2013). In other studies, self-efficacy has been found to be positively related to teachers' effective teaching, as those who see themselves as well-prepared are more likely to set higher goals, believe in innovative teaching and undertake challenging professional development (Bautista 2011; Nadelson et al. 2013); while self-efficacy has been described as an essential predictor of students' overall academic performance (Ferla, Valcke, & Cai, 2009). Therefore, it is essential that STEAM content is presented in an engaging way, through techniques that inspire students and regardless of the difficulty, they believe that they are capable of performing the activities and can achieve the desired results.

On the other hand, the results presented here suggest that teachers are willing to change and would like to receive more continuous training in STEAM. This is a demand that has already been reported in other works and there has been a call for universities in Mexico to incorporate specialised and high quality professional development programmes in the subject (Aziz & González, 2017; Romero-Ariza et al., 2021). But why does this need for professional development arise in both teachers and future professionals?

According to Chen et al. (2020), developing knowledge and understanding of STEAM enhances their positive pedagogical beliefs towards the approach and promotes the need for professional development. Affective attitudes have also been shown to play a role, as the more positive they are, the more motivated people are to act and learn about STEAM, increasing the need for education and training. This is consistent with the high levels of willingness, motivation and enjoyment found in this study in relation to STEAM-based training processes.

Finally, regarding the limitations of our study, it should be noted that participation in the survey was voluntary, with the risk of under-representing or over-representing a certain group of people and therefore the results cannot be interpreted in a general way for all teachers or students in higher education in Mexico. It is also necessary to highlight that, in this study, some of the participants' conceptions and self-assessments of their STEAM knowledge, skills and attitudes were investigated, so it is possible that the data obtained only reflect the perceptions of individuals and may not be representative of reality. On the other hand, it is worth mentioning that these results are presented in a preliminary way, as it is expected to work with a larger and more heterogeneous sample, in order to carry out more complex statistical analyses. Finally, we stress the need to continue assessing the validity and reliability of the proposed instruments, as so far neither construct validity, criterion validity nor test-retest reliability of the scales have been evaluated.

Conclusions

The scales on STEAM Education in Mexico for university students and for teachers, whose acronyms are respectively ESTEAM-33 and DSTEAM-36, were designed with the purpose of having information about the perception of students and university teachers about the conception, competences and attitudes of the term STEAM, which will allow the teacher to design strategies and methods to achieve a significant learning of the student, allowing him to reach a more complete and realistic vision of the professional world, he will have an approach to the different problems that he will face in the workplace.

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The selection of active, integrative and collaborative strategies presented in the study (Problem-Based Learning (PBL), Cooperative Learning (CL), Project-Based Learning (PBL) and Challenge-Based Learning (CBL)) will facilitate the teaching of academic content and the development of students' scientific and technological thinking, as they are pedagogical methods that allow students to consolidate their learning in the classroom; the choice of which method or strategy to use will depend on the educational context, the institution, the subject or objective of the syllabus and what is to be achieved, and it should always be kept in mind that they should be focused on a clear and achievable objective.

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