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STEAM competencies and attitudes in higher education: the evaluation of experts

Competencias y actitudes STEAM en la educación superior: la evaluación de expertos

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Abstract

The integrative trend of STEAM education allows for shaping an innovative, motivating, and enriching teaching and learning practice in the classroom. Currently, there is a wide repertoire of research on the effectiveness of educational practices based on this approach, however, at the national level, there is a lack of validated instruments that allow inquiring about the development of STEAM skills and attitudes in higher education. In this sense, this study's purpose consisted of designing and validating two socio-formative rubrics that address STEAM competencies and attitudes in both teachers and higher education students in Mexico. To do this, first a literature review was carried out, where the dimensions, items and descriptors of interest were identified; second, once the instrument was finalized, it was submitted for review by experts in STEAM, education, pedagogy, or didactics area; and finally, based on their judgment, the relevance of the items was calculated using Aiken's V coefficient and the 95% confidence intervals were estimated. In total, 16 researchers participated worldwide and the results show that the quantitative evaluation was quite positive, finding that the validity of the content had mostly scores above the expected value (0.80) in terms of relevance, writing, and coherence, in a way that Two pertinent instruments are presented that will make it possible to diagnose STEAM competencies and attitudes in national and international universities.

STEAM, Competencies, Attitudes, Validity, Higher education

Resumen

La tendencia integradora de la educación STEAM permite conformar una práctica de enseñanza y aprendizaje innovadora, motivadora y enriquecedora en el aula. En la actualidad, se cuenta con un amplio repertorio de investigaciones en torno a la efectividad de las prácticas educativas basadas en este enfoque, sin embargo, a nivel nacional se detecta la carencia de instrumentos validados que permitan indagar acerca del desarrollo de competencias y actitudes STEAM en la educación superior. En este sentido, el propósito del presente estudio consistió en el diseño y validación de dos rúbricas socioformativas que abordan las competencias y actitudes STEAM tanto en docentes como en estudiantes de educación superior en México. Para ello, primero se realizó una revisión a la literatura, en donde se identificaron las dimensiones, ítems y descriptores de interés; segundo, una vez finalizado el instrumento, se sometió a revisión por parte de expertos en el área STEAM, educación, pedagogía o didáctica; y finalmente, con base en su juicio, se calculó la relevancia de los ítems mediante el coeficiente V de Aiken y se estimaron los intervalos de confianza al 95%. En total participaron 16 investigadores a nivel mundial y los resultados muestran que la evaluación cuantitativa fue bastante positiva, encontrándose que la validez del contenido tuvo en su mayoría puntuaciones por encima del valor esperado (0.80) en términos de pertinencia, redacción y coherencia, de manera que se presentan dos instrumentos pertinentes que permitirán diagnosticar las competencias y actitudes STEAM en las universidades nacionales e internacionales.

STEAM, Competencias, Actitudes, Validez, Educación superior

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Introduction

Advances in science and technology in recent decades have raised fundamental questions about what kind of skills the next generations will need to be able to function in the knowledge society and develop their ability to solve problems in the context, applying complex, analytical, critical and systemic thinking (Tobón, 2017). These demands cannot be easily solved with current education, which is why they generate great pressure on the education system and lead teachers to search for and improve new teaching methodologies and approaches to make them increasingly relevant and innovative (Aguilar-Esteva et al., 2019). For this reason, the call to integrate curricula based on science, technology, engineering, arts and mathematics (STEAM education) into the curriculum has received increasing attention in the last decade and has been implemented for some years in countries such as China, India, the United States and Russia, showing positive results in teaching and learning processes (Chung, SK and Li, D. 2021).

STEAM education - Science, Technology, Engineering, Arts and Mathematics - is a complex and controversial approach, stemming from the foundations of STEM education, through which it aims to develop and guide educational processes in an interactive and motivating way, generating spaces to investigate, discover, create and apply knowledge, while incorporating art to encourage creative thinking and the development of socio-emotional skills (Holmlund, TD, Lesseig, K. and Slavit, D. 2018). The aim of this approach is for students to develop scientific-technological and artistic vocations, which go hand in hand with the competences and skills demanded by the 21st century, in the pursuit of sustainable development and social well-being (Greca *et al*., 2021).

One of the main characteristics of the STEAM approach is its interdisciplinary and transdisciplinary approach, as it promotes meaningful learning of science and technology, integrating other fields such as language, literature, music, dance, painting, animation, photography, among many others (Chung, SK and Li, D. 2021).

Thus, it is not only about dealing with rigorous academic concepts but, for this approach, the real world experiences of students are the starting point of knowledge and it is sought that the experience of everyday life in science, technology, engineering, mathematics and art, can be connected to the practices, knowledge and activities of the community, work and global business, enhancing sustainable social development and the ability to compete in a new economy (Holmlund, TD, Lesseig, K. and Slavit, D. 2018).

In the framework of higher education, this approach encompasses a contextual curriculum, where experiences and knowledge spaces related to the student's professional career are generated and activities that enhance creative thinking skills, problem solving and appropriation of learning are developed (Luo, T., So, WWM, Wan, ZH et al. 2021). As a result, STEAM subjects employ a creative educational process that allows students to identify a situation or problem, collaboratively collect and analyse data, exchange ideas, generate proposals, create academic products and reflect on the results (Gettings, 2016, Domínguez, et al., 2019). Thus, the methodological bases mostly used are scientific research, project-based learning and Studio Habits of Mind, creating spaces for students to plan, create, articulate, reflect, issue scientific explanations and communicate their findings (Donohue et al., 2020). Historically in the Mexican context, science education in primary and secondary schools has not been considered a priority for national development, considering that most students acquire knowledge in individual subjects, without a multidisciplinary approach (Montgomery and Fernández-Cárdenas, 2018) and the results of the PISA 2018 test it is possible to observe that in the country students have a low academic performance in fundamental areas, ranking 61 out of 78 with respect to other countries in mathematics (with 409 points), 57th in science (with 419 points) and 53rd in reading (with 420 points). This indicates that students are not only below the OECD average but also below the overall sample average (Aguayo-Téllez & Martínez-Rodríguez, 2020), demonstrating that the efforts of education policies, schools, curricular content and teaching practices have not been sufficiently focused on boosting STEAM education in the territory.

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In this regard, Pérez et al, (2020) express that in the country there is no systematic planning to promote STEAM education and increase the number of students who take this type of programme in higher education, nor has an official report been created to date with reliable indicators that show the reality of STEAM education at different educational levels, and as a result there are inconsistencies between students who follow STEAM careers and the needs of the current industry, According to the latter authors, reports suggest that in Mexico there is an urgent demand for engineers in industries such as automotive, aerospace, energy, biotechnology and information technology, among others.

In addition to this, it is important to highlight that teachers play a fundamental role in determining the success of STEAM education, as mentioned by Lee et al, (2019) there is a positive relationship between the effectiveness of pedagogical practices and teachers' attitudes towards STEAM teaching, they require knowledge of both the subject they teach and the ways to integrate the characteristics and advantages of teaching with the approach, which in many cases, ends up generating feelings of anxiety, stress or low confidence and these perceptions reduce the achievements and success of innovations (Lee & Tsai, 2010). The relevance of teachers' attitudes regarding their performance in STEAM practices is a field that seems not to have been sufficiently researched in Mexico.

With this in mind, and taking into account the existing literature, this study shows two instruments that allow us to investigate STEAM competences, skills and attitudes in the educational community and whose purpose will be to provide valuable information for future studies to broaden the panorama on the current state of STEAM education in Mexico. Thus, the purposes of this research consisted of: 1) designing two instruments to assess STEAM competencies and attitudes in teachers and students based on the challenges of the knowledge society and the socio-formative approach and 2) validating the content of the instruments by measuring their degree of relevance, pertinence, wording and coherence through the analysis of Aiken's V coefficient.

Methodology

Type of study

An instrumental validity and reliability study of two instruments to assess STEAM competencies and attitudes in higher education teachers and students was conducted. This was done through the assessment of an expert judgement, who evaluated whether the items were appropriate and congruent with the research objectives.

Participants

A total of 16 experts in the area of STEAM research in Mexico and professionals in education, pedagogy and didactics from different levels and areas participated, 56% of whom were men and 43.7% women, aged between 34 and 60; with different degrees of academic training: doctoral studies (68.8%), specialisation and master's degree (25%) and post-doctorate (6.3%), the evaluators came from different countries such as Mexico, Costa Rica, Colombia, Ecuador and Spain (Table 1).

Variable	Descriptors	Frequency	Percentage
Country	Mexico	12	75%
	Spain	1	6.30%
	Costa Rica	1	6.30%
	Colombia	1	6.30%
	Ecuador	1	6.30%
Sex	Man	9	56.30%
	Female	7	43.70%
Age range	30-35	1	6.30%
	36-40	4	25%
	41-45	3	18.80%
	46-50	4	25%
	51-55	2	12.50%
	56-60	2	12.50%
Academic Degree	Specialisation	2	12.50%
	Master's degree	2	12.50%
	PhD	11	68.80%
	Postdoctoral	1	6.30%
Years of teaching experience	0-5	2	12.50%
	06-Oct	3	18.80%
	Nov-15	2	12.50%
	16-20	3	18.80%
	21-25	6	37.50%
Years of experience as a researcher	0-5	5	31.30%
	06-Oct	5	31.30%
	Nov-15	6	37.50%
Approximate number of articles published	01-May	3	18.80%
	06-Oct	7	43.80%
	Nov-15	3	18.80%
	16-20	2	12.50%
	More than 20	1	6.30%

Table 1 Socio-demographic description of evaluators
Source: own elaboration

Procedure

In accordance with the purposes of the research, the study was carried out in the following phases:

Phase 1. Design of the instruments

The instruments developed are the result of the documentary review carried out on STEAM teaching and learning in the Scopus and Web of Science databases. The following dimensions, items and descriptors to be evaluated were identified:

Instrument for teachers

1. Pedagogical conceptions about STEAM teaching and learning: this dimension of the questionnaire is composed of 10 items through which they inquire about the beliefs, notions or pedagogical ideas related to the importance and applicability of the methodology at different educational levels, its impact on the professional life of students; the ways of working in the subjects, availability of timetables, resources and spaces to work on STEAM subjects and their vision regarding the quality of STEAM teaching both in the institution and in the country. The items are evaluated on the scale "strongly disagree, disagree undecided, agree and strongly agree" or with open-ended responses, some items were adapted from the original questionnaire by Arabit and Prendes (2020).

2. Self-efficacy, cognitive concept and skills in STEAM teaching: this section is based on the studies by Chen et al., (2021) and Lee et al., (2019) and includes 10 questions related to the extent to which a teacher perceives him/herself to be able to teach using the STEAM approach based on his/her knowledge, competences and skills. It includes items related to cognitive concept and equipped skills such as: understanding of the concepts, purposes and challenges of STEAM education, their current readiness in terms of STEAM knowledge and skills, their interest in lifelong learning preparation and strengths in STEAM teaching, as well as or the level of self-confidence they have in conducting scientific investigations, solving problems using technology, integrating engineering into learning activities; using mathematical thinking to represent data and solve scientific problems.

3. Affective attitudes towards STEAM teaching: considering the direct relationship between effectiveness and attitudes towards STEAM teaching, 4 items were included that inquire about the level of willingness, motivation and enjoyment that teachers feel when putting the methodology into practice.

4. Need for professional development: this dimension was based on studies by Arabit and Prendes (2020) and includes 4 items related to teachers' training and asks whether their training allows them to work efficiently, whether they would like to receive more continuous training related to STEAM teaching, in which aspects they would like to improve their training and whether their colleagues are able to work on STEAM subjects.

5. Teachers' conceptions about students' competences and attitudes towards STEAM education: this dimension aims to investigate the pedagogical beliefs of educators about the competences and skills acquired by their students through STEAM education and addresses questions 8 that also include the level of motivation and interest perceived in students towards this educational approach.

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Student instrument

1. Pedagogical conceptions about STEAM teaching and learning: this dimension of the questionnaire is composed of 9 items that aim to measure the beliefs, conception and importance of STEAM education at the higher education level, the impact on the students' professional life, ways of teaching STEAM subjects, availability of resources and spaces to work on STEAM subjects and their vision regarding the quality of STEAM education both in the institution and in the country. The items are evaluated in a combined way: likert scale and a couple of open-ended questions, which will allow us to know their perception of the subject.

2. Cognitive concept: this dimension specifically assesses the knowledge of STEAM. The item is composed of 5 items of original construction.

3. Self-efficacy and STEAM competencies: This section is based on the studies of Chung et al. It is composed of 15 items associated with the competencies that are developed with STEAM subjects and projects; communication, problem solving, collaboration, confidence and satisfaction gained from the successful implementation of the project are analysed.

4. Teacher management: this dimension is composed of 2 items, and directly evaluates the performance, orientation and guidance of the teacher during the implementation of the project in the classroom, which must subsequently be executed in a real situation.

5. Affective attitudes in STEAM teaching: the 3 items presented are based on the instrument designed for teachers, and directly measure the motivation, willingness and enjoyment of the student when receiving STEAM-based classes.

Phase 2. Review of the instruments

The instruments for teachers and students were reviewed by 16 and 14 experts respectively. As mentioned by Aliaga-Pacora et al. (2021), in this phase, the experts made comments, suggestions and corrections regarding the wording, pertinence and relevance of the proposed items and descriptors.

The experts were selected taking into account the following: doctoral degree, master's degree or specialisation, years of experience in the research area, experience in the review and validation of assessment instruments and/or experience in the STEAM area.

Phase 3. Statistical analysis: content validity

For the statistical analysis, Aiken's content validity coefficient V with a 95% confidence interval was calculated using Microsoft Excel (2016) and IBM SPSS 26 statistical software. According to Merinio and Livia (2009) and Aiken (1980), this coefficient is one of the most widely used techniques to quantify the content validity or relevance of the item with respect to a content domain in N judges. The magnitude of the coefficient ranges from 0.00 to 1.00 where the value 1.00 is the highest possible score and indicates perfect agreement among the judges regarding content validity and 0.80 was considered as the minimum value for the acceptance of an item as valid (Hernández, et al., 2020; values lower than 0.80 were not accepted and in those cases, the item or its respective descriptors were improved considering the observations made by the experts.

Ethical considerations

The present study adhered to the Personal Data Protection Law in force in Mexico. Participants were informed about the purposes of the study, their consent was requested and their right to withdraw at any time from the research was mentioned.

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Results

Based on the results of the quantitative evaluation regarding the relevance, coherence and wording of the instruments, content validity was analysed and a satisfactory opinion was found for all items and descriptors of the instrument for teachers (Table 2) and an outstanding opinion for most of the items of the instrument for students (Table 3). In the latter, there were some items that required extensive revision in terms of wording.

In general, the observations and recommendations of the experts denote that the items are relevant and coherent and some recommendations for improvement were taken into account in terms of defining or clarifying the meaning of the acronym STEAM, changing concepts such as the word "error", incorporating items related to the inclusion of women in the STEAM area, giving importance to the wording considering the gender perspective and the 2030 agenda, among others.

Item	Relevance	95% CI	Wording and coherence	95% CI
1	0.956	0.891 ± 1.021	0.889	0.799 ± 0.979
2	0.933	0.857 ± 1.010	0.956	0.891 ± 1.021
3	0.889	0.738 ± 1.040	1	-
4	0.933	0.857 ± 1.010	0.889	0.775 ± 1.003
5	0.889	0.799 ± 0.979	0.867	0.750 ± 0.983
6	0.911	0.764 ± 1.059	0.8	0.618 ± 0.982
7	0.956	0.891 ± 1.021	0.933	0.830 ± 1.037
8	0.911	0.764 ± 1.059	0.933	0.790 ± 1.080
9	0.911	0.802 ± 1.021	0.911	0.802 ± 1.021
10	0.889	0.775 ± 1.003	0.911	0.802 ± 1.021
11	0.978	0.930 ± 1.025	0.911	0.802 ± 1.021
12	1	-	0.956	0.860 ± 1.051
13	0.956	0.891 ± 0.978	0.978	0.930 ± 1.025
14	0.933	0.830 ± 1.021	0.889	0.775 ± 1.003
15	0.978	0.930 ± 1.025	0.933	0.857 ± 1.010
16	0.8	0.632 ± 0.968	0.844	0.691 ± 0.998
17	0.933	0.857 ± 1.010	0.911	0.827 ± 0.996
18	0.822	0.668 ± 0.976	0.822	0.704 ± 0.940
19	0.844	0.675 ± 1.013	0.911	0.827 ± 0.996
20	0.978	0.930 ± 1.025	0.911	0.827 ± 0.996
21	0.978	0.930 ± 1.025	0.978	0.930 ± 1.025
22	1	-	0.978	0.930 ± 1.025
23	0.844	0.675 ± 1.013	0.822	0.653 ± 0.991
24	0.978	0.930 ± 1.025	0.978	0.930 ± 1.025
25	0.978	0.930 ± 1.025	0.956	0.860 ± 1.051
26	0.889	0.738 ± 1.040	0.933	0.830 ± 1.037
27	0.978	0.930 ± 1.025	0.978	0.930 ± 1.025
28	1	-	0.956	0.891 ± 1.021
29	0.933	0.857 ± 1.010	0.956	0.891 ± 1.021
30	0.933	0.830 ± 1.037	0.8	0.618 ± 0.982
31	1	-	0.956	0.891 ± 1.021
32	0.956	0.891 ± 1.021	0.844	0.707 ± 0.982
33	0.889	0.775 ± 1.003	0.933	0.830 ± 1.037
34	0.978	0.930 ± 1.025	0.978	0.930 ± 1.025
35	0.978	0.930 ± 1.025	0.978	0.930 ± 1.025

Table 2 Content validity of the instrument for teachers
Source: Own elaboration

Item	Relevance	95% CI	Wording and coherence	95% CI
1	0.939	0.804 ± 1.074	0.909	0.764 ± 1.054
2	1	-	1	-
3	0.848	0.665 ± 1.032	0.758	0.555 ± 0.960
4	0.818	0.635 ± 1.002	0.727	0.532 ± 0.923
5	0.939	0.804 ± 1.074	0.788	0.607 ± 0.969
6	0.848	0.639 ± 1.058	0.727	0.466 ± 0.989
7	0.939	0.804 ± 1.074	0.818	0.664 ± 0.972
8	0.909	0.764 ± 1.054	0.848	0.665 ± 1.032
9	0.879	0.672 ± 1.086	0.909	0.710 ± 1.110
10	0.939	0.849 ± 1.030	0.879	0.728 ± 1.030
11	0.97	0.902 1.037	0.909	0.804 ± 1.014
12	0.909	0.764 ± 1.054	0.909	0.764 ± 1.054
13	0.818	0.550 ± 1.090	0.788	0.518 ± 1.058
14	0.758	0.532 ± 0.984	0.697	0.463 ± 0.931
15	0.848	0.639 ± 1.058	0.818	0.586 ± 1.050
16	0.909	0.710 ± 1.110	0.848	0.639 ± 1.058
17	0.879	0.672 ± 1.086	0.848	0.639 ± 1.058
18	0.97	0.902 ± 1.037	0.879	0.766 ± 0.992
19	0.939	0.849 ± 1.030	0.909	0.804 ± 1.014
20	0.97	0.902 ± 1.037	0.939	0.804 ± 1.074
21	1	-	1	-
22	0.939	0.804 ± 1.074	0.939	0.804 ± 1.074
23	1	-	0.97	0.902 ± 1.037
24	0.879	0.728 ± 1.030	0.879	0.728 ± 1.030
25	0.939	0.804 ± 1.074	0.879	0.728 ± 1.030
26	0.879	0.672 ± 1.086	0.848	0.639 ± 1.058
27	0.939	0.804 ± 1.074	0.939	0.849 ± 1.030
28	0.97	0.902 ± 1.037	0.879	0.766 ± 0.992
29	0.818	0.635 ± 1.002	0.818	0.635 ± 1.002
30	0.879	0.728 ± 1.030	0.848	0.695 ± 1.002
31	0.848	0.639 ± 1.058	0.788	0.581 ± 0.995
32	0.909	0.764 ± 1.054	0.788	0.607 ± 0.969
33	0.939	0.849 ± 1.030	0.879	0.728 ± 1.030
34	1	-	0.879	0.728 ± 1.030

Table 3 Content validity of the instrument for students
Source: Own elaboration

Variable	Mean (± standard deviation)	Aiken's V
Overall relevance (scale: 1-4)	3.87 (± .352)	0.956
Overall understanding (scale: 1-4)	3.73 (± .458)	0.911
Overall satisfaction (scale: 1-5)	4.53 (± .516)	0.883

Table 4 Overall assessment of the instrument for teachers
Source: Own elaboration

Variable	Mean (± standard deviation)	Aiken's V
Overall relevance (scale: 1-4)	3.80 (± .422)	0.879
Overall understanding (scale: 1-4)	3.50 (± .527)	0.833
Overall satisfaction (scale: 1-5)	4.40 (± .516)	0.85

Table 5 Overall assessment of the instrument for students
Source: Own elaboration

Similarly, the results of the satisfaction survey (Tables 4 and 5) showed that all the judges considered the instruments for teachers and students in general to be relevant (Aiken's V = 0.956 and 0.879), comprehensible (Aiken's V = 0.911 and 0.833) and expressed high satisfaction with the final questionnaire (Aiken's V = 0.883 and 0.850).

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Discussion

Given the need to strengthen STEAM education in Mexico, it is considered that the development of instruments and research on the subject will allow us to know the pedagogical conceptions about teaching and learning, self-efficacy, cognitive concept, teaching skills, affective attitudes and the need for professional development of teachers.

It is identified that little research has been conducted to probe students' conceptions of approach, cognitive concept, self-efficacy, competencies, perceptions of teacher management and their affective attitudes towards STEAM-based teaching and learning processes. The results of this study suggest that the instrument that was designed is valid and reliable for examining the dimensions mentioned above, as a result of the positive and satisfactory assessment by the national and international experts who participated in the analysis.

To support that the instrument is valid and reliable for research purposes, the literature points out the importance of having the judgement of experts in the field, as it is they who, through analysis and evaluation with methodological rigour, will test the proposed design (allowing the identification of strengths and areas of opportunity, making decisions, making modifications, integrating or eliminating some components, etc.), which ensures the relevance, clear wording and understanding of each of the items of the instrument (Dorantes - Nova, et al. 2016).

It is worth noting that the Aiken V coefficient is a widely used method in the field of social sciences and psychology (Boluarte and Tamari, 2017 and Galicia et al., 2017). It is the formula that is computed as the ratio of a data obtained over the maximum sum of the difference of the possible values, and can be calculated on the ratings of a set of judges in relation to an item or as the ratings of a judge with respect to a group of items (Escurra, 1998). The latter author highlights the selection and number of experts as a fundamental factor for an adequate content validity analysis, since the larger the group of judges, the lower the concordance is required, without the item being invalid. For this reason, assuming that the value of the agreement index is equal to or greater than 0.80 is only relative and depends on the size of the sample of judges being studied.

The most important aspect of this process is that the instrument acquires transcendence for future research and can be replicated, based on evidence that it was supported by theoretical-documentary studies, backed by reliable statistical analyses that ensure the instrument's ability to measure the target variable (Guevara-Rodríguez, G. & Veytia-Bucheli, M., 2021). For authors such as Lagunes (2017), Lynn, (1986), Hyrkäs et al., (2003) and Mills et al., (2012), this method of analysis and review of the instrument must be carried out by specialists with full knowledge of the subject matter to be evaluated, since the choice of judges is fundamental. For this reason, the evaluators in the present study all have a broad professional profile and experience in research, some with a recognised role in the STEAM movement in Mexico and with expertise in education, pedagogy, science and technology.

Based on the above, the questionnaire of "STEAM competences and attitudes in higher education" for teachers and students fills the gap in the existing methodological instrumentation in the country and investigates relevant issues raised previously throughout the article, in addition to the fact that it is supported by instructions and adaptations of terms that facilitate understanding for the population of interest.

Conclusions

This work provides two new specific instruments for the evaluation of STEAM competences and attitudes in higher education teachers and students, which are made up of 35 and 34 items and integrate 5 and 6 dimensions respectively. These instruments are understandable and relevant for application in the mentioned populations, considering that experts and practitioners satisfactorily evaluated the content indicating their validity and relevance.

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The final products were designed on the basis of exhaustive research and validation methods, supported by the documentary review process (from which the proposed dimensions, items and descriptors are derived), and the qualitative and quantitative review and evaluation of the content by judges selected for their academic quality and experience in the field.

Finally, the collaboration of international experts broadens the scope and coverage of the instrument to be implemented in various countries outside the national territory.

As a recommendation, further analyses should be carried out after the application to a pilot group to confirm the reliability and internal structure of the instrument and also to clarify the configuration of the correlations between the criteria and the representation of the concept by means of factor analysis.

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