



Measurement of the social construction of knowledge: validation and reliability of the K-Social-C instrument

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Received: 17 March 2021 / Revised: 4 February 2022 / Accepted: 6 February 2022
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Abstract

The social construction of knowledge developed in social innovation laboratories occurs through the open innovation approach, which is the focus of the present study. The study variables were measured with the K-Social-C questionnaire. It was necessary to consider the indicators of each of these variables reported in the literature and the characteristics of construct, content, and criterion validity and reliability to demonstrate solidly that the instrument measures what it is intended to measure. This document confirms the conceptualization and measurement of three variables: social construction of knowledge (SCK), open innovation (OI), and social innovation laboratories (SIL). The K-Social-C questionnaire is a self-administered instrument that can measure the three variables and their indicators. The questionnaire's validity and reliability were demonstrated through statistical procedures; the content validation and expert agreement were through Kendall's concordance coefficient and the content validity coefficient. We also calculated the internal consistency with Cronbach's alpha as the reliability coefficient. We extended the calculation with exploratory factor analysis and convergent and discriminant validity. However, to study the SCK, OI and SIL variables, we still had to consider the needs and social implications of innovation in each context.

Keywords Validation of instruments · Reliability of instruments · Social construction of knowledge · Open innovation · Social innovation labs · Educational innovation · Higher education

1 Scope

This research identifies the relationships between content, construct, and criterion validity to determine the validity and reliability of a questionnaire that measures the social construction of knowledge. We approached the project of social innovation laboratories through open innovation. To build the assessment questionnaire, we began with a fundamental literature review to determine the main categories and indicators that would best support meaningful conceptual

descriptions and objectives and demonstrate each variable's level. One objective was to contribute to knowledge about the variables in this study because no evidence of measuring the three constructs was found. Finally, each of the steps reported in the literature was carried out to demonstrate the process to be followed for the design, validation, and reliability of the data collection instrument.

2 Introduction

The social construction of knowledge (SCK) has been observed as an activity of idea-sharing through the interactions and socialization of people with a common purpose from a critical and reflective perspective (Fajardo-Mora 2013). Social innovation labs (SIL) have been visualized as collaborative, interdisciplinary spaces to solve problems through experimentation (Gianfrate et al. 2020). Our work used the open innovation (OI) approach to knowledge sources because knowledge flows from the inside out and

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vice versa (Hidalgo 2017) and is generated through open access in various science areas.

SCK is a collaborative model in learning communities where individual interaction creates ideas and builds practical knowledge. As a natural coherent, SILs have shown that co-creation and co-production are carried out by quadruple helix actors (Ballaris 2016) considering that relationships can occur in two, three or four such dimensions (Leydesdorff and Park 2014). Public and private communities openly participate in developing potential, role-sharing, and collaborative ideas as standard practices (Plasencia-Vilchis 2016; Thees et al. 2020). A SIL is considered a platform for collaboration and active participation for SCK by joining efforts to create common goods.

Measuring SCK makes it possible to explain learning success and the efficiency of collaboration in the teaching spaces. SCK refers to the learning process (Rodríguez-Gómez 2010), and SILs are open and autonomous spaces where knowledge sharing is achieved through creative practices mediated by experts (Marcelloni 2019). Knowledge exchange relies on OI resources that participants and experts manage in collectives, governments, and universities (Bonina 2015). They are responsible for raising awareness and creating usable products in real environments.

In 2020, universities were observed as the drivers of SIL with an OI approach for the social construction of knowledge (SCK). In Finland, they conducted studies to determine the continuity of activities inside and outside formal educational settings (Siekkinen et al. 2020). In Russia, they conducted a study of improvisation as a driving factor of urban spaces as living laboratories that generate knowledge on urban issues and policies (Müller and Trubina 2020). Both studies highlighted the importance of multipurpose approaches to SCK driven by OI through practices that create new public knowledge, giving way to technological, social and cultural innovation (Moffett and McAdam 2009).

In the literature reviewed for the present study, we found three fundamental aspects of OI. The flexibility of the actions, the participants' characteristics, and the contextual needs determine the relevant knowledge needed for contexts that require addressing or problems to be solved (Scholl and Kemp 2016; Elci 2009). Areas of opportunity are generated when the end-users have participated in SCK (Breunig et al. 2016), the changing environment presents challenges to implement or address, and local problem solutions are scaled to global responses (Chatterton et al. 2018). It is also necessary to determine the societal implications of innovation by assessing the laboratories' final products (Nitz et al. 2014).

This study's objective was the design, validation, and reliability testing of the K-Social-C questionnaire that measures the SCK of SIL work teams using the OI approach. The questionnaire's design was based on works that conceptually described the variables and the categories and indicators that

other authors measured. Secondly, the work was assisted by five experts in the areas of educational innovation, strategic planning, educational research, research methodology, and educational evaluation to create the first version of the questionnaire. For validation, 13 experts from educational innovation, discourse analysis, educational evaluation, educational research and educational quality determined the content validity coefficient (CVC). For reliability, we determined internal consistency with Cronbach's alpha as the reliability coefficient and also performed Exploratory Factor Analysis and convergent validity and discriminant validity testing.

The following section presents the theorists who conceptualized this study's variables, i.e., SCK, SIL, and OI. In an SML (systematic mapping of literature), the authors of this study did not find studies that presented the conception of the three variables; therefore, a conceptual background is presented discussing the choice of the indicators to be measured in each variable (Yañez-Figueroa et al. 2016). A section describing the methodology that guided the present study is included, integrating as background the review of works by authors who have designed instruments that measure the variables SCK, SIL and OI to strengthen the design of the K-Social-C questionnaire and determine its categories and indicators. In the same space, information on the process used to determine the validation and reliability of the questionnaire is integrated, thus confirming the qualities, content and criteria of the construct, in Fig. 1, we can see the process that was carried out. The pilot test confirms the efficacy of the instrument since the data collected were carried out in a setting similar to the population of interest and to reduce biases or errors in data collection. The results of the pilot were analyzed with statistical techniques such as the internal consistency of the items by means of Cronbach's Alpha and Confirmatory Factor Analysis. The discussion section closes with a comparison of the results obtained in light of the theory reviewed, confirming the validity and reliability of the K-Social-C instrument. The article ends with the conclusion section with contributions to knowledge and relevant considerations for the social construction of knowledge through the open innovation approach.

3 Background

3.1 Social innovation labs

Social Innovation Laboratories are growing and developing, providing possible solutions and attention to problems that continue to afflict our societies. One of the advantages highlighted in this article is that the results are enriched by the characteristics of interdisciplinary groups, since it is common to observe that different areas of science

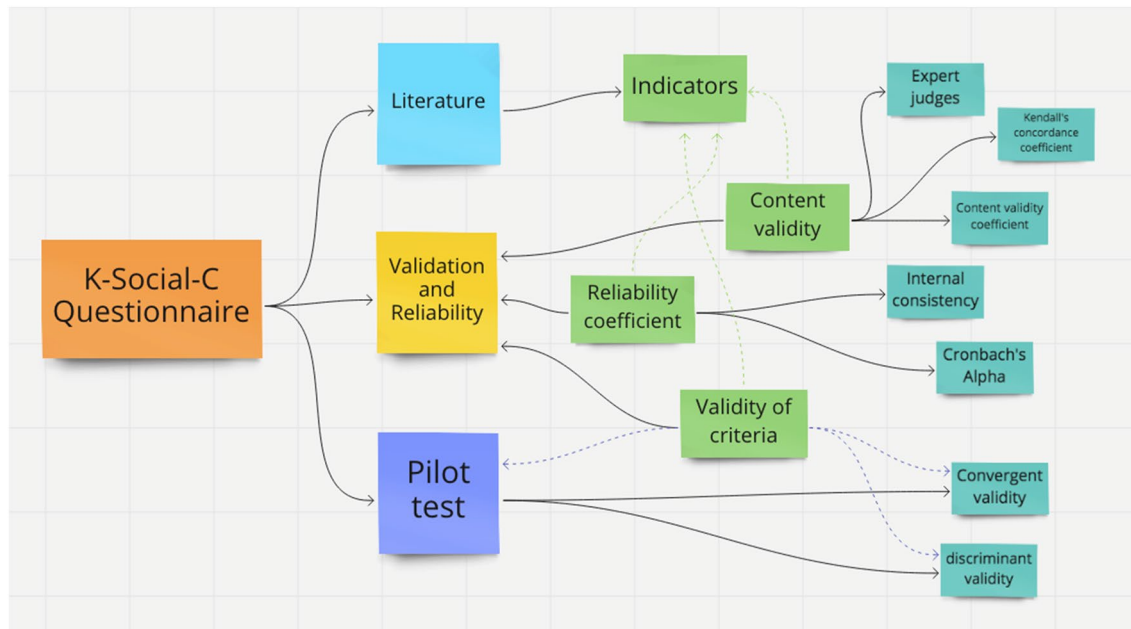


Fig. 1 Diagram of K-Social-C questionnaire construction. *Note:* Own elaboration

participate collaboratively in these flexible and open spaces (De la Fuente 2020). Such interaction promotes knowledge sharing and role playing are present in SIL as factors that develop innovative and creative ideas (Rådberg et al. 2020). A strength is driven by human potential that promotes active participation to discover opportunities for knowledge production that can be applied in real environments (Hassan 2014). The results of SILs are disseminated with open access digital platforms and resources from the public and private spheres (Guevara-Castro and Calderón-Carvajal 2018). The main value of knowledge is problem solving; it requires the right degree of thinking to create solutions (Beckamp and Schlieter 2020). Up to the time of writing the article, the studies reviewed showed that SCK is developed through the laboratory and depends on the interdisciplinary experience of the participants in each project and the guidance of specialists.

One of the considerations of the present study is to determine the areas of science that are convened in laboratories to assess the social impact of the results. Therefore, it is highlighted that in the literature review, studies were found in the social, cultural, educational, economic, political, and environmental domains (Nadkarni and Prügl 2020). Collaborative platforms for documenting the process of building laboratory resources have been found to contribute for teams to achieve knowledge production (Schrape 2020). In that sense, labs are practical ways for individuals from different scientific areas to collaborate using a flexible methodology to create innovative solutions (Pascale and Resina 2020). Labs go by various

names, such as innovation labs or living, urban, citizen, and virtual labs. However, whatever the case, their results are generally creative prototypes that address a problem (Mérindol and Versailles 2017). It is expected that the results of the upcoming laboratories will promote the creation of public policies and regulatory laws themselves that are contributions from various areas of society for the construction of knowledge with an open innovation approach.

In the same vein, the end result of each lab team's work should be a solution or solution to a problem. The solution, commonly responds to a local need and is postulated as scalable to a global level. For this reason, innovation will seek that the new ideas change the environment where they are applied. The results can be a product, a service, a strategic plan, an object, a device or technological resource (Pérez-Espinoza 2018). In laboratories, the participation of end users is sought and there are two moments: involving them from the beginning or in the testing stages to determine the functionality of the prototype (Jaramillo et al. 2019). Labs are open spaces that use the commons to create open science. They are always oriented to the construction of practical knowledge. Therefore, organizers who come from academia are responsible for disseminating documentation on open access platforms (Hammond 2020). Laboratories that are communities of practice or learning communities have been disruptive spaces for vulnerable groups or marginalized societies to find solutions to the needs or demands of their communities. Labs serve for interactions and knowledge sharing in public spaces,

libraries, governmental areas and, in recent years, university facilities.

3.2 Social construction of knowledge

SCK is an activity that takes place in formal and informal spaces, where teaching actions are carried out or where people interact to generate ideas and build an argument. Cantoral (2019) mentions that SCK is a human sociocultural activity and that identifying and evaluating it depend on the sources and origin of knowledge. In that sense, Jara-Roa et al. (2019) state that one of the predictors for learning to be achieved is SCK. To make sense of knowledge valuation, Silva (2014) defines a model of knowledge construction in four stages: socialization, externalization, combination, and internalization. In each stage, knowledge can be observed to consider if it was constructed socially. In the framework of SCK, synonyms have been addressed, as is the case of collective construction of knowledge (Durán-Pineda 2019), which is carried out through reflective actions where citizens participate in training processes consolidating responsibility, ethics, and decision-making to improve the environment that surrounds them.

Another concept that has categories of indicators to measure SCK in environments, such as SIL, is the co-construction of knowledge. Negotiation or co-construction is carried out through five stages proposed by Beltrán-Hernández de Galindo and Ramírez-Montoya (2019): clarifying the meaning of terms, negotiating arguments, identifying agreements, proposing new compromises and elaborating a proposal that integrates the constructed knowledge. Adamides (2020) states that knowledge construction is systematic through activities or practices in a given context, which he called activity-based analysis, recognizing that the activity or practice is used for knowledge construction. Authors such as Akram et al. (2019) also propose terms such as knowledge management, knowledge acquisition, knowledge diffusion, and knowledge receptivity. These describe social exchange activities that position knowledge at the center of a cluster that must be protected, nurtured, and shared. Thus, LISs use the OI approach to disseminate knowledge, and their participants play an active role in its utilization, transformation and dissemination, depending on the context.

The SILs emerge in universities to promote the SCK with activities that involve the actors of the quadruple helix. From a local–global dimension that seems the best candidate for the model of globalization, economics, scientific publication and problem solving to have mutual redundancy in a coherent way (Leydesdorff and Meyer 2006). Moodley and Mutekwe (2019) contribute that SCK is a way to conceive a diversified educational system that promotes openness and the participation of anyone interested in activities that benefit their communities and achieve social transformation. In

the same vein, Khanlari (2020) has shown that SCK is based on Vygotsky's Sociocultural Theory of Learning, which affirms that cognitive processes emerge in groups of people as a function of cultural, historical, and social interactions. By definition, SCK is not performed by a single person; therefore, the present study analyzes the perspectives of the participants. Kane (2019) adds that SCK results from the conversation between two or more people he calls peers. As we can see, SIL participants have the perspective to measure the indicators of SCK categories. These can also be determined by analyzing the documentation created throughout the process of building a prototype.

3.3 Open innovation

Open innovation is a participatory process of initiative development in which the expertise of different people comes into play. One of the indicators of IoT observed in this study is that LIS participants are quadruple helix actors. To confirm that their participation benefits end users and their varied experiences contribute to new ideas generating new products, services or objects and producing successful prototypes (Bethlendi and Vértesy 2020). In the present article, the contexts of the quadruple helix are science represented by schools, the economy brought into play by private enterprise, the government responsible for policies, and the citizens of society, who are the end users in charge of testing them before their final implementation (Bader and Buhr 2020). It is common that we observe various sources and resources that are provided to LIS participants as knowledge exchanged through collaborative processes for organizational learning in scenarios where knowledge is mobilized through experimentation (Josef 2020).

As the name implies, open innovation is an approach to SCK from a flexible environment integrating the formal and the informal. Thus, resources, sources, and participants are not limited to what comes from inside a laboratory (Dröge 2020; Teo 2020). The actors involved in SCK actively collaborate to transfer knowledge and experience to a product or service prototype that addresses or solves a community problem. The knowledge circulates within and outside the SIL boundaries that Chesbrough and Tucci (2020) have called open innovation. Success is achieved because three fundamental elements are contemplated: the experience of the participants, the context in which it will be applied and the contributions of the end users (Abhijeet 2020). In industry, successful business models have used OI to develop functional products, technologies, and services that change the context. OI invites collaboration and, in SIL, there is a high degree of collaboration among participant teams and the guidance of experts called mentors (Abhijeet, 2020).

The OI approach has allowed knowledge to be produced in different scenarios, which is why innovation laboratories,

urban laboratories, living laboratories, and citizen laboratories have been created. Thus, topics such as urbanism, environment, art, or culture speak of participatory governance to commercialize knowledge through the exchange of ideas among the SIL participants, who create new knowledge that impacts the development of communities (Gebhardt 2020). Likewise, SILs are open collectives for using ideas and resources to share practices and put people at the center of the SCK process in a democratic, collaborative and voluntary environment (Borda and Bowen 2019; Resina and Güemes 2019). Therefore, OI is considered a practical approach to attend or solve problems. As can be seen in this section, it has measurable and observable indicators in the SIL through the participants as information sources and the documentation of the processes to create the final prototypes. At the same time, OI has characteristics that can be contrasted with SCK.

4 Methodology

4.1 Previous validation and reliability studies of instruments

One example serving as background for the K-Social-C questionnaire design is a study conducted by Hernández et al. (2018) that contemplated three research questions related to innovation, laboratories' trends, and their importance for the academic community. Data were collected analyzing an innovation laboratory from five variables: participation of the quadruple helix actors in a learning community where collaborative ideas triggered the construction of knowledge that guided a problem solution in an interdisciplinary space, where the participants came from different areas of science. The data were analyzed, coded, and synthesized with MAXQDA software. Thus, the K-Social-C questionnaire determines (a) that the participants come from the quadruple helix; (b) the learning or experimentation communities work in flexible, autonomous, creative environments where knowledge is exchanged; (c) the laboratories to develop ideas promote collaboration among experts and participants who are affected by the problems; (d) the characteristics of the disciplinary areas of the participants, and (e) the verification that the prototype solves or addresses a problem.

For the SCK variable, we sought studies that examined collaborative knowledge construction and knowledge dissemination. The study by Badia et al. (2010) contemplated five dimensions of collaborative knowledge construction: sharing or comparing information; Discovery and exploration of dissonance or inconsistency between ideas, concepts or statements; Negotiation of meaning or co-construction of knowledge; Confrontation and modification of proposed syntheses or co-construction; and

Agreed statements or applications of newly constructed meanings. The dimensions are presented in an Interaction Analysis Model to assess SCK in computer-mediated communication. The categories of this analysis model provided indicators of the K-Social-C questionnaire, such as the interaction of the participants for the construction of meaning, the actions taken to analyze a problem and carry out negotiation among the participants, and the sharing of information as part of the knowledge applicable in different environments. The knowledge diffusion proposed by Akram et al. (2019) sought to determine the transfer or dissemination of individual knowledge to a group, organizational or public level. The indicators were knowledge mobilization and knowledge openness, which are used in the K-Social-C questionnaire.

4.2 Categories and indicators

The K-Social-C Instrument is a self-administered questionnaire containing 34 items. It has five sections. The first gives general instructions and states the instrument's purpose; it also has a question asking if the participants agree to share personal information that would be used for academic purposes. The second section collects demographic and educational data from the participants. The third collects information from the perspective of the participants about the social innovation labs. The fourth section collects data related to the social construction of knowledge, and the fifth section collects information on open innovation. Table 1 shows the operationalization of the variables used for the construction of the K-Social-C questionnaire.

It has three types of questions, demographic questions that are open and questions with a four-level Likert scale (1-Totally disagree; 2-Disagree, 3-Agree; 4-Totally agree) for the participants to describe their perspective on the three variable indicators present. There are questions with checkboxes for the respondents to indicate the characteristics of the laboratories, the social construction of knowledge, and open innovation present in the context analyzed.

4.3 Validation and reliability

4.3.1 Content validity

The content validation and expert concordance of the K-Social-C questionnaire was carried out using Kendall's concordance coefficient and the content validity coefficient, whereby 13 evaluators confirmed that K-Social-C is a valid and reliable questionnaire (Yañez-Figueroa et al. 2020). These statistical techniques objectively measured the constructs and the variables established by the literature to construct the questionnaire, guaranteeing that this instrument

Table 1 Operationalization of variables

Construct	Indicators	Theoretical-conceptual	Theoretical-instruments
Social innovation lab (SIL)	Quadruple helix participants	De la Fuente (2020), Guevara-Castro and Calderón-Carvajal (2018)	Ballaris (2016), Müller and Trubina (2020)
	Collaborate openly in interdisciplinary groups	Beckamp and Schlieter (2020), Méridol and Versailles (2017)	Serrano (2018), Thees et al. (2020)
	Solution to a problem, need, or idea	Rådberg et al. (2020)	Scholl and Kemp (2016), Chatterton et al. (2018)
	Open spaces for experimentation	Matters (2020), Pascale and Resina (2020)	Scholl and Kemp (2016), Chatterton et al. (2018)
	Areas covered	Hassan (2014)	Jaramillo et al. (2019)
	Labs as a system for developing creative ideas	Méridol and Versailles (2017), Hassan (2014), Matters (2020)	Marcelloni (2019), Scholl and Kemp (2016)
Knowledge construction (SCK)	Interaction to clarify terms	Beltrán-Hernández de Galindo and Ramírez-Montoya (2019), Kane, (2019)	Fajardo-Mora (2013), Elizondo-García and Gallardo (2020)
	Negotiation of arguments	Durán-Pineda (2019)	Vuopala, Näykki, Isohätälä and Järvelä, (2019), Morueta, López, Gómez and Harris (2016)
	Identify agreements	Jara-Roa et al. (2019), Khanlari (2020)	Moffett and McAdam (2009)
	Responsibility and ethics for new commitments	Durán-Pineda (2019) Beltrán-Hernández de Galindo and Ramírez-Montoya (2019)	Plasencia-Vilchis (2016), Nitz et al. (2014)
	Cognitive processes, conceptual construction	Cantoral (2019), Khanlari, (2020)	Hu, Donald, Giacaman and Zhu, (2020), Badia et al. (2010)
	Dissemination of knowledge (SCK)	Applicable knowledge	Adamides (2020), Cantoral (2019)
Type of final product		O'Reilly (2019), Lay (2020)	Vuopala, Näykki, Isohätälä and Järvelä (2019), Rodríguez-Gómez (2010)
Socialization of knowledge		Silva (2014), Akram et al. (2019)	Badia et al. (2010), Nitz et al. (2014)
Define agreements		Silva (2014)	Fajardo-Mora (2013), Badia et al. (2010)
Open knowledge sharing		Moodley and Mutekwe (2019), Lay (2020)	Moffett and McAdam (2009), Nitz et al. (2014)
Open innovation (OI)		Use of different knowledge sources or resources	Bethlendi and Vértesy (2020), Dröge (2020)
	Product quality product does not exist	Teo (2020), Gebhardt (2020)	Bonina (2015), Vázquez-González, Jiménez-Macías and Juárez-Hernández (2020)
	Creation of collaboration networks	Gebhardt (2020), Borda and Bowen (2019)	Bravo, Montes and Moreno (2017), Hidalgo (2017), Elci (2009)
	Characteristics of open innovation	Resina and Güemes (2019)	Robalino-López, Ramos, Unda and Franco (2017), Gong, Wang, Zhao and Yu (2018)
	Social implications of open innovation	Abhijeet (2020)	Vázquez-González, Jiménez-Macías and Juárez-Hernández (2020), Breunig et al. (2016)

measures the social construction of knowledge using the open innovation approach, carried out in experimentation scenarios such as social innovation laboratories.

4.3.2 Construct validity

Cronbach's alpha, the reliability coefficient most commonly used in the social sciences, was used to measure internal consistency. The standard procedure for estimating the alpha

coefficient is based on the correlation matrix. SPSS software was used for the calculation (George and Mallery 2003). Exploratory Factor Analysis was also performed using some indexes such as Chi-square over degrees of freedom (CMIN/DF), the composite reliability index (CFI), the root mean square error of approximation per degree of freedom (RMSEA), and the PCLOSE. Data were extracted using the AMOS v24 software (Rojas-Torres 2020; Chiu et al. 2020).

4.3.3 Validity of criteria

Convergent validity and discriminant validity are aspects that should be evaluated in tests that measure people's perceptions. In this study, respondents assessed the degree of presence of the indicators of the variable's social innovation laboratories, the social construction of knowledge, and open innovation using a Likert scale. Convergent validity is understood as the positive correlation among the variables, indicating that both variables recruit the same process. Discriminant validity is understood as the absence of statistical correlations among the variables' indicators, indicating that the variables in question do not involve the same processes (Hogan 2004).

4.4 Piloting

To strengthen validity and reliability, a pilot test was conducted with a convenience sample of 67 volunteer participants in the second innovation lab, "technologies for the development of educational innovation". The probability sample was used as a justification factor as the representative amount of the population of interest (Fox et al. 2009). The pilot test was conducted as a previous simulation to decrease biases and errors in obtaining data (García-García et al. 2013) as well as it was applied with people with similar attributes to the participants of the laboratories. They answered the questionnaire at the end of the laboratory to indicate their perspective on the variables measured in the K-Social-K questionnaire (innovation labs, social construction of knowledge, and open innovation). Personalized invitations to participate were sent through email and a WhatsApp message. People responded from different science areas, participating in interdisciplinary groups in an open educational resource initiative prototype. Forty-three women

and 24 men comprised the sample. Their ages ranged from 21 to 64 years old. Their educational backgrounds included 18 participants with bachelor's degrees, 26 with master's degrees, and 23 with doctoral degrees. In terms of countries, 50 participants were from Mexico, six from Guatemala, two from Colombia, two from Chile, one from Argentina, one from Venezuela, one from Cuba, and one from Peru.

5 Results

To collect information related to the three variables (innovation laboratory, the social construction of knowledge and open innovation), we designed a questionnaire with 42 items (see Table 2), of which 23 employed a Likert-type scale with four categories (strongly disagree, disagree, agree and strongly agree). The remaining items were not Likert-type and were validated for content and expert agreement. The P-code was used to determine the question and item number.

A pilot study was conducted with 67 respondents, and information was collected on the variables with the 23 Likert-type scale items (see first column Table 3). Fifth column 5 of Table 3 shows the evaluation of internal consistency using Cronbach's alpha, and a mean value of 0.957 was obtained, which is excellent (George and Mallery 2003). Furthermore, in the fourth column of the Total correlation of corrected items, there are no negative coefficients or coefficients lower than 0.20 (Frías-Navarro 2020). Therefore there was no need to reject or reformulate any item (see Table 3).

In Table 3, we can see that the second column presents the mean of the total scale scores and the third column contains the scale variance of each item. The second column presents the mean of the total scores of the scale if in the sum of these scores the corresponding item is eliminated. For example, item p13 its value is 75, which is the mean of the variable in the sum of P14 + P16 + P16.1 + P16.2 + P16.3 + ... + P32. In the same sense, the third column shows the scale variance if the element has been suppressed, considering that the variance is the degree of dispersion, that is, how far it departs from the central value of the general mean. The data in the fourth column indicate that Pearson's correlation coefficient has a strong correlation since it is above, 50; items 13 and 14 have a moderate correlation since they are between 30 and 50. In the fifth column we can see that

Table 2 Distribution of items, according to study variables

Variables	Items
Social innovation labs	P7, P8, P9, P10, P11, P12, P13, P14. P15, P16. P16.1, P16.2, P16.3, P16.4 Y P16.5
Social construction of knowledge	P17, P18, P19, P20, P21, P22, P23, P24,P25, P25.1, P25.2, P25.3, P25.4, P25.5, P25.6, P25.7, P25.8, P25.9, P26 Y P27
Open innovation	P28, P29, P30, P31, P32, P33 Y P34

Table 3 Corrected total correlation coefficient of elements

Ítem número	Scaling average if the element has been suppressed	Scale variance if the element has been suppressed	Total correlation of corrected items	Cronbach's Alpha if the item has been deleted
P13	75,00	191,000	0.421	0.959
P14	75,27	190,351	0.383	0.960
P16	75,36	181,900	0.730	0.955
P16.1	75,48	182,799	0.723	0.955
P16.2	75,61	185,211	0.664	0.956
P16.3	75,21	180,380	0.752	0.955
P16.4	74,99	180,257	0.763	0.955
P16.5	75,03	182,726	0.698	0.956
P17	74,85	188,493	0.645	0.956
P18	74,72	187,358	0.801	0.955
P19	74,64	187,142	0.839	0.954
P20	74,64	188,112	0.785	0.955
P21	74,82	186,664	0.752	0.955
P22	74,64	186,203	0.836	0.954
P23	75,39	188,574	0.582	0.957
P24	74,75	186,071	0.813	0.954
P26	74,67	186,406	0.815	0.954
P27	74,60	187,729	0.800	0.955
P28	74,76	188,215	0.745	0.955
P29	74,72	187,964	0.768	0.955
P30	74,94	187,754	0.682	0.956
P31	75,42	190,732	0.539	0.957
P32	74,72	186,267	0.766	0.955

P=Question = ítem; in spanish = Pregunta

the Cronbach's Alpha coefficient for all the items achieved a value between 0.954 and 0.960, which is considered a high reliability of the scale.

5.1 Confirmatory factor analysis (CFA)

The study's latent variables (innovation laboratory, the social construction of knowledge, and open innovation) were made up of 8, 10 and 5 Likert-type items (observable variables), respectively. Based on this information and the AMOS v24 program, the path diagram or path graph was constructed (see Fig. 2), which shows the relationships of the variables and the items of the K-Social-C questionnaire of the present study.

Table 4 specifies the measures to be calculated to determine the goodness-of-fit, understood as the degree of coupling between the original data and the theoretical values, with their corresponding acceptable thresholds (Hu and Bentler 1999). Table 4 shows the CMIN/DF values where it is presented that less than 3 is a good value. The Composite Reliability Index (CFI) values established that greater than 0.95 is very good, 0.94–0.90 is acceptable in a traditional perspective, and 0.89–0.80 is sometimes permissible.

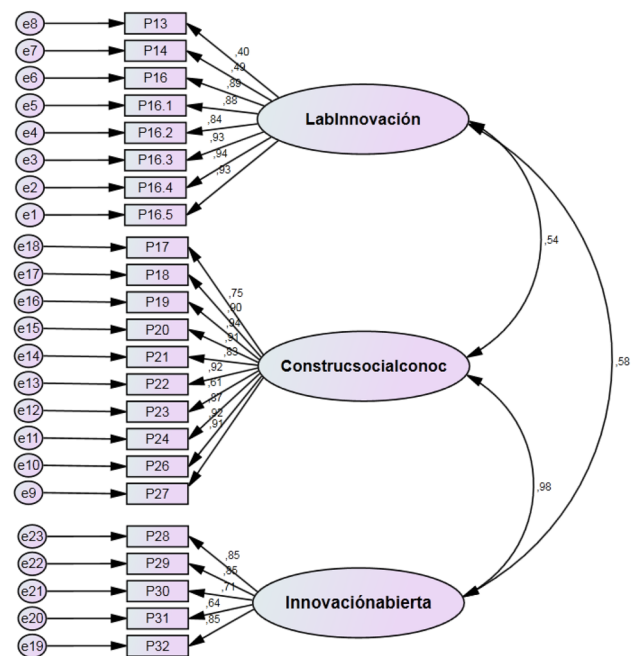


Fig. 2 Unspecified path chart

Table 4 Goodness-of-fit measures with their thresholds

Measure	Threshold
Chi-square/DF (CMIN/DF)	< 3 good; < 5 sometimes permissible
p-value for the model	> 0.05
CFI	> 0.95 great; > 0.90 traditional; > 0.80 sometimes permissible
RMSEA	< 0.05 good; 0.05–0.10 moderate; > 0.10 bad
PCLOSE	> 0.05

Table 5 Re-specifications of the model and goodness-of-fit measurements

	CMIN/DF	CFI	RMSEA	PCLOSE
AFC Initial	2.113	0.858	0.130	0.000
1a Respecification	1.751	0.906	0.107	0.000
2a Respecification	1.546	0.932	0.091	0.001
3a Respecification	1.287	0.966	0.066	0.147

The goodness-of-fit statistics obtained in each re-specification, the initial confirmatory factor analysis, and the three model re-specifications are illustrated in Table 5. The CMIN/DF is good since from the initial to the third re-specification, it is less than 3, as stated by the model in Table 4. The composite reliability index (CFI) is between 0.858 and 0.932, which are sometimes conceived as permissible from a traditional perspective, and the RMSEA, as well as the PCLOSE, do not fit the guideline thresholds illustrated in Table 4.

As we can see in Table 5, in the third re-specification, the goodness-of-fit indices were achieved, indicating that the model fits well with the observed variables. The RMSEA obtained was 0.066, and Table 4 states that 0.05–0.10 is moderate. We also observe that the PCLOSE obtains a score of 0.147, which is greater than 0.05, as shown by the goodness-of-fit measures and their thresholds in Table 4.

5.2 Convergent and discriminant validity

According to Campbell and Fiske (1959), convergent validity occurs when the same construct measures have high correlations. There is discriminant validity when the correlation is greater than the measures proposed for a different

construct. In other words, there is convergent validity when the measurements in the desired concept have a high correlation (close to 1) (see Table 6). Convergent validity can be assessed through the average variance extracted (AVE). Discriminant validity measures the theoretical difference between the different constructs, which should have low correlations between them. There should be high correlations between the observed variables (items) and the construct being measured, but there should not be high correlations with other constructs in the study. The coefficient is determined as follows: $MSV < AVE$ (Table 6).

Once these indexes were obtained in the third re-specification, the plugin called validity and the reliability test (Gaskin, 2021) were run, which generated the information in Table 6, where it is observed that the composite reliability index (CFI) in the three factors is excellent (George and Mallery 2003): 0.93 for the innovation laboratory variable; 0.96 for the social construction of knowledge variable, and the items of the open innovation variable registered a reliability coefficient of 0.89. As for the average variance extracted (AVE), Fornier and Larcker (1981) suggest that the construct should have AVE values equal to 0.5 or higher. In this case, the results of this table evidence that they fit the suggested criterion (Aldás-Manzano 2005). Consequently, the model has convergent validity, but only factor 1 (innovation laboratory) presents discriminant validity because $MSV < AVE$ (0.335 is less than 0.661). In factors 2 and 3, this criterion is not met, nor is it fulfilled that the diagonal values of these two factors are greater than the correlation coefficients below the diagonal.

Based on the relationships indicated in the index modification, when the initial CFA was performed, the first model re-specification consisted of correlating the observable variables P13 and P14; P16.4 and P16.5, and also P19 and P22 (see Fig. 3). The results are similar to those in Table 5, which leads to the same conclusion: the goodness-of-fit indexes indicating that the model fits well with the observed variables were not achieved.

When making the second re-specification in the AMOS output, it was observed in the results of the index modification that the following observable variables should be related: P13 with P14; P16.4 with P16. 5; P17 with P24; P18 with P19; P18 with P20 and P19 with P22 (see Fig. 4); the results of these relationships do not show favorable changes in the discriminant validity in factors 2 and 3 (see Table 7), i.e., in factors 2 and 3 this criterion is not met, nor are the values of

Table 6 Composite Reliability Index, convergent and discriminant validity, not re-specified

	CFI	AVE	MSV	F1	F2	F3
Social innovation labs-F1	0.936	0.661	0.335	0.813		
Social construction of knowledge-F2	0.966	0.741	0.957	0.541	0.861	
Open innovation-F3	0.888	0.617	0.957	0.579	0.978	0.786

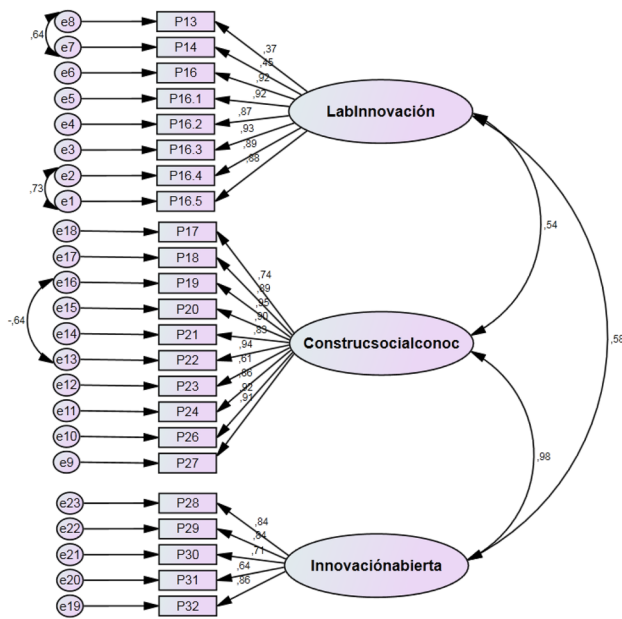


Fig. 3 Path chart, 1st re-specification

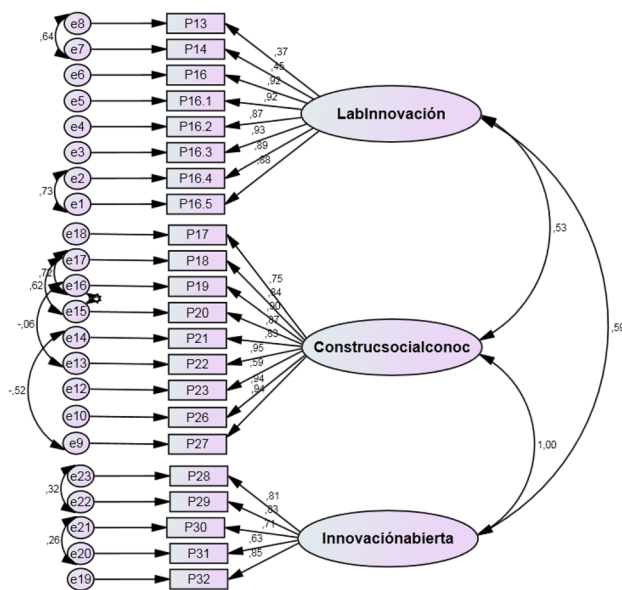


Fig. 4 Path chart, 2nd re-specification

the diagonal of these two factors greater than the correlation coefficients below the diagonal.

Based on the results suggested in the index modification, the observable variable P24 was eliminated, and P19 was correlated with P20 (see Fig. 5). This process produced the results in Table 8, which do not show discriminant validity in factors 2 and 3. Despite this we can see that the three respecifications were necessary to achieve acceptable goodness-of-fit indices, as can be seen in Table 5. Likewise, in Table 4 we can see that the CMIN/DF is good since, from the initial to the third respecification, it is less than 3, as indicated by the model in Table 4. Also in Table 4 the composite reliability index (CFI) is between 0.858 and 0.932, which are sometimes conceived as permissible from a traditional perspective.

On the other hand the RMSEA, as well as the PCLOSE, do not conform to the indicative thresholds illustrated in Table 4. The RMSEA obtained was 0.066, and Table 4 states that between 0.05 and 0.10 is moderate. We also note that PCLOSE scores 0.147, which is higher than 0.05, as shown by the goodness-of-fit measures and their thresholds in Table 4. The question that may arise is: What is the point of re-specifications to the model if there are no favorable changes in discriminant validity in factors 2 and 3? Desirably, all favorable convergent and discriminant validity and composite reliability indices would have been achieved, but this is not always the case. These re-specifications were necessary to achieve acceptable goodness-of-fit indices, as shown in Fig. 5 (3rd re-specification).

From the psychometric analysis of the information collected with the 23 Likert scale items, it is concluded that 22 items collect valid and reliable information on the variables of the study, which are made up of the items shown in the path graph in Fig. 5 and Table 9.

6 Discussion

The present study confirms the validity and reliability of the K-Social-C questionnaire, fulfilling its objective, which was that the design of the instrument that measures the SCK of SIL work teams using the OI approach was valid and reliable. The content validation and expert concordance were performed using Kendall's concordance coefficient and content validity coefficient (Yañez-Figueroa et al. 2020). This article reports the reliability coefficient results determined through internal consistency with Cronbach's alpha as the reliability coefficient and the Exploratory Factor Analysis and the convergent

Table 7 Composite reliability indices, convergent and discriminant validity, second re-specification

	CFI	AVE	MSV	F1	F2	F3
Social innovation labs-F1	0.933	0.650	0.335	0.806		
Social construction of knowledge-F2	0.966	0.743	0.957	0.541	0.862	
Open innovation-F3	0.888	0.616	0.957	0.579	0.978	0.785

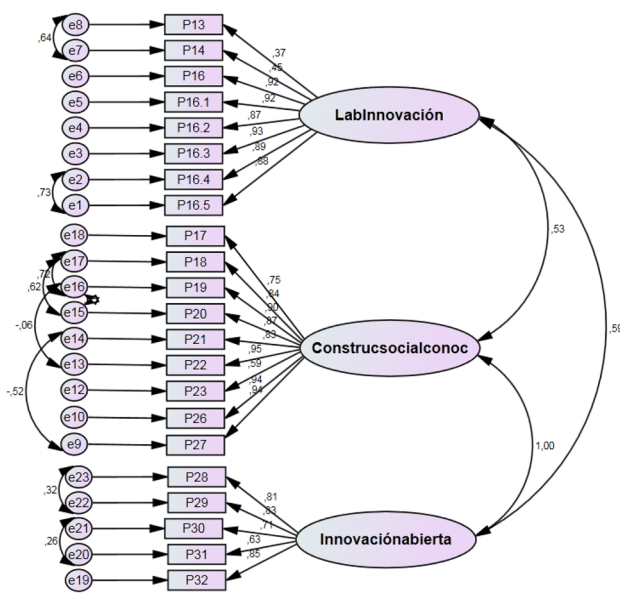


Fig. 5 Path chart, 3rd re-specification

validity and discriminant validity. Therefore, it is concluded that they have psychometric qualities to measure SCK, OI, and SIL variables.

The K-Social-C questionnaire can be applied to people who participate in experimentation spaces such as innovation laboratories and in interdisciplinary content creation workshops that seek to address the problems, needs, or ideas of various stakeholders in society. In that sense, in communities where public and private groups of people openly participate in collaborative exchanges of roles and ideas as standard practices (Plasencia-Vilchis 2016; Thees et al. 2020), the K-Social-C questionnaire can be applied to determine the process of the social construction of knowledge using open innovation. For the design of instruments that seek to measure the social construction of knowledge, the characteristics and needs of the knowledge to be applied in real environments must be considered (Scholl and Kemp 2016; Elci 2009). The social implications of innovation must be determined by assessing the laboratories' final products (Nitz et al. 2014).

Another contribution that we point out in this study is that the necessary re-specifications in validation and reliability should be carried out, as has been demonstrated in the K-Social-C questionnaire, confirming that there is convergent validity in the construct measures, as evidenced by the high correlations between them (Campbell and Fiske 1959).

Table 8 Composite reliability indices, convergent and discriminant validity, third re-specification

	CFI	AVE	MSV	F1	F2	F3
Social innovation labs-F1	0.933	0.650	0.350	0.806		
Social construction of knowledge-F2	0.959	0.726	0.996	0.528	0.852	
Open innovation-F3	0.879	0.596	0.996	0.592	0.998	0.772

Therefore, in this study, the Exploratory Factor Analysis was carried out using indices such as Chi-square over degrees of freedom (CMIN/DF), the composite reliability index (CFI), the root mean square error of approximation per degree of freedom (RMSEA), and the PCLOSE. The data was extracted using the AMOS v24 software (Rojas-Torres 2020; Chiu et al. 2020).

7 Conclusions

In this study, the piloting of the K-Social-C questionnaire shows that it complied with all the recommendations of the statistical tests, confirming validity and reliability, thus ensuring that it measures the intended variables and their indicators. The validation of content and concordance of experts through Kendall's concordance coefficient and content validity coefficient and the calculation of internal consistency with Cronbach's Alpha as reliability coefficient extended the calculation with the Exploratory Factor Analysis and convergent validity and discriminant validity, the above consolidates the validity and reliability through the validation of expert judges confirming the qualities of an instrument such as: clarity, pertinence and correspondence, providing psychometric qualities to measure the variables SCK, OI and SIL. With the above, the objective of creating a data collection instrument that measures the aforementioned variables and that can be used by other researchers interested in one or all three variables was achieved. The use of the questionnaire can be carried out with the assurance that it is valid and reliable.

The social construction of knowledge is a variable studied and it was determined that it stands out as a contribution to the knowledge of science because it is carried out in processes of exchange of ideas through interaction and

Table 9 Distribution of items with psychometric qualities, intended to measure the study variables

Variables	ÍTEMS
Social innovation labs	P13, P14, P16, P16.1, P16.2, P16.3, P16.4 y P16.5
Social construction of knowledge	P17, P18, P19, P20, P21, P22, P23, P26 y P27
Open innovation	P28, P29, P30, P31 y P32

socialization of people. The main objective of the social innovation Laboratories is to solve problems through experimentation and the use of knowledge as success factors, findings that are confirmed by the participants of the study. The present research confirms that by creating individual ideas and building practical knowledge where public and private spheres converge, we are contributing to the common science, the science of knowledge. In social innovation laboratories using the open innovation approach, the final products can be analyzed after a period of implementation to extend the social construction of knowledge with open innovation. The study is limited by its focus on quantitative methodological design, so the findings can be extended by experimenting in studies with mixed approach. The instrument will be used in social innovation labs that the authors will be designing to measure the contributions of the social construction of knowledge from the open innovation approach. The questionnaire and the contributions to knowledge will be published in open access articles so that the community interested in the study variables will have access to the information resulting from the research processes.

Acknowledgements The article is part of the Academic Production of the Doctorate Program Training in the Knowledge Society of the University of Salamanca, Spain. This work is partially funded by CONACYT-SENER (Mexico) through the project, "Binational Laboratory for the Intelligent Management of Energy Sustainability and Technological Training" (Ref. 266632) for the CONACYT-I0028-2016-04 (Mexico) project, "Increase the visibility of RITEC by improving the user experience and its interoperability with the National Repository" (Ref. 280318) and by the Ministry of Economy and Competitiveness (Spain) through the project, "DEFINES" (Ref. TIN2016-80172-R). The authors would like to acknowledge the technical support of Writing Lab, Institute for the Future of Education, Tecnológico de Monterrey, Mexico, in the production of this work.

Authors Contribution All authors contributed to the study conception and design.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. This work is partially funded by CONACYT-SENER (Mexico) through the project, "Binational Laboratory for the Intelligent Management of Energy Sustainability and Technological Training" (Ref. 266632) for the CONACYT-I0028-2016-04 (Mexico) project, "Increase the visibility of RITEC by improving the user experience and its interoperability with the National Repository" (Ref. 280318) and by the Ministry of Economy and Competitiveness (Spain) through the project, "DEFINES" (Ref. TIN2016-80172-R).

Availability of data and material Not applicable'.

Code availability Not applicable'.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

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