Diagnostic Instrument of the Level of Competencies in Cloud Computing for Teachers in Education 4.0

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Abstract. Universities face a paradigmatic educational challenge, driven by Industry 4.0 technologies such as Cloud Computing, producing the need to develop new teaching competencies. The question arises: How can we diagnose the level of Cloud Computing competencies that teachers have in the context of Education 4.0? To address this question, the objective was to design a valid and reliable instrument to measure these competencies. A literature review and expert collaboration were carried out. For validation, it was submitted to expert judgment and Kendall's W concordance coefficient was calculated; for reliability, a pilot test was carried out with teachers of the Computer Systems Engineering career and the KR20 (Kuder-Richardson) was used. The result was an instrument with 23 items capable of measuring seven competencies identified by the collaborative network Industry 4.0 Node. This instrument contributes as a guideline for educational institutions, bridging the gap between technological progress and formal education.

Keywords: Teaching competencies · Education 4.0 · Educational innovation · Cloud computing · Higher education

1 Introduction

During the last decade the use of technologies related to Industry 4.0 has grown exponentially, the World Economic Forum after applying surveys to business leaders in 25

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countries states that the adoption of technologies such as Cloud Computing, Big Data and E-Commerce are a sustained trend [1], this implies that every day a greater number of jobs require people who have developed competencies aimed at addressing them. The disruptive emergence of various technologies has led to the need to develop new skills and even rethink new careers at the educational level or adapt curricula to meet these new challenges [2], this has been identified by various agencies, such is the case of the Government of the State of Mexico (GEM), one of the 32 states of the country Mexico.

The GEM, with the vision of preparing its higher education students in cutting-edge technologies, formed a collaborative network called Industry 4.0 Node composed of teachers and researchers specialists of Higher Education Institutions (HEI) of state control that offer undergraduate and graduate academic programs with profile in these technologies, this network aims to determine through a structured methodology, the competencies aligned to Industry 4. 0 that are required in a local, national and global context to implement them in the curricula of these HEIs [3], this implementation brings with it several challenges, one of them is education 4.0.

1.1 Education 4.0

It arises in response to the challenges presented by the disruptive innovations of the Industrial 4.0 [4], it is an education characterized by the use of digital technology in the process of multiple and flexible learning independent of time and place [5–7]. The use of Information and Communication Technologies (ICT) allows students to learn on the move through blended and virtual learning [8]. Learning is built around students in terms of where and how to learn and the tracking of their performance is done through data-driven personalization [5], in other words, education 4.0 redefines the educational landscape by placing the learner at the center of the ecosystem and shifting the focus from teaching to active learning [9].

Likewise, education 4.0 produced a new way of solving problems and new methods of thinking [6], this paradigm shift allows the creation of collaborative networks, in which teachers assume the role of learning facilitators [5], which implies on the part of teachers a great commitment so that they also develop certain competencies, this is important because they are responsible for the training of future generations [10], therefore, the teacher of education 4.0 has to be a facilitator, possess soft skills, have a human sense and must manage the new technology [11].

The challenge of education 4.0 in universities is that these competencies go beyond digital literacy, exerting on teachers and the school an increase in the expectations that society places on them [12]. Regarding the mastery of emerging technologies, some universities have taken significant steps in this direction, for example, Wester Sydney University, in 2017 published some guidance on its curricular reform, projected advances in alternative credentials oriented to future work and new curricula [13].

Following this inertia, the Industry 4.0 Node, in order to impact the curricula of its institutions, after an analysis in economic units at the State of Mexico, national and international level, identified 15 Industry 4.0 technologies, the first of these technologies is Cloud Computing (CC) [3], which is the focus of this work.

1.2 Cloud Computing

There is currently no single definition for CC as there are variations depending on the services and applications, which can range from educational to business [14], however the most widely used is the one outlined by the National Institute of Standards and Technology "NIST" which states that CC is a model that allows ubiquitous, convenient and personalized access to a set of computing resources that can be configured according to the need or demand of the user, among which are: applications, networks, servers and storage. Differentiating three service models: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [15].

CC, can be seen as a group of interconnected computers where there is a wide range of users with different requirements for access to applications and data provided from anywhere, be these applications information or storage space, such as Dropbox or Google Drive [16, 17]. This has caused it to become a very popular and required tool within organizations to manage ICT workloads [18] allowing the use of applications or software without the need to know technical details, offering in turn the possibility of implementing large-scale projects without having to rely on qualified personnel or infrastructure experts [19], with variable costs depending on what is needed at a given time.

CC is also being widely required in the educational field and with great force due to the Covid-19 pandemic contingency, since it allows improving organizational efficiency [20], increasing collaborative work favoring not only learning, but also research, giving students access to knowledge efficiently and at a lower cost, being able to provide a wide range of benefits by offering academic resources, high-performance computing services, a large amount of storage, research applications and various tools for use in favor of learning [21], for this reason, several institutions are migrating from the classic e-learning platforms to the tools offered by CC, providing a more unified user experience [14], offering quality education even in remote or distant areas that have inadequate and inefficient infrastructure [22].

After the identification of technologies as CC, the Industry 4.0 Node used a three-phase methodology to generate a catalog of competencies that contemplated each of them, the institutions of the Node particularly decide which of these 15 technologies they will implement, in the case of the Tecnológico de Estudios Superiores de Chalco (TESCHA), the possibility of implementing a specialty focused on CC technology was evaluated and that is where the question arises: How can we diagnose the level of competence that teachers have in this technology in the context of Education 4.0? To address this question, the objective was to design a validated instrument to measure CC competencies defined by the Industry 4.0 Node in order to perform a diagnosis in higher education institutions that want to implement them.

The structure of this work includes the topic of education 4.0 and CC, the methodology followed for the design and validation of the instrument, the results obtained after the expert judgment and the pilot test, the link to the questionnaire and finally the conclusions with the projections of possible future work such as the application of the instrument in other higher education institutions are presented.

2 Methodology

The type of study was instrumental, according to Montero and León [23], it consists of the development of tests and devices, including their design and adaptation, as well as the study and analysis of their psychometric properties, in this case the CC competencies diagnostic questionnaire. The construction of the instrument was carried out between the months of February-April 2021 and applied in a public institution in the State of Mexico. It was developed in four stages: analysis of the CC competencies of the Industry 4.0 Node, literature review, then content validation by expert judgment, and finally a pilot test was applied.

First, a questionnaire was designed based on the CC competencies defined by the Industry 4.0 Node [3]. The literature was reviewed in search of other instruments related to cloud computing, analyzing five of these. Two of these were focused on cloud computing usage [24, 25], two on cloud computing adoption [22, 26] and one on the level of readiness to migrate to cloud computing [27]. All of these instruments used a Likert scale. In addition each one went through a validation and reliability process among which are, test retest, piloting, Crombach's Alpha. After this, the questionnaire was drafted in collaboration with two experts in Information and Computer Technologies, one from Chile and the other from Mexico. For validation, expert judgment was used, which is defined as an informed opinion of people with experience in the subject, who are recognized by others as qualified to provide information, evidence, judgments and evaluations [28]. Four experts participated and the results were statistically analyzed using Kendall's W coefficient of concordance, which attempts to provide the degree of agreement between various ranks of n objects or individuals [29].

A pilot test was also applied to check the reliability of the instrument [30] using the KR20 - Kuder Richardson. The pilot test involved teachers from TESCHA, a public institution located in the east of the State of Mexico, which is part of the Industry 4.0 Node, the sample was non-probabilistic, by convenience, where teachers of Computer Systems Engineering who meet the characteristics of the target population (n = 17), 5 women and 12 men, participated by invitation. Of the total, (n = 8) Computer Systems Engineers, (n = 2) Masters in Computer Science, (n = 2) Chemical Engineers, (n = 1) Electronics Engineer, (n = 1) Telematics Engineer, (n = 1) Master of Science in Energy Systems Engineering, (n = 1) Master in Information Technology and (n = 1) Bachelor in Computer Science and Systems Development.

3 Results and Discussion

Initially, the CC Competencies Diagnosis instrument was composed of 21 items covering 7 competencies (Table 1). After the experts' evaluation, Kendall's W coefficient of concordance was calculated, whose statistic showed a significance of 0.02 and a concordance among experts of 0.548, so it was considered that the items with a high agreement among the judges were maintained. The experts' observations regarding the relevance, coherence, clarity and pertinence of the items were also reviewed in order to make the suggested corrections, which added two items to the instrument, specifically in the competency Apply a language to solve problems for mobile devices.

Table 1. Items by competence (first version)

Competence	Items
Uses development tools for web and mobile applications, data and client/server communications	1–3
Apply the syntax of a language for mobile and web applications	4–6
Develop embedded systems that enable automatic control and data transfer from a mobile device	7–9
Apply a troubleshooting language for mobile devices	10–12
It uses modeling techniques for problem solving	13–15
It uses security services, access, data, with the purpose of integrating information in the cloud in real time	16–18
Implements physical and virtual infrastructure for data, web and file transfer servers	19–21

After taking into account the observations of the expert evaluation, the seven competencies were maintained and the result was an instrument with 23 items. After piloting, the K20 - Kuder Richardson calculation resulted in a reliability index of 0.8425, which is considered adequate.

In terms of content, the instrument measures the following seven CC competencies presented in Table 2 (for reasons of space, only the question stem is included). Each item has four response options, only one of which is correct. This questionnaire can be consulted in full at https://doi.org/10.5281/zenodo.4729221.

Table 2. Items of the CC competence diagnosis instrument (final version)

Cloud computing competencies	Items
1- Uses development tools for web and mobile applications, data and client/server communications	R-1 In CSS it is known as the space outside the element that separates it from the others
	R-2 It is the most widely used software for client/server communication
	R-3 Allows direct management of user data
2- Apply the syntax of a language for mobile and web applications	R-4 Which of the following instructions is correct?
	R-5 This is the basic structure of an HTML5 document
	R-6 This is the basic structure of a form
	R-7 It is the SQL code that connects a web page to a database

(*continued*)

Table 2. (*continued*)

Cloud computing competencies	Items
3- Develop embedded systems that enable automatic control and data transfer from a mobile device	R-8 Bluetooth permission settings for Android
	R-9 Allows you to register a service on the local network
	R-10 Allows autocompletion of a database from the file system
4- Apply a troubleshooting language for mobile devices	R-11 It is the basic structure of a Java program
	R-12 This is the basic structure of a Kotlin program
	R-13 What is the result of the following code?
	R14 What is the result of the following code?
5- It uses modeling techniques for problem solving	R15 Which of the following is a modeling language?
	R-16 Which of the following models is oriented to model processes of a system?
	R-17 With what can an algorithm or process be represented graphically?
6- It uses security services, access, data, with the purpose of integrating information in the cloud in real time	R-18 Which of the following is NOT Cloud Computing?
	R-19 What is one of the main security models implemented by Cloud services?
	R-20 Cloud resources and workloads are exposed to a wide variety of cybersecurity threats, such as:
7- Implements physical and virtual infrastructure for data, web and file transfer servers	R-21 The most basic category of cloud computing services. IT infrastructure (servers, virtual machines, storage, networks, operating systems) is rented from a cloud service provider and paid for on a per-use basis
	R-22 What are the categories (types) of Cloud depending on the role and control exercised by user and provider?
	R-23 In cloud environments the update, both software and hardware, is left to the:

4 Conclusions

The objective was achieved; to design a validated instrument to measure CC competencies in teachers of higher education institutions, becoming a tool to answer the question:

How can we diagnose the level of CC competencies that teachers have in the context of Education 4.0?

This instrument was the result of the collaborative work of researchers from four institutions and used as a basis the collaborative work of the Industry 4.0 Node, made up of higher education institutions of the GEM with educational offerings focused on Industry 4.0, which highlights the usefulness and relevance of this type of collaborative networks.

The results show that the instrument to measure CC competencies is pertinent and presented internal consistency when piloted with different teachers specialized in Computer Systems Engineering. On the other hand, the expert judgment methodology was determinant to consolidate and improve the instrument to measure CC competencies, because the participants demonstrated an academic level and experience in the evaluation of instruments.

The instrument designed measures the seven competencies of one of the 15 Industry 4.0 technologies identified by the Industry 4.0 Node. It is relevant to note that there are other instruments that measure the use, adoption and readiness for migration in CC, however the present instrument focuses on measuring competencies in CC. As future work, it is suggested to design instruments that measure the competencies of the other 14 technologies, and to apply this instrument to the other institutions of this collaborative network and to professors of any institution that wants to measure CC competencies.

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