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Research article

Evaluating an integrated cognitive competencies model to enhance teachers' application of technology in large-scale educational contexts

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ABSTRACT

There are cultural and educational barriers that hinder the adoption of technologies in educational practice. This is mainly owed to how the majority of teachers are still digital immigrants lacking adequate preparation to work in an environment of fast-paced innovation and without the corresponding updates of cognitive technology. In order to mitigate this problem, in this paper we present an alternative framework that intends to increase the effectiveness of technological application in broader educational contexts bringing together three constructs causally relating the domains of Cognitive and Motivational Competencies (CMC) – relating to people; Organisational Institutional Complexity (OIC) – educational systems and Behavioural Intentional Use of Technology (BIUT) relating to adoption of attitudes. Measurement indicators were applied to evaluate each construct in order to better predict teaching behaviour in a broader educational context. The framework evaluation was performed by two focus groups composed of experienced, highly specialised education consultants who assessed the pedagogical, technological, teacher's behaviour and overall institutional/organisational environment involving the proposed alternative solutions. The discussions and results show that participants agreed on the proposed framework's usefulness and its contributions to help teachers mediate the gaps between school and the outside world, all the while considering political and administrative barriers. The evaluators also highlight the structured motivational and self-efficacy aspects that must involve teachers and other stakeholders concerned with adopting a new social action profile for the benefit of collectives. The next work to follow this paper will be a dissemination proposal concerning the Brazilian National Educational Plan, a technological adoption that effectively meets Education's institutional principles in this country.

1. Introduction

The complexity of the contemporary educational process (Morin, 2007), in its traditional form, still poses significant challenges to the development of ideas and strategies for properly applying Information and Communication Technologies (ICT) in sync with pedagogical, technological, and content competencies.

Studies conducted by the Organization for Economic Cooperation and Development (OECD) in the last years have shown that the use of technology has done little to improve academic performance and has mostly consisted of equipping students and classrooms with electronic devices (OECD, 2019). The Global Information Technology Report also posits as technologies are rapidly evolving and can be expected to have a profound impact on our economies and societies, new governance structures will also urgently need to be put in place in order to channel technological forces in ways that bring broad-based gains to societies (Baller et al., 2016).

Despite the considerable workload education professionals already shoulder, we need to understand that new trends and high-speed technological innovation can prove invaluable if educational systems are to fulfil their task of helping students develop the skills and competencies that are necessary in this new, globalised world.

Thus, in view of the importance of pedagogy in teaching and learning practices, and also of the lack of readiness to innovate as evidenced in the aforementioned OECD studies, that Organisation has just announced that their monitoring system will be improved with the implementation of a robust project based on innovative pedagogies, evidence, and concepts, encouraging young people to be more involved and motivated, in keeping with the demands of the 21st century (OECD, 2019). Besides, a new framework and questionnaire will provide a comprehensive strategy to

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register and "identify how teachers, schools and education systems integrate ICT into pedagogical practices and learning environments," (Lorenceau et al., 2019, p.4).

The purpose of this paper is to validate an alternative framework for the pedagogical application of ICT in teaching and learning processes. A disciplined application can add value to and provide better results for said processes. With this direction, the main study aimed to test an artefact model that best represents a strategic path for managing the adoption of technology in the Brazilian educational system, considering the principles and isomorphism of a complex national organisation as well as interactions involving people, organisations, and technology.

Moreover, to ensure that the study would be valid in broader contexts, we examined the variables related to the organisational context of institutional conditions, as well as influencing factors that reinforce teachers' adoption of intentional behaviours related to the use of and support for technology in educational processes.

The challenge lies in the pursuit of a strategic path that answers the question of how to improve the results and effectiveness of teaching and learning processes in order to compensate for the cognitive lag with respect to the speed of technological innovation.

The critical point in this compensatory effort is the teacher's role as a model; teachers are responsible for creating a motivational atmosphere, mainly because their work takes place in the context of a transformational process in an organisational environment that is governed by institutional policies and is also subject to regional policies and cultural differences.

This study combined established references in the education arena with some notions and ways of thinking from administration and management studies, notably from information systems for decision-making, considering that the proposed pedagogical framework aims to solve a real-life problem by employing the same practice that many large companies use successfully. This idea is anchored in the initial concept of Project/Artificial Science – Design Science (DS), according to Simon (1996), to later apply the method that builds this project – Design Science Research (DSR), according to March and Smith (1995); Cantamessa (2003); Hevner et al. (2004); Manson (2006); Järvinen (2007), as seen in Lacerda et al. (2013). For that reason, the methodology employed was Design Science Research (DSR), with focus groups as the evaluative technique.

Despite being somewhat unusual, this association between education and administration and management studies has produced a useful result because we now have a proposal that can be offered for discussion in the academic world as well as to school units of various sizes and from diverse experiential backgrounds. Thus, we believe that in readers' eyes, this difference appears as merit and innovation.

The focus group participants, all of whom were education specialists, were stimulated beforehand with a questionnaire that featured questions indicating the results for the various constructs (hypotheses) that comprise the framework under evaluation. Integrated Cognitive Competencies (ICC) are conceived under three potential success hypotheses, so that the effective use of technology may be replicated in different-sized educational processes. Adaptations and combinations of technological models that are highly valued in the academic literature served as theoretical references, inspiring the new formulations for the project.

The Brazilian educational system was the environment that was referenced in this study, both due to its cultural and demographic complexity and excellent opportunity to gather contributions from education specialists that have been tireless advocates[1] of the national educational system, which has been poorly evaluated in OECD results since the first PISA[2] publications.

[1] Teachers, researchers and educational consultants, participants in the focus groups applied in the evaluative sessions of this project.

[2] PISA: Programme for International Student Assessment: First held in 2000 and repeated every three years by the Organization for Economic Cooperation and Development (OECD) to improve educational policies and outcomes.

This paper is structured as follows. After the Introduction, Section 2 presents conceptual and theoretical references, first describing the complexity of education and the new competencies that are required for social activities, then discussing the concept of ICC and justifying the pedagogical application that is proposed in this study. Section 3 presents the research plan and the hypotheses that comprise the final model, which was built using the DSR methodology. Section 4 details the qualitative process used to evaluate the proposed model and its results. Given that one of this study's goals was to determine whether our model is viable for real-life application, the evaluation was conducted via focus groups, the members of which were transdisciplinary participants who proved invaluable to obtaining our research results. Lastly, Sections 5 and 6 present a discussion and final conclusions, respectively.

The results show that participants agreed on the proposed framework's usefulness and on its contributions to help teachers mediate the gaps between school and the outside world, all the while taking into account political and administrative barriers. The evaluators also highlight the structured motivational and self-efficacy aspects that must involve teachers and other stakeholders concerned with adopting a new social action profile for the benefit of collectives.

The next session addresses the complexity of education in the contemporary world and why it requires us to develop a new social action profile.

2. New competencies for a "new social action profile"

Even in the context of digital contemporary culture, teaching and learning are part of the same process (Freire, 2001, 2003). By the time children go to school to learn how to read and write, most can already proficiently use many technological devices. Meanwhile, teachers, many of whom are digital immigrants, learn about new ICT applications via social networks and are constantly making new discoveries on the Internet (O'bannon & Thomas, 2014).

Conflicts and uncertainties in contemporary social life led us to understand and interpret the epistemology of complexity, as proposed by Morin (2001, 2007, 2009). According to this author, the meaning of his thought comes from interconnections within the mesh of a network, or if we prefer, the 'complexus', which comes from the Latin term meaning 'stitched'. The term has an epistemological and philosophical sense, as it relates to the formation of knowledge through our interconnected social relations' presence in educational processes and in-network life.

Castells (2001) suggests that one way to delve deeply into technology's impacts on educational processes is to begin by understanding the complexity of education. As an example, we may posit the new organisational complexity added to higher education, that is, employability challenges due to commercialisation on the competitive global market; this begs the question of whether it positions itself as a business reality or as a societal aspiration (Sanfor et al., 2015; Pucciarelli and Kaplan, 2016).

Along these lines, Yukawa (2015) recommends preparing for the complexity and the problems arising from the world's adversities by employing learning transformation approaches. On the other hand, Kegan and Lahey (2016) point to an organisation project that aims at the deliberately developmental through a culture in which everybody is supporting personal learning, with a focus on identifying negative personal profile traits and devising strategies for overcoming them.

There are variations of the same fundamentals of complex thinking that Yeyinmen's (2016) approaches in research on how high-performance leaders' practices exceed limits by prioritising nonobvious connections to develop engagements that promote broader, more sustainable relationships.

The various examples that are covered are based on learning new competencies for profiling the actions that are necessary in interconnected life. As Morin points out, much is gained from this perspective; many of humankind's most significant discoveries could not have been accomplished without the revelation of a simplicity hidden behind the

apparent multiplicity and disturbance of phenomena. However, the whole and the parts, order and disorder, and the observer and the observed are parts of the same process. Complex thinking addresses the reality and therefore must be able to understand and act in a multidisciplinary manner (Morin, 2007).

Libâneo (2005) posits that knowledge networks are characterised by the exchange, multiplicity, and complexity of relationships, and by shared meanings. In contemporary life, knowledge, which is networked on a daily basis, is linked to social practices. Libâneo also says that consequently, knowledge arises from a network of relationships in which people share meanings. However, Bruner (2002) points out that during learning processes, science and common sense combine by virtue of the contradiction between scholarly and daily knowledge, the coexistence of which facilitates the formation of the real social subject, as opposed to the one that schools idealise.

We should therefore be concerned about how connective technology has already changed the way we learn, ever since the Internet and its informational and relational smartphone applications through became virtually ubiquitous. Relevant research on two Australian universities, aimed at evaluating the use of technology in higher education, suggests that digital technologies are not 'transforming' the nature of university teaching and learning (Henderson et al., 2017); the authors conclude that the uses, and practices are not the most expressive and exciting that digital technologies could offer and that universities need to continue developing their digital resource repositories, improving reliability and know-how in terms of what to do and how to act concerning improvement.

This fact calls for urgent pedagogical reflection. The notion of 'school' needs to be reconfigured. In addition to the challenges of assimilating innovative technology (a problem that is also faced in other areas of application), pedagogical aspects must be combined with learning content if educational processes are to benefit from proper assimilation (Khoeler and Mishra, 2007; Mouza et al., 2017).

New educational complexities due to the world's digital transformation raise a conceptual idea that underscores critical pedagogy concepts (Giroux, 1994), which the global scholarly community should revise. To put this in question form: Is it not time for educators and policymakers to rethink education beyond schooling? (Collins and Halverson, 2018).

Although Paulo Freire did not experience the digital age, there are convergences between his ideas and our understanding of pedagogical interest in using technology in learning processes. By stating that "Teaching is not transferring knowledge but creating possibilities for its own construction" (Freire, 1996, p. 22), Freire anticipated the current phenomenon of online learning, converging with the idea of prospecting a new means of providing democratic education, based on the concept of education for citizenship. Thus, there is a pedagogical basis for the pertinence of using technology in learning processes, according to a constructivist theory, in which knowledge is the construction of the human being in time and in a dialectical relationship with the object (Freitag, 1989).

Given this complexity and context, the student is a builder and an active participant in the learning process, while the teacher strives to be a mediator and a promoter of the acquisition and recovery of knowledge, thus creating the process but not the product (Weisz, 2002). According to Davis and Sumara (2014, p. 4), this idea remains up to date because complex thinking interrelating several theories "is a new attitude toward studying particular sorts of phenomena that is able to acknowledge the insights of other traditions without trapping itself in absolutes or universals". The Internet as an intelligent learning environment allows its users to form and reformulate some exploratory models, building knowledge through these new step-by-step, cognitive, metacognitive, and epistemological experiences, and practicing and constructing new forms of learning (Tsai, Chin-Chung, 2004; Colchester et al., 2017). This context provides great opportunities for teachers to be well-prepared, thus facilitating their assumption of the important mediator role.

It is evident, however, that the new technological environment gradually changes our social relationships, workplaces, and eventually, our own way of learning in the face of media and technological news. According to Colchester et al. (2017), in this development field, adaptive teaching platforms are being thought of as a response to individual and metacognitive differences in learning.

There has been a significant advancement in terms of the complexity of education with respect to some ideas that were designed for smart cities such as the creative school, which offers individual developmental schedules in place of a standard curriculum; Gomede et al. (2018), posit that self-learning through the promotion of self-study, via several initiatives, provide students of all ages with a menu of courses covering all areas of knowledge; and a virtual world that is populated by virtual teachers who reach students via applications, allow the classroom to break the boundaries of the physical school.

Given the technological speed of innovation, we need to learn how to deal with barriers to change. According to Fullan (1993, p.8), "change is ubiquitous and relentless, forcing itself on us at every turn". The authors also say that the secret to development and growth is eliminating negative forces and taking advantage of positive ones.

In research on barriers that affect the adoption of technology, Ertmer et al. (1999), have already highlighted first and second-order barriers since 1999, that is, both the material, instrumental and technological as well as the cultural ones linked to the pedagogical beliefs of teachers and their own origins and training outside the technological world.

It is not only a matter of attracting massive investments in technology; a promising future also requires a better understanding of how superior performance is combined with societies' willingness to adopt economic, social, and technical changes. This connection is proposed by critical pedagogy, according to which education must reflect a society's aspirations and political needs (Giroux, 1994). Questions like "Where does ICT fit in pedagogical processes?" and "How does ICT affect students' cognitive abilities?" are still open for research (Flogie et al., 2018). Even applications that produce an adequate level of learning retention through artificial mentoring systems in the intelligent learning environment face difficulties adapting not only to learners' knowledge but also to their emotional states and the context in which learning takes place (Herder et al., 2017).

The need for change has become more urgent since the 1990s in response to the world's new globalised action patterns, in which the mobilisation of resources, people, and novel knowledge has become necessary to more efficiently achieve social and economic growth, differentiation, and competitiveness goals (Prahalad and Hamel, 1990).

It is vital to understand that because this behaviour refers to the knowledge associated with the will to do things, it goes beyond transforming knowledge into attitude and explicit action in practice (Zarifian, 2001; Fleury & Fleury, 2001).

According to Levy (2007) and Kerchove (2014), the technological environment for a new competence profile is defined by the collective intelligence that links social ties to knowledge and materialises this relationship in the dimensions of the mind as well as in the network and the world in which we live today. This perception needs to be rapidly assimilated and developed on peril of a cultural abyss caused by how technological innovation seems to be happening at a rate that is light-years ahead of organised, effectively-implemented educational actions.

This new educational complexity must also deal with the transformational advent of digital technology, constant innovations, and new media influencing novel behaviours and challenging the credibility of ethical values. At this point, we appreciate Finland's exemplary attitude, as the country has put educational guidance on fake news in place for children, as evidenced in 'Education — How Finland is fighting fake news in the classroom' (Charlton, 2019).

Another concern about ethical values for the future comes from UNESCO guidelines for their smart cities project, which involves the assignment of educational responsibility for non-compliant conduct from the outset. Despite the lack of a consensus on a universal definition for

'smart city', even in educational principles (Allam and Newman, 2018), it is easy to understand that the inhabitants of such cities will need technological competencies to live in an environment that is interconnected through the Internet of things (Mikusz et al., 2015).

This new profile will delineate a multidisciplinary way of dealing with complexity in line with Morin (1992), as well as understanding the impacts of technology with Castells (2001).

As Collins and Ting write (2014, p. 5), "That is what makes education a unique profession. Teachers are immersed all day in the lives of their students, continually getting to know them, keeping up with changes in their lives at school and at home"; hence, teachers significantly affect students' lives. The competence to think and act critically and ethically to orient students to the future is another unique challenge that contemporary education faces, and which should therefore be included in the model, the research plan, the hypotheses, and the constructs to be evaluated, which will be presented next.

Finally, review in Table 1 a reflective synthesis of the key elements in changing contemporary life affecting the teaching and learning processes and understand the scope of adopting a new social action profile through the integrated cognitive competencies proposed in this study.

The Coronavirus (COVID-19) pandemic raised awareness of the extreme need to set up a new way of living, learning, and teaching with the necessary efficiency and speed, and thus recovering our cultural backwardness. Critical pedagogy points to a new political awareness and global social responsibility. We have already assumed the fear of death and economic losses. Now we must definitively assume the collective conscience for change and innovate leading our Destiny.

3. Research plan, hypotheses, and constructs for evaluation (H1, H2, H3)

3.1. Research plan

In accordance with Dresch et al. (2015), the DSR methodology is used to reach a solution for a specific, real-life problem by arriving at a "solution that can be generalised, so that other researchers in different situations may also make use of the produced knowledge" (p. 68).

In addition, these authors and Hevner et al. (2004) highlight the value of DSR prerequisites, namely rigour and relevance in application, from the point of view of the professionals who is intended should utilise the research, as well as the credibility and reliability of the contributions with respect to a given area's existing knowledge (p. 68), according to the phases presented in Figure 1.

Our research plan adapts the guidelines listed by Dresch et al. (2015), while emphasising the preponderant factors in the execution flow presented in Figure 1, such as:

- The existence of a real problem that allows for an alternative solution, leading to the creation of a new artefact or model for thinking about an issue for which other solutions have already been proposed and nonetheless remains unsolved (Hevner et al., 2004; van den Akker et al., 2006).
- Accuracy in the presentation of theories and arguments that form the basis of the proposed solution (Collins and Bielaczyc, 2004; Myers and Venable, 2014).
- Rigorous evaluative techniques, with focus groups comprised exclusively of participants who are experienced professionals and connoisseurs of the factors that are involved in the studied problem (Kontio et al., 2004; Filep et al., 2018).
- Such a process should provide a mental model for what DSR output looks like (Peffers et al., 2020).
- Findings, with the dissemination of results (Van den Akker et al., 2006).

3.2. Research hypotheses

This study aimed to demonstrate that the efficient adoption of technology in educational processes is the result of a conjunction of factors involving the three sets of contextual conditions gathered in the constructs H1, H2, and H3. They are also called domains and can be understood as a series of causes and effects involving people, technology, and organisations, all of which are interrelated and converge for the intended purpose, as shown in Figure 2.

The primary conditions in this study are described below in H1, H2, and H3. The hypotheses were put forward based on three theoretical models that have already proven effective for the adoption of technology; we adjusted those models or combined with other models. The theories that support H1, H2, and H3 are classics of academic literature in technological, organisational, and institutional adoption, and have been applied in the most diverse set of organisations and situations.

In the case of this research, the Brazilian educational system served as the reference environment because it shares characteristics with a large multinational organisation in terms of its organisational and institutional complexity. The necessary adaptations were made in the elaboration of content for the measurement indicators, while keeping the theoretical structure intact. In H1, Khoeler and Mishra's (2007) technological

Table 1. Key elements reinforcing the understanding of the new social action profile.

Challenged changing factors	Impacts on teaching and learning
Contemporary conflicts and uncertainties.	They are part of the epistemological complexity to be understood and assimilated: (Morin, 1992, 2001, 2007, 2009).
Teaching and learning as part of the same process in interconnected life.	New social practices with communicative technology in real-time. New cognitive and integrated competencies for a new planetary coexistence in constant changes (Morin, 1992).
Cultural delay and overcoming gaps with technology and innovations to be assimilated and managed including fake information and disruptive moral behaviour.	Critical pedagogy defining how society wants to learn and teach (Freire, 2003; Giroux, 1994); overcoming barriers (Tondeur et al., 2017; Flogie et al., 2018; Fullan, 1993).
Self-efficacy, motivation, and ethical vision to human being.	(Bandura et al., 2008; Morin, 2001).
Teachers taking a leading role in guiding and mentoring the educational process: "Teaching is not transferring knowledge but creating possibilities for its own construction" (Freire, 1996, p. 22).	Teachers and students assuming the construction of their own learning in the school and in the networks enabled by the collective intelligence (Levy, 2007; Kerchove, 2014; Freitag, 1989; Weiz, 2002; Tsai, Chin-Chung, 2004; Colchester et al., 2017).
The educational process constantly renewed and fed with innovative technological resources: Creative school, individual developmental schedules, self-learning, and several other initiatives breaking the boundaries of the physical school.	It is time to understand what pedagogy means. The notion of school needs to be reconfigured. Pedagogical aspects must be combined with learning contents and technological applications (Khoeler and Mishra, 2007; Mouza et al., 2017; Gomede et al., 2018, Colchester et al., 2017).

This article presents an alternative proposal for application in a large-scale educational system, which no longer has time to consider long-term progress. The challenge is to implement a model that results in a new social action profile centred on integrated cognitive competencies, combining knowledge with the assimilation of the desire to build and transform reality with actions driven by self-efficacy and antropoethical sense for the benefit of collectives.

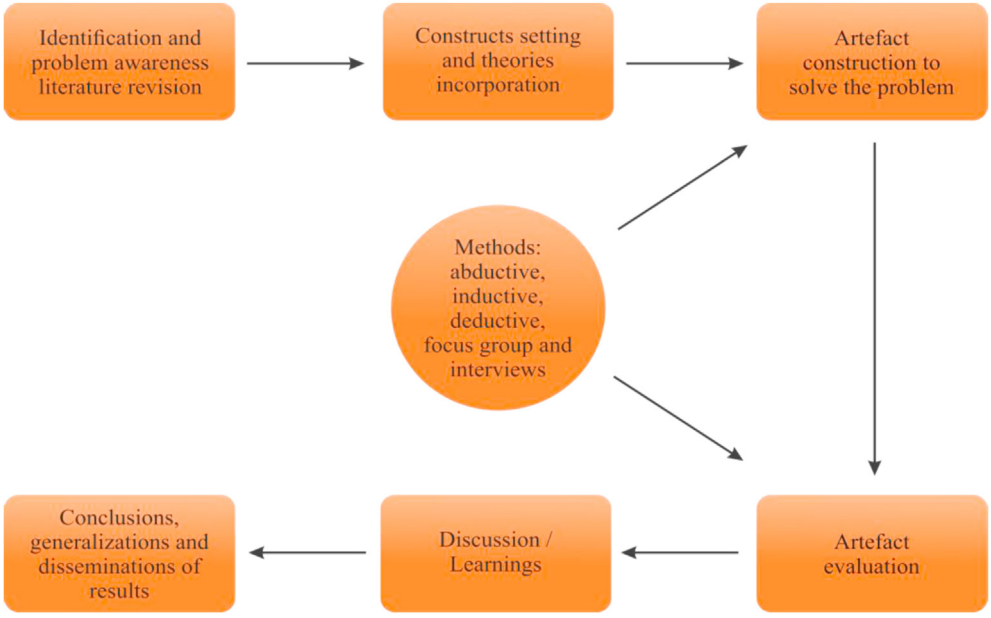

Figure 1. DSR Stages and Methodology. *Note:* adapted from Dresch et al. (2015).

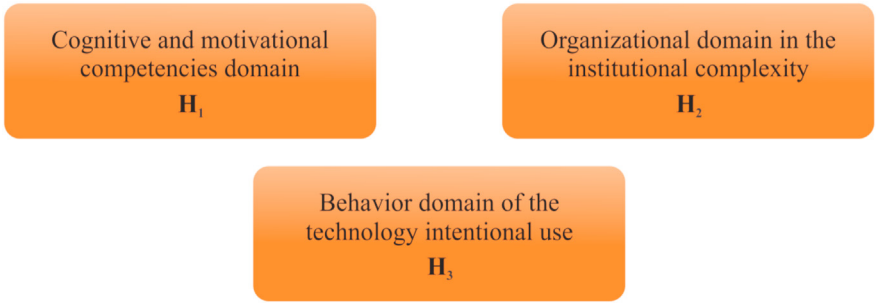

Figure 2. Domains identifying the evaluated project's hypotheses: H1, H2, and H3.

pedagogical content knowledge (TPACK) was made more appropriate through our adaptations, as will be shown in the development.

Following the project design, measurement indicators were developed based on the literature review and some were adapted during the focus group discussions.

The knowledge that teachers acquire and act on is driven by their desire to achieve self-efficacy (the motivational context), which is produced by their own conditions and the personal exercise of self-control. However, this paper raises the following questions for discussion:

- Which integrated cognitive competencies can help increase the effectiveness of technological application in broader educational contexts?
- Do teachers know how to cope with pressure from their near surroundings, such as institutional and organisational conditions?
- How could the combination of H1 and H2 facilitate the acceptance and implementation of technology in educational pedagogical projects?

3.2.1. H1: cognitive and motivational competencies (CMC)

CMC directs teachers and anyone else who is involved in educational processes to mobilise the *competencies* of integrated application (and not merely the knowledge) of course content, associating it with pedagogical concepts and canons, and also with ICT, in line with the educational project at hand.

The H1 measurement indicators come from TPACK theory, that is technological pedagogical content *Knowledge* (H1a, H1b, and H1c), supplemented by a new indicator that is based on Bandura's theory on motivational/self-efficacy (H1d), as shown in Figure 3.

Our first construct, H1, refers to the domain of people who are focused on education with the new 'knowing how to act' outlook and are endowed with ICC, comprising the causal relationships in TPACK theory, which was originally developed by Khoeler and Mishra (2007) and inspired by Lee Shulman (1986), who sees the structure of pedagogical knowledge as the essence of effective learning practices.

In their academically well-established framework, Koehler and Mishra propose that knowledge should be the focus of school subject elements (pedagogical, technological, and content).

The CMC construct (H1) reconfigures the central position that knowledge occupies in the TPACK theory. Based on two contemporary reference parameters, knowledge is repositioned as the competence of responsibly applying 'know how to act', which involves mobilising, integrating, and transferring knowledge, innovation, resources, and skills. It also adds value to an environment that is undergoing fast-paced transformation without necessarily leading to higher levels of competitiveness, as has been seen in large-scale corporate environments (Fleury & Fleury, 2001; Prahalad and Hamel, 1990; Zarifian, 2001). The ICC relate simultaneously to a school subject's field of study, to pedagogy, and to technology itself, as they are "derived from the intellectual capacity followed by knowing how to deal with concepts and theories, knowing

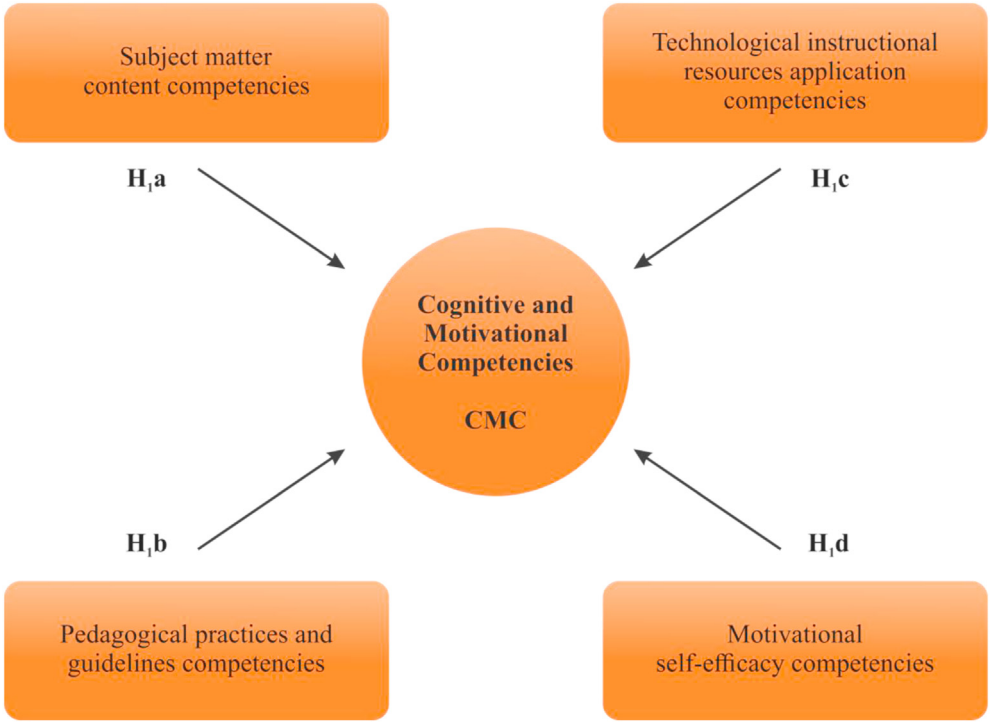

Figure 3. Cognitive and motivational competencies and measurement indicators.

how to generalise, to apply terminologies and classifications, to relate and integrate content" (Resende, 2003, p. 59).

As a significant parameter and conceptual basis, we have introduced the concepts of cause and effect into the construct with respect to teachers' self-efficacy behaviour, in the context of Albert Bandura and his collaborators' social cognitive theory. Thus, the ICC are incremented using behavioural analysis that helps teachers overcome obstacles and ferments the desire to develop eager-to-learn attitudes regarding technological instructional resources and their adoption in support of their teaching activities.

The CMC approach also considers Bandura's (2008) reflections on how these challenges involve cultivating and adopting research attitudes that are eager to produce knowledge based on experience and teaching practices, thus contributing to the accumulation of new educational knowledge. This process involves perception, thinking about information, learning, and regulating self-efficacy in the epistemological creation of each teacher's own practice and improved, organising, and executing courses of action that are aimed at a performance. Cognitive social theory supports this pedagogical proposal because in its definition of agency, "People are self-organised, proactive, self-regulating, and self-reflective, contributing to the circumstances of their lives, and they are not just products of these conditions" (Bandura et al., 2008, p. 15).

3.2.2. H2: organisational and institutional complexity (OIC)

Teaching activities generate more expressive results under favourable conditions in the context of institutional and organisational complexity. To consolidate awareness and the tools for a holistic design in approaching the research problem, we analysed the literature for successful applications of technology adoption/acceptance models. With some room for adaptation, we also looked for complementary models to help complete the composition of our ICC constructs.

Thus, our model combines two theoretical references that are well-established in the academic literature for the adoption of technology in various sectors and business organisations, but with measurement indicators that are entirely focused on the reality of the Brazilian educational systems organisational and institutional conditions.

The technology, organisation environment (TOE) framework that Tornatzky and Fleischer developed in 1990 consists of three contexts that influence the adoption of innovation in a company's internal or external environments. Combined with institutional theory (IT) (Christensen and Scott, 1995; Scott, 2001), TOE was used in this study as a conceptual reference, bearing in mind that the large environment being studied (the Brazilian educational system) presents significant, peculiar factors pertaining to how structure and organisational actions are conceived.

According to Christensen and Scott (1995), decisions are not guided purely by rational efficiency goals, but also by the social and cultural factors that lead to processes that are required to have the same form in other sectors in which the same conditions exist. Institutional environments constitute significant factors that affect organisational structure, therefore action that is in keeping with that is required.

As an example, Scott (2015) posits that higher education in today's context includes a more diverse range of organisational forms, depending on certain specific objectives.

Hawley (1968) in DiMaggio and Powell (2000) argues that an isomorphic process as a constraining process that forces one unit in a population to resemble other units that face the same set of environmental conditions; such processes are important features of the considerably large Brazilian education system, which spreads across the country's five regions. They can have the same effect in the educational environment.

The Brazilian educational system (which was taken as a case study) is governed by a national constitutional contract; therefore, the educational environment is expected to become isomorphic due to federative entities interdependencies and exchanges, both among themselves and between each entity and the federal government (Meyer & Rowan, 1977).

In this scenario, the educational system is subject to political and demographic influences, a pressing need to make up for delays, and national plans governed by the country's constitution, which, unfortunately, have not been adequately fulfilled due to ineffective and not-quite-uniform management. In line with these system goals, the measurement indicators incorporate elements that are related to institutional isomorphism as predictors of success in the adoption of ICT in Brazilian education.

In terms of institutional complexity, the organisational domain is the construct that gathers the measurement indicators that define the actions that are necessary to execute and achieve results in the organisational and institutional context of the Brazilian educational system. These

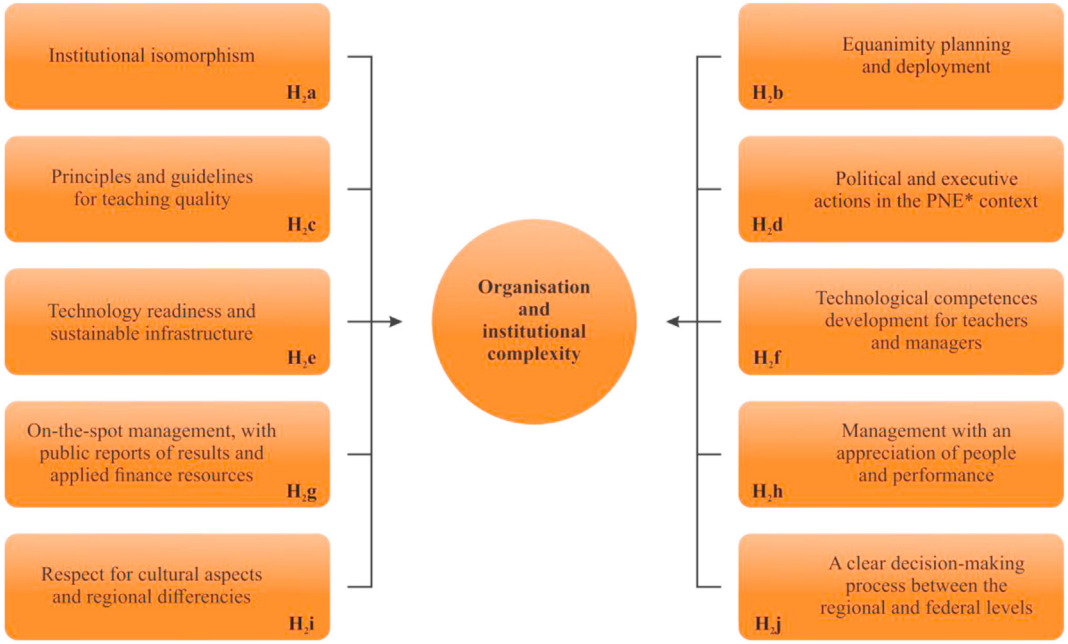

Figure 4. Organization in the context of the Institutional Complexity, and measurement indicators. *Note:* *PNE – Nacional Education Plan: constitutional instrument validated by the Brazilian National Congress for a 10-year compliance extension.

indicators, which were evaluated by the focus groups, underwent some content or wording changes during the process of reaching a consensus within the group. For example, in H2c, the indicator that was initially described as Teaching quality rules became 'Principles and guidelines' in the post-discussion version (see Figure 4).

3.2.3. H3: behavioural intentional use of technology (BIUT)

The teaching environment, which incorporates social relationships, family, co-workers, students, etc. influences or reinforces the adoption of intentional behaviours regarding the use of technology and related instructional support in educational processes. Under favourable conditions, the work environment may generate performance expectations and effort expectancy.

This domain employs adaptations of UTAUT – Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), and UTAUT 2 is one of the best-known adoption models, as well as TAM – Technology Acceptance Model (Davis, 1985) and TPB – Theory of Planned Behaviour (Ajzen, 2011).

There are countless reports of successful UTAUT application experiences regarding evaluating acceptance behaviours and the use of innovations such as mobile banking, comparisons between different countries' acceptance processes, third generation mobile telephony, wireless network technologies, mobile banking systems, and notably, mobile-commerce, mostly due to advantages such as ubiquity and immediacy (Anderson and Schwager, 2004; Carlsson et al., 2006; Dwivedi et al., 2019; In et al., 2011; Min et al., 2008; Palau-Saumell et al., 2019; Williams et al., 2015). This theory is regarded as important work, and it integrates eight major theories. It considers performance expectancy, effort expectancy, social influence, and facilitating conditions as measurement indicators that exert significant impacts on users.

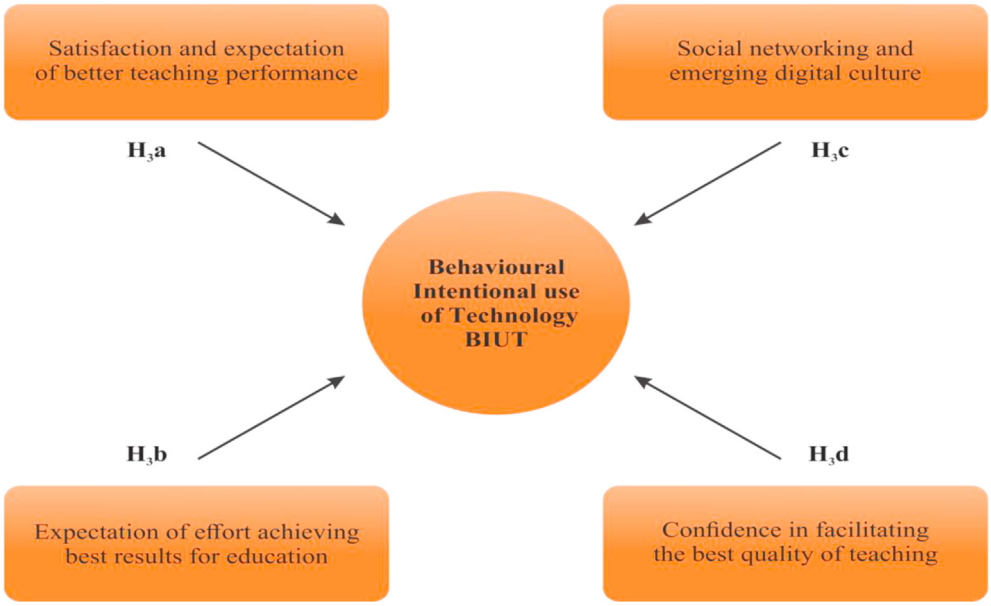

Figure 5. Behavioural Intentional Use of Technology and measurement indicators.

Table 2. Constructs, adaptations, and theoretical sources.

Construct	Adapted conceptual variables	Authors
H1 CMC	Technological pedagogical content **knowledge** TPACK	Koehler and Mishra (2007)
	Technological pedagogical content **competencies**	Wiziack and Santos (2019)
	Motivational self-efficacy competencies	Bandura (1977)
H2 OIC	Institutional theory; H2a, H2b, H2c	
	Technology – organisation – environment, H2d, H2e, H2f, H2g, H2h, H2i, H2j	Tornatzky and Fleischer (1990)
H3 BIUT	Unified theory of acceptance and use of technology; H3a, H3b, H3c, H3d	Venkatesh et al. (2003)

An extension of this theory, the UTAUT 2 by Venkatesh et al. (2012) includes measurement indicators like hedonic motivations, price and habit, explaining 74% of variance of intention of behaviour and 52% of behaviour of use; it is considered effective for consumption situations (Herrero Crespo et al., 2017; Faria et al., 2014; Ramírez-Correa et al., 2019).

Teachers feel they are doing collaborative work when they share their difficulties as well as what they have learned. This attitude motivates them to take pleasure in overcoming obstacles together, with the overarching goal of helping students perform better.

Hedonic motivation (present in UTAUT 2) is, therefore, a function of the positive results that are obtained collectively, combining satisfaction with improved teaching performance and confidence in facilitating the best quality of teaching, as shown in Figure 5.

4. Method: building the framework to solve the problem

Our framework integrates people, organisations, and technology. It employs CMC to address the contemporary reality of how teaching should be transformed by digital culture. The CMC in our proposed framework consider the teacher's role to be the most strategically-positioned for enhancing the application of technology in large-scale educational contexts.

The first step was to reconfigure the TPACK-inspired vision (Khoeler and Mishra, 2007) by changing knowledge to *competencies* and including self-efficacy as a perspective and as a motivator for teachers' actions, as seen in Bandura (1977).

The next stage was to integrate the CMC construct in our proposed framework, together with OIC and BIUT. The causal relations among the three dimensions that were studied will constitute the determinant success factor with respect to the framework's adoption.

Finally, the measurement indicators that we have applied to evaluate each construct in order to better predict teaching behavior in a broader context, under the influence of the national education system's organisational and institutional forces, also came from the referenced National Education System, as well as IT, TOE, and UTAUT theories, as shown in Table 2 (see Figure 6).

With these adaptations, we considered DSR – Design Science Research in the methodological scenario going through the following phases:

4.1. Methodological scenario and goals

DSR was adopted due to its applicability in decision information systems, in accordance with the guidelines proposed in the studies and through the observations of several reputable authors who were involved in the development of DSR and in the formulation of its key concepts and practices (Baskerville et al., 2009; Hevner et al., 2004; Peffers et al., 2007; Van Aken and Berends, 2018).

In this sense, our main concern in the present study is a method for addressing the matter artificially (Simon, 1996), so as to lead to a design that can solve a worrying, known problem in educational management.

Although DSR is relatively recent in terms of practice, with open, developing criteria and forms of evaluation, it is considered an established method in the literature (Prat et al., 2014). These authors argue that in terms of information systems research, DSR aims to assist with creating models, which are also called artefacts, to solve practical issues. Although it has only recently been put to use and the applicability criteria are fragmented and incomplete, the authors have contributed by offering an inductive study of 26 articles published in the last five years.

In their 2014 study, they present a holistic view of DSR evaluation criteria and generic methods drawing from general systems theory and thus considering its object as an organised whole in which the parts are related, which generates emerging properties and has certain objectives.

Hevner et al. (2004) conducted an extensive methodological study focused on the application of DSR to information systems research issues; they have verified the existence of conceptual similarities that provide ample support for the applicability of our research. In the comparative summary that is presented in Table 3, it is clear that the organisational and behavioural paradigms do involve the studied process's environment (the educational system) and, most importantly, that the results depend on the performance and motivation of people who are subjected to an organisational model as well as on an institutional structure that is subjected to a management system.

Design science focuses on the creation of artificial systems and solving issues through the construction and evaluation of artefacts that represent the needs and solutions that have been identified with regard to the studied business and real-life problems (Barab and Squire, 2004; Hevner et al., 2004; Van den Akker et al., 2006). According to Barab and Squire (2004), it is important to understand that "Cognition is not a thing located within the individual thinker but is a process that is distributed across the knower, the environment in which knowing occurs, and the activity in which the learner participates" (p. 2).

In view of justifying the set of methodological activities that were employed in this study, certain parameters served as guiding principles for the step-by-step development of a subsequent planning process built upon the central hypotheses evaluated in the **ICC** model. Those parameters are:

- The school's social and institutional challenges in view of teachers' reinterpretation and preparation through curricular renewal.
- Holistic, systematic problem-solving, considering the following dimensions: objective, environment, structure, activity, and evolution.
- The re-establishment of convergent concepts for the application of a *cyborg pedagogy* (Haraway, 2013)[3] that best fits today's education as well as the future's, considering the educational cycles and their respective specificities for the coexistence of human and non-human resources in a state of constant knowledge update.
- The need to act in a transdisciplinary, democratic, and participatory way, ensuring the visibility of all designed dimensions (people, organisations, and technology), so that the knowledge that is obtained by applying the proposed model can be of practical use in the educational system.

[3] Haraway (1991), see in Garoian and Gaudelius (2001), defines the cyborg as "a hybrid of machine and organism, a creature of social reality as well as a creature of fiction" (p.149).In this line of thought, we only defend, not the metaphor, but the real practice that the contemporary and future humans should teach and learn mediated by a reconfigured innovative pedagogy that incorporates the technology devices in education.

Figure 6. Research stages.

Table 3. Applicability of DSR to ICC according to Hevner et al.'s (2004) comparison of conceptual frameworks in DS information systems research (adapted and translated by the authors).

Hevner et al. (2004) and decision information systems

Applicability in information systems	DSR applicability in ICC
1. Most research includes questions about behavioural sciences and Design Science.	1. Integrated cognitive competencies refer to people's knowledge, abilities, and attitudes, while one of those three dimensions is researched.
2. The behavioural science paradigm seeks to develop and verify theories that explain or prevent certain human and organisational behaviours.	2. The dimension of the ICC is based on Albert Bandura's cognitive social theory and the pedagogical concepts of Paulo Freire, Lee Schulman, and others (as well as behaviour theories).
3.The design science paradigm seeks to extend the boundaries of human and organisational capacities, thus creating new, innovative artefacts.	3 The proposed Artefact considers human capacities and motivations that are aligned with the structures and technological resources that have been experimentally applied in an organisational environment.
4. Both paradigms are fundamental in the IS, as this subject is in the confluence between people, organisations, and technology.[1]	4. The construction and implementation of this project will mobilise a large educational management system involving individuals, organisations, and technology.

The main study aims to test an artifact model that best represents a strategic path to manage the adoption of technology in the Brazilian educational system, considering the principles and isomorphism of a highly complex national organization.

People, Organisations, and technology

[1]Davis and Olson (1985) cited in Hevner et al. (2004).

An awareness of the relevant problems and their conceptual specificities has led us to propose a strategic path, which was discussed and validated by education specialists in focus groups. The resultant conclusions and contributions allowed us to postulate a possible means of properly adopting technology in learning processes in broader educational systems, in a manner that is both planned and institutionalised, with the potential for efficacy, as endorsed by our model.

4.2. ICC – the Design Science framework

Finally, we arrived at the framework itself, which consists of three sets of contextual conditions gathered in the constructs H1, H2, and H3. Those domains are rooted in cause-and-effect situations involving interrelated people, organisation, and technology that converge to serve the intended purpose.

The central construct, H1–ICC, combines four indicators that are intrinsically linked to people, especially teachers, who play a key role by constituting the meaning and reason for the existence of H1, the measurement variables of which are mutually dependent. On the other hand, H2 is comprised of institutional and organisational conditions, using correlated indicators, though not maintaining a rigid interdependence relationship between them. With its five associated indicators, the latent variable H3 represents the best condition for acceptance and engagement in the project of adopting technology in education.

The relationships that the three constructs have created and projected amongst themselves are, by abduction and induction, considered to be part of an information system for the configuration of the intended project.

At this stage of methodological application, it is crucial to reinforce the understanding that the framework under evaluation is an *alternative*

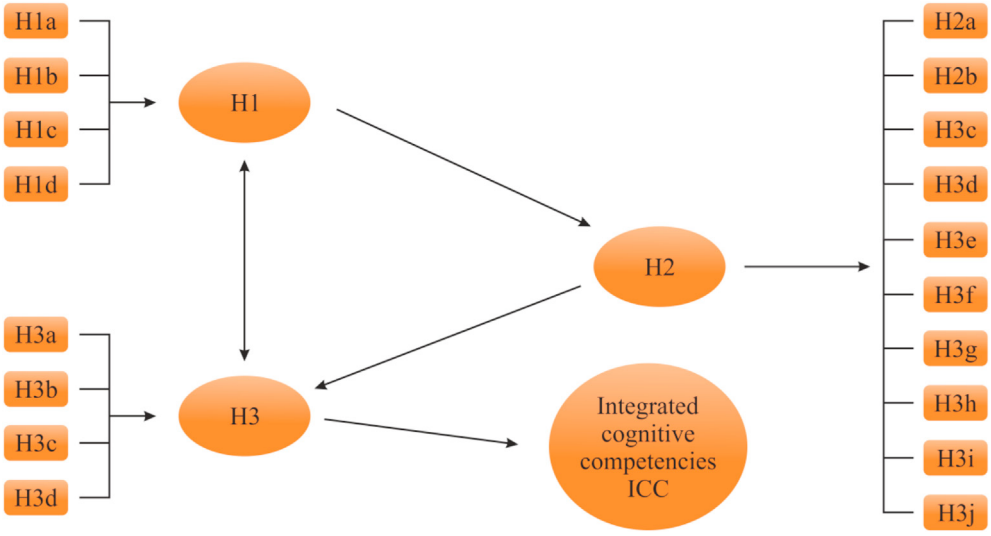

Figure 7. The ICC framework assessed as an alternative project for educational systems.

project that offers a solution to a *real-life problem*. However, there are always other variables to consider.

Figure 7 depicts the set of measurement variables, supported by theoretical references and practical observations, that were presented as propositions to the two focal groups; the specialists commented on them and hence contributed to a final solution to the problem.

4.3. Structural framework – the ICC assessment process

The goal of this section is to demonstrate the criteria that were applied in this study and present a comprehensive report that shows how the work was rigorously and empirically validated by means of two focus groups and three individual interviews, to a total of 25 qualitative evaluation participants (see Additional Information).

The project consists of designing an alternative means of implementing an effective educational management system that is understood as a set of cause-and-effect relationships between people, organisations, and technology. All three elements are interrelated, converging in some way towards the success of the planned adoption of a model for incorporating technology into the Brazilian educational system. The evaluators discussed and approved this, and it also finds support in scholarly references and research through the process that will be described next.

4.3.1. The focal group technique

The use of two focus groups[4], the members of which were education specialists with diverse experiences, allowed for higher critical quality in the designing stage. The measurement variables that were extracted from the theoretical frameworks were used to support the study and raised awareness of possible difficulties. Based on the experiences that were gathered, we diversified the actions to be discussed.

Focus groups originated in the field of clinical psychology as a tool to help researchers understand how emotions, associations, and motivations influence human behaviour. Later contributions led to the use of focus groups in marketing research to gauge consumers' perceptions of prices, products, and brands, as well as their reactions to advertisements and other things related to consumer behaviour, and this use of focus groups continues to this day (Stewart and Shamdasani, 2014).

The marketing community's adoption of the focus group technique has already supported many projects, prevented commercial disasters, and improved results through a better understanding of consumers' attitudes (Langford and McDonagh, 2003).

According to Paez et al. (2017), changes that can be traced in education history as well as changes in the social context influence how people remember past events, even in recent times. Biases can sometimes determine what is historically significant for those who are in power at a particular time. In our research, the focus group participants were experienced professionals with high moral autonomy; they are also fully capable of dealing with the conflicting situations in the recent history of Brazilian education, even as presented in controversial educational texts.

The specialists discussed and guaranteed the understanding and exploration of the contents of the research hypotheses, based on the corresponding theoretical references. We also administered an ancillary process of registering all the participants' proffered data and contributions to perform a cross-check before finalising the exercise.

Previous preparation involved a reflective paper on the concepts used to stimulate interaction among focus group participants. This helped ensure additional corrective contributions to the project under evaluation. The focus group played an active role in reformulating the hypotheses that were considered in the final construction of the model.

We have highlighted these significant contributions in the Results section. This approach demonstrates that in line with its underlying philosophy, DSR was a learning process through the act of constructing (Vaishnavi and Kuschler, 2008).

4.3.2. The process

The three domains (H1, H2, and H3) consist of variables that are not directly observed (latent) but which can be evaluated by their indicators, using the evaluators' perceptions and knowledge (Vilares and Coelho, 2011).

Thus, regarding the H1 construct (cognitive and motivational competencies), the evaluators agreed with the explanatory power of the indicators (measurement variables) H1a, H1b, H1c and H1d to form the H1 hypothesis. Therefore, by abduction if these indicators explain H1, they are correct. This finding was also validated for the other variables, H2 and H3, and their respective indicators or measurement variables.

The evaluation of the framework (H1 + H2 + H3) followed the same process. The focus group participants evaluated each latent variable (H1, H2, and H3) with regard to its level of contribution to the desired result;

[4] *Focus Group 1:* GEPEM - Moral Education Studies and Research Group, which includes education researchers and consultants from UNESP - Rio Claro State University and UNICAMP - Campinas State University - São Paulo State - Brazil (17 participants). *Focus Group 2*: Municipal Public Primary School of Valinhos, state of São Paulo: five public school coordinators in the municipality (43 K-12 schools).

they also suggested corrections to the statements used in the measurement indicators, when necessary.

The qualitative evaluation process, which was conducted via focus groups and interviews with specialists was performed in four sequential steps, as described in the next section.

4.3.3. Model evaluation stages

As preliminary preparation, the evaluators received a questionnaire one week before the focus groups meetings. The questionnaire featured statements about the variables and their indicators, and it was intended that the participants should read, respond, and engage in prior reflection. They were asked to evaluate their level of agreement on a 4-point Likert scale: *I disagree*, *I partially agree, I agree*, *I strongly agree.*

- During the first stage of the evaluation meeting, the participants discussed questions that were classified as "partially agree" or "disagree". None of the issues to be addressed were excluded, and there were no suggested wording changes or content corrections. The observations that were collected were considered in the formulation of the measurement indicators of our model's hypotheses, as will be detailed next, in Section 5.
- In the second round, after the conceptual discussions, the evaluators initially assigned a score ranging from 1 to 4 (lowest to highest) to each construct's measurement indicators as a means of evaluating the respective contribution forces in the latent domain or in the explained variable. It was a complementary way to express each measurement indicator's weight in relation to each latent variable's quantitative importance.
- In the third round, the focus groups evaluated the contributory force of each construct (H1, H2, and H3) regarding the formation of the desired structural model. They applied the same quantitative approach, with the weight value of each latent variable, in the final framework.
- In the last round, the participants made their final contributions to the conclusion. Finally,[5] two specialists from a private school in the areas of computer laboratory and robotics and the public Municipal Directorate of Elementary Education of the city of Valinhos – SP participated in in-depth interviews in which the entire research process was reviewed and commented. It was also an opportunity for clarifications and where we could receive suggestions of pedagogical aspects to be considered involving technological applications, difficulties, and family engagement. They also discussed teachers' lack of competencies and development of plans to adopt technological tools.

5. Assessment: results and discussion

H1 – CMC was elected to carry the highest weight in the final framework, bearing in mind the crucial roles that self-efficacy and teacher motivation play in this complex mission.

Moreover, competencies in the use of technological tools associated with the correct pedagogical application to teaching represent the heart of Khoeler and Mishra's well-established TPACK theory, which has repeatedly been proven reliable through steadily positive academic outcomes in several countries throughout its 17 years of existence. It should be noted that in the over 100 publications on TPACK that were perused during this study, we have found no construct-specific adaptations, as we propose in this paper.

ICC consider the concept of competence instead of knowledge and incorporate motivation and self-efficacy into the construct. Koehler et al. (2013, p.14) have recognised, and stated this, and recommended new paths, as follows:

> teachers operate in diverse contexts of teaching and learning and teaching with technology is a complex, ill-structured task. We propose that understanding approaches to successful technology integration requires educators to develop new ways of comprehending and accommodating this complexity.

The authors also state in this text that the application of the framework has to be thought of as the best way that the teacher has to teach the intended content. Just as an example, a practical application of TPACK was a *conceptualization for the learning environment* platform called 'MyCloud'. The authors report that the model integrated pedagogy and content taught through mobile-cloud the integration, showing good usability as perceived by students (Wong et al., 2014).

This domain in our research is valid only by means of the strength of its four measurement indicators, which maintain correlations between them and point, as a causal factor, to an explanation and confirmation of H1.

For this competence to be valid, predictive indicators should be explicit and thus establish a causal relationship for the formation of an integrated cognitive competence. In addition to meeting with the evaluators' strong acceptance, all measurement indicators are important concepts in the academic literature, supported mainly by Koehler and Mishra (2007), Shulman (1986) and Bandura (2008), as shown in Table 4.

The evaluators confirmed construct H1 as having the greatest strength and weight in terms of importance for the structural model (then) under development, as will be shown in the statistical analysis (see 5.1).

In the composition of the ICC, a key discussion topic was an essential aspect of teaching life, namely structured motivation, a concept that points to the environment in which the teacher lives and the challenges he/she faces regarding constructing and transmitting knowledge (Becker, 1992). Structured motivation is the result of the set of conditions pertaining to the teacher, the student, the family, and the school, and can contribute to or hinder the achievement of the desired goals.

These factors require education subjects (teachers, students etc.) to reflect on the reality of their respective environments, "kneeling on this and, who knows, being able to correct, compensate, replace, improve, anticipate, enrich and give meaning to what was done" (Macedo, 1994, p. 32). Many studies, however, point to self-efficacy as the human capacity of being motivated to overcome obstacles.

Bandura et al. (2008, p. 100) points out that people are endowed with distinctive capabilities that define them as humans, primarily planning alternative strategies, anticipating, and learning from experiences:

> Human beings who use their symbolic abilities can extract meaning from their environment, create action scripts, solve problems cognitively, defend lines of action in advance, acquire new knowledge through reflective thoughts and communicate with others in space and time.

The conjunction of interactions between people and context is a key idea in social cognitive theory (Bandura, 1977, 2001) and considering the personal factors of teachers' lives, combined with their performance, given the complexity of the educational system, we have acknowledged the importance of investigating to what extent teachers' self-efficacy affects and is in turn impacted by the school's contextual conditions. To this end, we have included predictive indicators of behaviour that is causally related to these situations, which are presented in the construct H1 and in Table 4.

In the *H2 – OIC construct,* isomorphism dictates that common core factors of Brazilian culture must be prioritised, such as discipline with regard to implementation and the assurance of equanimous resources for all public education units in the country, in line with a plan and responsibilities that are assigned and guaranteed in its execution.

The evaluators concluded that the sentiment and attitude of loyalty and commitment to a project of this magnitude would be driven by

[5] Individual interviews: The Municipal Directorate of Elementary Education of the city of Valinhos – SP presenting the organisation and the main difficulties related to the pedagogical applying of technology.

Table 4. Cognitive and motivational competencies and indicators.

Latent variable	CMC	Indicators definition
H1	H1a	Content knowledge is essential for integrated learning and for the choice of pedagogical resources
	H1b	Conceptual and practical mastery of the pedagogical component of learning
	H1c	Mastery of instructional and computational technological resources with a pedagogical meaning
	H1d	Competencies related to the self as an agent motivated by self-efficacy

Table 5. Organisational and institutional complexity indicators.

Latent Variable	OIC	Indicators definition
H2	H2a	*Institutional isomorphism ensuring participatory management by observing regional needs and potentialities when applying resources*
	H2b	*Principles and guidelines for quality of education*
	H2c	Planning and implementation in an equitable manner ensuring credibility
	H2d	Political and executive actions in accordance with the NEP, guaranteed by civil accountability of the leading managers
	H2e	Technological readiness and sustainable infrastructure
	H2f	Support for the development of technological competencies of teachers and administrative staff
	H2g	On-the-spot management with the disclosure of targets, results, and use of financial resources in a transparent manner through a public progress report
	H2h	*Management with appreciation for people and performance, adopting parameters in line with federal and local responsibilities and realities*
	H2i	Respect for cultural aspects and regional differences
	H2j	*Clear and shared decision-making processes between the local and federal administrative levels.*

balanced, effective management, with fair appreciation and treatment of people regarding their results and performance (H2h). In sum, people-appreciative management is a critical success factor (Glover et al., 2014).

It should be noted that the indicator H2j (clear decision-making process shared between the regional and federal levels) complements this very close causal relationship between communication, trust, and commitment, all of which are valued by the participants of the focus groups and by those individually interviewed with a great deal of reflection on the subject of intentional behaviours of acceptance and use of technology.

With regard to the organisational aspect, the evaluation groups acknowledged the extreme difficulty in executing such a complex project. However, they asserted that the measurement indicators being evaluated, as well as the strength of the H2 construct in the structural model's composition, are adequate and fundamental for the feasibility of a project with such challenging objectives.

These indicators were adjusted and agreed upon by the evaluators in their new definition (as well as in H2a, H2b, H2h, and H2j), which is italicised in Table 5.

However, legitimacy is a critical institutional concept, essential for the operational validation of the variables defined in H2, as a perspective on and a guarantee of the process (Suddaby et al., 2017). According to Suchman (1995, p. 574), "legitimacy… [is] a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially-constructed system of norms, values, beliefs, and definition". The Brazilian educational system, as well as other large, complex organisations, needs legitimate institutional sustainability in daily life to leverage the future.

Recent research shows a significant and direct relationship between technological, organisational, and environmental factors in TOE contexts with personal development (Awa et al., 2017). This fact strengthens the evaluating groups' conclusions about the need for technological readiness and sustainable infrastructure (in terms of continuity and maintenance) as additions in support of the teachers' and educational managers' development.

This construct is supported by the particularly important fact that large organisations take into account that the prospects for a stable, sustainable system that guarantees the continuity of a business depend on integrated management, with strategic planning and the clear, shared implementation of actions. They also recognise environmental constraints and imperfect or incomplete powers of control. It is therefore necessary to build a quality organisational atmosphere that features integration between people and actions (Zsidin et al., 2005).

H3 – BIUT is heavily influenced by the other two domains (H1 and H2), according to the discussions that took place in the focus groups and the conclusions that were reached. The most sensitive indicators relate to teacher satisfaction and the expectation of improved performance, which are allied to confidence in the quality of teaching and in facilitating conditions; these are concentrated mainly in the H2 construct.

The same reasons explain that in any situation that is experienced in the business world, satisfaction, favourable expectations, and trust are always related to previous practices and experiences (Teo and Noyes, 2014).

It was evident in the focus groups' discussions that once we are able to overcome the difficulties that arise as a result of those who seem to resist changes due to a lack of skills and even fear of the advent of technology, their engagement will gradually be secured through the influence of social use and ever-growing connectivity. In addition, it was strongly agreed that motivation is bolstered by expectations of and satisfaction with improved teaching and learning performances in this new, ever-changing scenario[6].

Cultural factors are not included, but we evidently must consider the possible impact differences caused by this factor. Studies on technological adoption with consideration to cultural differences have already been conducted in several countries (In et al., 2011). Brazil is a country with a formidable territorial extension as well as cultural diversity among the regions, and indeed, technology-related behaviour also differs among teachers.

In their discussions of H3, the focus groups confirmed behaviour pertaining to expectations that technology will enhance teaching

[6] Individual interviews: Two educational technology coordinators and robotics teachers at Inovati - Community School of Valinhos - São Paulo contributed to discussions with the authors about the difficulties and ongoing actions related to assimilating digital culture in teaching and learning processes. This school, led by these coordinators, has received awards and distinctions for events that are considered incentives and encouraging technological adoption challenges among regional elementary schools.

Table 6. Behavioural intentional use of technology indicators.

Latent Variable	BIUT	Indicators Definition
H_3	H3a	Satisfaction and expectation of better teacher performance.
	H3b	*Expectation of effort required to achieve better educational results*
	H3c	Social network influence and emerging digital culture
	H3d	Confidence in facilitating conditions to improve teaching quality

performance, even requiring a higher degree of effort, which will be mitigated by facilitating infrastructure conditions. The social influence of networking is also a significant decisive factor, according to Davis (1985), Venkatesh and Davis (2000), and Venkatesh et al. (2012), who authored and developed the referenced model (see Table 6).

5.1. Validating the structural framework

The structural framework (Figure 7) under study is artificial and is a socio-technical process built on cause-and-effect relations, the relations between its hypotheses. It was examined considering the actual experiences of the education specialists who participated in the focus groups and in the individual interviews.

Bearing the framework's usefulness in mind, all the evaluators agreed that H1, H2, and H3 represent cause-and-effect relations, thus contributing to an alternative concept of a framework for reaching the proposed goals. This verdict means that the information system that has been produced for decision-making is a viable alternative for practical application.

It is undeniable that the topic needs to be visible and reasonable, so that evaluators can see it as an alternative solution to a real problem. Thus, the methodological proposal is evidenced as artificial science, allowing analysis based on the theoretical foundations presented in confrontation with and complemented by observations of the evaluators' practical experiences. This specific intersection constitutes the extraction and formation of knowledge that is supported by the explicit representation of the ideas in the form of a coherently-organised model or construct.

Finally, it is important to recognise the DSR methodology that was used with the focus group technique to highlight some essential contributions arising from the discussions, many of which have the potential to be converted into reflections, strategies, and actions for teachers and educators, in general, such as:

- *Endorsement* of the CMC construct as carrying the most critical weight for the
  ICC framework. This conclusion means that the formation of a superior profile of teachers is essential, with a focus on knowledge of their taught subjects but emphasising knowing how to integrate them with others pedagogically and, above all, creating skills for the use of technological instructional resources.
- Technology changes all the time, and unfortunately, we lose its application benefits in education due to inadequate teacher training. It is therefore necessary to reconfigure content curricula with a *strong focus on pedagogical practices* and technological skills competencies in addition to the ICTs used in social life.
- In other words, there is no point in having countless technological resources and not knowing how to use them or not knowing the pedagogical path to follow. The teacher of the future will *undoubtedly master technology*, but he/she will also *need integrated competencies*, as validated in this project.
- Due to the socio-geographical complexity, technological adoption in national public education needs to happen through a *broad, well-structured planning project,* in line with the ten actions that are highlighted in the organisational and institutional complexity indicators construct (see Table 5, p. 32).
- Large multinational companies implement complex projects on a global level and achieve on-time execution and the planned level of quality due to managerial leadership with *strategic discipline.* This is also possible in large-scale education.

The numerical data the evaluators pointed out also indicated a statistically-representative structural model in which the conclusions recognised *the usefulness and potential efficacy of the hypotheses*, necessarily generating a *challenging but viable project.*

5.2. Statistical approach

A qualitative method was used in the focus groups and was also applied to the confirmatory factor analysis of the constructs' weights in the framework; the same analysis related to each factor's contribution to its constructs. The results are shown in Table 7.

In Table 7, given that the sample standard deviation, which is around the average of most variables, is less than 1 (except for H2b), the amplitude (the difference between the upper limit and the lower limit of the confidence interval for the sample mean) of the 95% confidence interval is also less than 1. In addition, for the experts, most variables' importance was found to be greater than or close to 0.7, hence the variables and the indicators carry great informative weight for the construction of the suggested model.

It is noteworthy that indicators H2a, H2b, and H3b have lower averages and higher standard deviation values, as well as a load factor that is less than 0.7 means that those indicators exert a lesser impact than others in terms of the information that is necessary to understand the construct. However, the inadequacies were *corrected in the evaluators' discussions,* and those indicators are thus maintained in Tables 3 and 4, (pages 23 and 30, respectively), where they have already been altered as per the corrections.

It is also worth noting that the weight reflecting CMC's importance as compared to OIC and BIUT, due to the expressive load factor (0.937), confirms the emphasis and qualitative reasons attributed to teachers in the evaluated structural model. Considering the remarkable importance that the focus groups have placed on CMC, we feel justified in believing that:

- The evaluators acknowledged that the measurement indicators H1a, H1b, H1c, and H1d correlate qualitatively and, together, strengthen the hypothesis H1 around the existence of the ICC concept which was the study's conceptual focus. The better the competence that is defined in each measurement indicator, the better the quality of the H1 construct.
- The statistical interpretation confirms this relationship of linearity, since the value of R-Linear association is positive, ranging from 0.41 to 0.73, thus indicating that the associations range between moderate and high. See the linearity relationships in Table 8.
- By abduction, if the indicators, respectively, explain H1, they can also be considered correct.

The analysis results showed the importance of the role played by teachers in this alternative framework of technological incorporation in educational processes, adding value and outcomes to the ICC profile. Initially, CMC (H1) were confirmed as comprising the most critical framework constructor. There is a consensus that the teacher's role is

Table 7. The constructs' strengths and their measurement indicators.

Variable	Statistic		
	Average	Standard deviation	Load
CMC	3.75	0.413	0.937
H1a	3.85	0.366	0.962
H1b	3.75	0.444	0.937
H1c	3.05	0.759	0.762
H1d	3.45	0.759	0.862
OIC	2.95	0.510	0.737
H2a	2.55	0.825	0.637
H2b	2.45	1.099	0.612
H2c	2.85	0.810	0.712
H2d	3.15	0.812	0.787
H2e	3.25	0.638	0.812
H2f	3.55	0.686	0.887
H2g	3.15	0,812	0.787
H2h	3.35	0.670	0.837
H2i	3.60	0.680	0.900
H2j	3.20	0.767	0.800
BIUT	2.72	0.850	0.681
H3a	3.05	0.825	0.762
H3b	2.30	0.934	0.575
H3c	3.00	0.858	0.750
H3d	3.30	0.864	0.825

Table 8. Linearity relationships between CMC indicators.

	CMC	*H1a*	*H1b*	*H1c*	*H1d*
CMC	1.00	0.30	0.50	0.63	0.46
H1a		1.00	0.73	0.41	0.44
H1b			1.00	0.51	0.51
H1c				1.00	0.69
H1d					1.00

ahead of organisational resources for teaching. Moreover, CMC also include motivation and self-efficacy as driving forces for teaching activities under any circumstances.

Furthermore, the focus group specialists' evaluation evidenced that teachers' mediation is the newest and the most important role that has emerged in the partnership between education and digital technology.

Thus, assuming the role of the teacher presents an even bigger challenge, especially for most digital immigrants, because, according to Bandura's (2001) concept, the agency perspective involves the ability to deliberate on, choose, predict, plan, and regulate courses of action, instead of passively waiting for them to happen.

Pedagogical mediation, in light of Schulman's concepts, meaning the ability to apply and develop a repertoire of situations to facilitate learning, must be accompanied by an inspiring, motivating attitude among students. Hence, it is significantly vital to have a leadership profile that mobilises capacities built on the teacher's underlying characteristics, thus allowing students to perform well, while also mobilising intrapersonal and interpersonal competencies, which are known to constitute emotional intelligence (Goleman et al., 2013). In this challenging context, a *teacher's self-efficacy* is a jewel in his/her profile.

The organisational and institutional complexity (H2) predicted in the research was discussed and evaluated using indicators that represent the best description of the real terms and opportunities for the execution of a technological adoption project on a large scale of complexity.

In addition to the discussions qualifying the profile defended in the CMC, we also highlight the most relevant statements from the OCI construct for planning the adoption of a technological teaching system in a broader educational order such as in Brazil:

- *Principles and guidelines* should direct education rather than the previous form, which was guided by normative rules and execution pressures.
- Education, as a *transformative action*, does not transfer knowledge. However, it must deal with teachers' mediation of the world outside the school, seeking integration and technological assimilation, and developing an innovative spirit in an environment of openness and democratic participation with all those involved in taking up responsibilities.
- *Institutional isomorphism* ensuring participatory management by observing regional needs and potentialities when applying resources.
- Principles and guidelines for *quality education.*
- Management with *an appreciation for people and performance,* adopting parameters in line with federal and local responsibilities and realities.
- *Clear decision-making* processes that are shared between the local and national administrative levels.

These thoughts firmly guided the project's vision. In order to facilitate these in the context of a complex institutional process, it is necessary to identify the cultural elements and strategies that are increasingly appropriate for humanising individuals. The digital revolution that

produces new forms of communication and social relations must incorporate speed and quality into educational processes.

Finally, observed as a motivation conclusion, despite current feelings and the lack of recognition for teachers' status and professional conditions, the third evaluated construct, behavioural intentional use of technology (H3), confirmed the high expectations and level of motivation that a project like this conveys to its actors. This project could ensure hope for effort expended towards and confidence in facilitating the best quality of teaching, which is required to achieve better educational results for all.

6. Conclusion

The goal of this paper was to validate a framework for the pedagogical application of ICT in teaching and learning processes. The proposed framework combines educational references and Design Science Research methods, and it was tested and improved using focus groups composed of education specialists who evaluated the frameworks' various constructs.

The results indicate that the proposed framework is feasible, viable, well planned, and anchored in ICC, which can add value to educational processes. The model also facilitates individual and collective contributions to the orderly improvement of learning processes towards attainment of better results in regard to teachers' self-efficacy. Another valuable contribution of this study relates to teachers' cognitive and behavioural focus within their integrated and independent institutional and organisational environment.

As already argued, we have to reinforce the executive limitations of this challenging proposal for technological adoption in a large-scale system: they are centred on the need for a great effort of managerial and political leadership, supported by public policies that guarantee balanced sustainability between resources and legal responsibilities, assigned and distributed by the state, or by a governance system in the case of private organisations. Despite this fact, in the future, according to the methodological DSR principles, as delineated in the research plan (Figure 1), the next work will be a dissemination proposal based on this paper. With regard to the Brazilian National Educational Plan (NEP), there could be a project of technological adoption in education that effectively meets the institutional principles, thus avoiding the risk of an irreversible deepening of the developmental delay that exists in the current system. This initiative could be the best way to improve the ideas generated by the current proposal due to the significant involvement the educational demands.

It is also important to reinforce that the pedagogical monitoring project that the OECD announced in 2019 will undoubtedly add value to educational processes in a global context, particularly through the exchange of *comparable* experiences among the participants' countries.

Declarations

Author contribution statement

João Carlos Wiziack: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed analysis tools or data; Wrote the paper.

Vitor Manuel Pereira Duarte dos Santos: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Appendices.

Table 9. Descriptive statistics of constructs CMC – OIC – BIUT and measurement indicators

Statistic	CMC	H1a	H1b	H1c	H1d	OIC	H2a	H2b	H2c	H2d	H2e	H2f	H2g	H2h	H2i	H2j	BIUT	H3a	H3b	H3c	H3d
Mínimum	3.000	3.000	3.000	2.000	2.000	2.000	1.000	1.000	1.000	2.000	2.000	2.000	1.000	2.000	2.000	2.000	1.000	1.000	1.000	1.000	1.000
Q1	3.500	4.000	3.750	2.750	3.000	3.000	2.000	2.000	2.000	2.750	3.000	3.000	3.000	3.000	3.000	3.000	2.000	3.000	2.000	2.750	3.000
Mean	3.750	3.850	3.750	3.050	3.450	2.950	2.550	2.450	2.850	3.150	3.250	3.550	3.150	3.350	3.600	3.200	2.725	3.050	2.300	3.000	3.300
Median	4.000	4.000	4.000	3.000	4.000	3.000	3.000	2.000	3.000	3.000	3.000	4.000	3.000	3.000	4.000	3.000	3.000	3.000	2.000	3.000	3.500
Mode	4.000	4.000	4.000	3.000	4.000	3.000	3.000	2.000	3.000	4.000	3.000	4.000	3.000	3.000	4.000	3.000	3.000	3.000	2.000	3.000	4.000
Q3	4.000	4.000	4.000	4.000	4.000	3.000	3.000	3.250	3.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	3.000	4.000	3.000	4.000	4.000
Maximum	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Std deviation	0.407	0.360	0.437	0.746	0.746	0.502	0.811	1.080	0.799	0.799	0.628	0.675	0.799	0.659	0.669	0.755	0.836	0.811	0.908	0.844	0.850
Lower lim. 95%	3.647	3.759	3.640	2.861	3.261	2.823	2.345	2.177	2.648	2.948	3.091	3.379	2.948	3.183	3.431	3.009	2.514	2.845	2.070	2.787	3.085
Upper lim. 95%	3.853	3.941	3.860	3.239	3.639	3.077	2.755	2.723	3.052	3.352	3.409	3.721	3.352	3.517	3.769	3.391	2.936	3.255	2.530	3.213	3.515
Loading	0.938	0.963	0.938	0.763	0.863	0.738	0.638	0.613	0.713	0.788	0.813	0.888	0.788	0.838	0.900	0.800	0.681	0.763	0.575	0.750	0.825
Int. amplitude	0.206	0.182	0.221	0.378	0.378	0.254	0.411	0.547	0.404	0.404	0.318	0.341	0.404	0.334	0.339	0.382	0.423	0.411	0.459	0.427	0.430

Table 10. Correlation matrix between construct CMC- OIC – BIUT and measurement indicators.

	CMC	H1a	H1b	H1c	H1d
CMC	1.000	0.434	0.501	0.629	0.461
H1a		1.000	0.728	0.407	0.445
H1b			1.000	0.507	0.507
H1c				1.000	0.689
H1d					1.000

	BIUT	v15	v16	v17	v18
BIUT	1.000	0.845	0.546	0.721	0.691
H3a		1.000	0.463	0.817	0.789
H3b			1.000	0.266	0.343
H3c				1.000	0.709
H3d					1.000

	OIC	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14
OIC	1.000	0.443	0.136	0.235	0.273	0.363	0.383	0.273	-0.100	0.091	0.161
H2a		1.000	0.409	0.679	0.498	0.524	0.181	0.106	0.204	0.131	0.399
H2b			1.000	0.669	0.451	0.056	0.283	-0.080	0.418	-0.028	0.262
H2c				1.000	0.434	0.177	0.156	-0.203	0.198	0.076	0.135
H2d					1.000	0.735	0.505	0.283	0.188	0.400	0.371
H2e						1.000	0.510	0.330	0.154	0.363	0.429
H2f							1.000	0.505	0.246	0.383	0.380
H2g								1.000	0.381	0.590	0.455
H2h									1.000	0.438	0.572
H2i										1.000	0.564
H2j											1.000

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