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Digital information competence: a predictive model in schoolchildren

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ABSTRACT

Digital information competence (DIC) is essential for schoolchildren facing an increasingly complex and misinformative online environment, a challenge that intensified during the pandemic. In Peru, no prior studies have examined jointly the educational, psychological, and sociodemographic predictors of DIC. This study aimed to validate a structural equation model (SEM) in 502 secondary school students, aged 15 to 17, from two Peruvian cities. Results showed that motivation is the strongest predictor of DIC, followed by mother's educational level, virtual interaction, and school-related information and communication technology (ICT) tasks, respectively. Interaction had both direct and indirect effects on DIC through motivation. Subsequently, we achieved a partial factor invariance by gender and school type, suggesting differences in DIC scores and the strength of predictors across groups. Findings suggest that pedagogical interventions should prioritize student motivation and virtual interaction to enhance DIC, highlighting the need for educational policies tailored to these specific sociocultural and psychological predictors.

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1. INTRODUCTION

Digital information competence (DIC) is defined by DIGCOMP 2.0: the digital competence framework for citizens as knowledge, skills, and attitudes related to searching for, evaluating, and storing digital information [1], [2]. This competence is particularly necessary in a context where, although it is true that the digital ecosystem represents an opportunity for communication and access to global and networked information, it also implies an amplification of disinformation of varying degrees of severity and complexity that is very difficult for democratic systems to control [3] and which poses new challenges with the advent of generative artificial intelligence (GAI) [4]. This study seeks to address this situation from an educational perspective, seeking to understand the factors that explain and predict DIC in basic education students.

Contrary to expectations regarding the "digital native" generation, there is evidence that students have low digital competence. Gómez-Pablos *et al.* [5] point to various studies that demonstrate students' difficulties in searching for information, such as low use of various web search engines, lack of word combinations in searches, and a tendency to focus only on the first results without analyzing their accuracy or truthfulness. They are also unfamiliar with the structure of web pages, yet they have a positive self-perception of their digital competence, while their teachers believe the opposite. On the other hand, Spanish secondary school students have been found to frequently use information and communication technologies

for social issues, but not for analyzing the information they access [6], [7]. These data highlight that there is a problem in education and among students with regard to the development of their DIC, as they are exposed to false information and its negative influence [2].

The development of DIC in secondary school students is essential for their development in the workplace or in higher education, which they must pursue during their schooling. However, although the question of how to develop this competence in students is always raised [8], this paper seeks to understand and contribute to the debate on the factors that condition the development of DIC in order to address this educational development from a more comprehensive, meaningful, and holistic perspective of the problem. The scientific literature highlights the existence of various factors associated with this skill, such as motivation to learn (MOT), interaction in virtual learning contexts (INT), and certain educational and sociodemographic variables, which have been studied independently. No studies have been conducted on how these factors, taken together, can explain and predict DIC in secondary school students. Some researchers, such as Gómez-Pablos *et al*. [5], refer to this gap in Spain, warning of the need to respond with further research. In the Peruvian context, there are few studies that directly address DIC as a formal construct. Among them, Fabian *et al*. [9] identified adequate levels of DIC in school students in a city in Junín, yet empirical findings across the country remain inconsistent. This still shows that there is a lack of consensus on the degree of digital competence, including DIC, among the younger generations of Peruvian citizens.

Recent studies have proposed novel theoretical models to explain some types of digital competence in students [10], but none of them have focused on DIC specifically. Most empirical studies have focused on factors in isolation, and not as an integrated model. For this reason, the objective of this study was to validate a structural equation model (SEM) to measure the predictive capacity of a set of variables, such as MOT, INT, father's age (AGE_FATHER) and educational level (EDU_FATHER), mother's age (AGE_MOTHER) and educational level (EDU_MOTHER), information and communication technology (ICT) activities in the classroom (ICT_TASKS), and diversity of digital devices (DEVICES), which together would affect DIC in secondary school students in two cities in Peru.

As noted, the trend in literature is to study factors individually. Regarding MOT, it has been found that high expectations of self-efficacy and positive beliefs about oneself in virtual learning are associated with better results in the use of ICT [11]. Over the past 50 years, multiple authors have theorized about motivation as a crucial part of learning development, both in the educational context and in general [12]–[18]. These studies show that there is a positive and significant relationship between DIC and MOT (H_1).

Alternately, INT could be a crucial component for developing DIC, particularly when it occurs in the virtual classroom with classmates, teachers, and educational materials [19], [20]. It has also been found that digital interaction with peers in and outside the classroom facilitates learning new software applications and resolving difficulties in the use of ICT [21]. That is, there is a positive and significant relationship between DIC and INT (H_2).

Regarding technological factors, some authors identify that the variable use of ICT is associated with digital skills, especially school tasks [5], although other authors deny this relationship [21]. The possession of various digital devices in different contexts, such as school and home, has been little analyzed in relation to digital skills [5]. Here, two working hypotheses can be distinguished: there is a positive and significant relationship between DIC and ICT_TASKS (H_3), and between DIC and DEVICES (H_4). Other factors that have also been associated with digital skills are the use of ICT in schools, the educational level of parents, their age, and their digital education [22]–[25]. In this case, there is a significant negative relationship between DIC and the AGE_FATHER (H_5) and AGE_MOTHER (H_6), but a significant positive relationship between DIC and the EDU_FATHER (H_7) and EDU_MOTHER (H_8).

There are variables that can also generate differences in the proposed model, such as gender and type of school. There is extensive literature on these differences in digital skills, such as higher performance in men than in women [26]–[28]. Likewise, the type of school is a factor that can favor or hinder the acquisition of DIC, due to economic and infrastructure disparities between public and private schools [29]. This allows us to see that there are differences in the predictive model of DIC according to gender (H_9) and according to the type of school (H_{10}).

Taking all these factors from the theoretical exploration, this paper proposes a theoretical model which has been illustrated in Figure 1. This model allows us to test the parental, socioeconomic and psychological factors of DIC in a country with profound disparities. Knowing these predictive factors will enable the development of more effective curricula, methodologies, and teaching resources, as well as interventions to ensure equity and guide teacher training in the meaningful use of ICT. In this sense, it contributes to the design of more equitable and sustainable public policies for the achievement of a critical, ethical, and competent digital citizenship in Latin America.

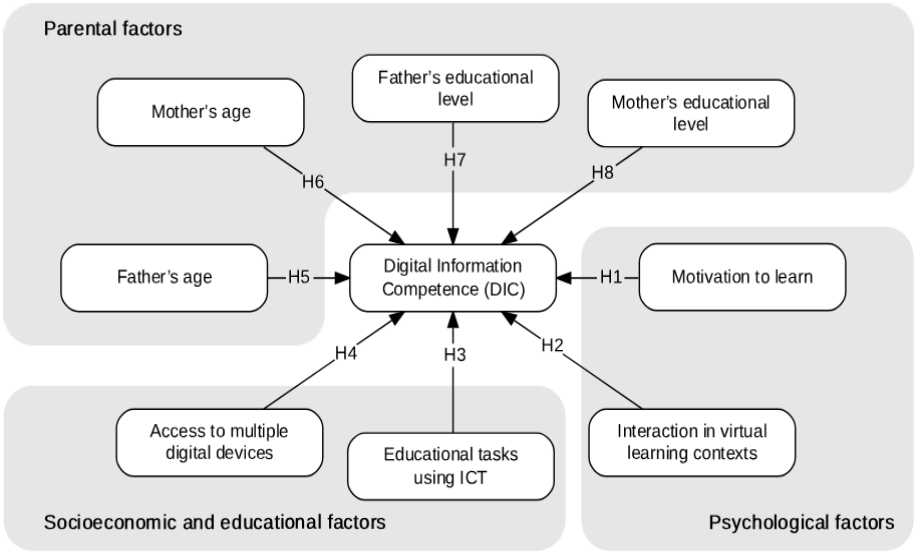

Figure 1. Proposed theoretical model

2. METHOD

2.1. Instruments

In this study, DIC, MOT, and INT were measured using three psychometric tests validated as part of the overarching research project [30]–[32]. These previous publications ensure semantic, content, and construct validity, as well as reliability, as shown in Table 1. Since the current sample is drawn from the same population as the validation studies, their psychometric properties are applicable here; furthermore, we corroborated this evidence within the measurement model in the results section.

DIC was measured with the "Information" subscale of the digital competence assessment scale for secondary school students (ECODIES) [33] which assesses three topics: i) navigation, search, and filtering of information; ii) evaluation of information; and iii) information storage and retrieval. These topics are evaluated through an ability dimension (multiple-choice questions scored by correct/incorrect) and attitude dimension (items with Likert scale). This test is based on the DIGCOMP digital competence model [2] and has also been validated for Spanish [34] and Colombian [35] schoolchildren.

To measure MOT, we used the motivated strategies learning questionnaire (MSLQ) [16], which has been used extensively in various parts of the world [36], [37], including in our sample population. On the other hand, INT was measured using the virtual learning context interaction scale (VLCIS) [38], which measures the dimensions of student interaction with the teacher, with peers, and with learning materials.

Table 1. Description of psychometric tests

Instruments	Dimensions	Items	Answers	Reliability	Validity	
					Content	Structural
ECODIES-information	Knowledge and ability	12	Multiple Choice, 5-point	α=0.748	V=0.952	χ^2/df=1.37
	Attitudes	6	Likert scale	ω=0.768	(J=8, p<0.01)	RMSEA=0.043
						SRMR=0.047
						CFI=0.973,
						TLI=0.963
MSLQ	Intrinsic value	10	7-point Likert scale	α=0.949	V=0.974	χ^2/df=1.963
	Extrinsic motivation	4		ω=0.951	(J=7, p<0.01)	RMSEA=0.055
	Self-efficacy	9				SRMR=0.054
						CFI=0.934,
						TLI=0.927
VLCIS	Interaction with teacher	10	5-point Likert scale	α=0.901	V=0.89	χ^2/df=1.71
	Interaction with materials	7		ω=0.904	(J=10, p<0.05)	RMSEA=0.047
	Interaction with other students	7				SRMR=0.056
						CFI=0.914,
						TLI=0.905

Note: α=Cronbach's alpha, ω=McDonald's omega, V=Aiken's V coefficient, J=judges which assessed its content validity, RMSEA=root mean square error of approximation, SRMR=standardized root mean square residual, CFI=comparative fit index, and TLI=Tucker-Lewis's index. All coefficients come from their Peruvian adaptations [30]–[32].

Finally, a short survey was also developed to collect information on the variables of age (15-17 years old); gender (male or female); city of residence (Lima or Cusco); type of school (private or public); age of mother and father (under 30 and over 60 years old); level of education of mother and father (university, technical, secondary, primary; no education); number of school activities involving ICT during the week (from 1-2 tasks to more than 20 tasks); and DEVICES used for tasks (laptop, computer, phone, and/or tablet).

2.2. Sample

The sample consisted of 502 secondary school students from Lima (the capital city) and Cusco (a regional city), thereby increasing the socio-territorial heterogeneity of the sample and strengthening the external validity of the study. 46.4% were female (n=233) and 35.3% came from public schools (n=177), as shown in Table 2. Urban schools were selected based on geographical accessibility, with coordination facilitated by school directors. Specifically, a convenience sampling method was employed due to logistical constraints during the COVID-19 pandemic. While this approach may limit generalizability, the findings offer key insights into DIC predictors. Regarding ethical procedures, following parental approval, all students provided informed assent. The only exclusion criterion was age outside the 15-17 range; accordingly, three participants were excluded. Finally, it should be noted that no sample weighting was applied.

The instruments were administered using the digital platforms that each school used for its classes, such as Zoom, Meet, and WhatsApp. Given that it was during the pandemic, school classes were entirely virtual, so Google Forms had to be used to register our data. The level of difficulty at each school was related to the technological facilities available to them. In the case of public schools, some used only WhatsApp to conduct classes with their students, which was also the method used to administer the instruments. All applications were online and with the permanent presence of the researchers. In the case of WhatsApp, the instructions were sent by recording, along with the instruments to the chat, and then we waited online in case there were any questions. The research was approved by the Institutional Research Ethics Committee of the Cayetano Heredia Peruvian University on March 12, 2021.

Table 2. Sample distribution by demographic factors and school type

Variables		Lima schools		Cusco schools		Total (N=502)
		Private (N=242)	Public (N=65)	Private (N=84)	Public (N=111)	
Gender	Female	125 (51.7%)	33 (50.8%)	42 (50%)	33 (29.7%)	233 (46.4%)
	Male	117 (48.3%)	32 (49.2%)	42 (50%)	78 (70.3%)	269 (53.6%)
Age	15 years	129 (53.3%)	18 (27.7%)	45 (53.6%)	50 (45%)	242 (48.2%)
	16 years	107 (44.2%)	38 (58.5%)	33 (39.3%)	46 (41.4%)	224 (44.6%)
	17 years	6 (2.5%)	9 (13.8%)	6 (7.1%)	15 (13.5%)	36 (7.2%)
School year	10th grade	142 (58.7%)	26 (40%)	66 (78.6%)	61 (55%)	295 (58.8%)
	11th grade	100 (41.3%)	39 (60%)	18 (21.4%)	50 (45%)	207 (41.2%)
Total		242 (48.2%)	65 (13%)	84 (16.7%)	111 (22.1%)	502 (100%)

2.3. Statistical analysis

Initially, the central tendency, variability, and position indices were estimated for the latent variables and their dimensions, as well as the strength and statistical significance of the correlations with Spearman's rho coefficient. The theoretical model was represented in an SEM with 13 observable parameters, 11 unobservable parameters, 96 variances/covariances, and 62 degrees of freedom. In order to prevent an over-identified model due to a high item-to-construct ratio, we opted to parcel the items according to their theoretical dimensions. This procedure aggregated the original items into composite scores, allowing the indicators to be treated as approximately continuous variables.

The SEM was estimated using maximum likelihood with robust standard errors and the Satorra-Bentler scaled test statistic [39] to reduce the bias of sample non-normality and unequal sample sizes for future comparisons by gender and school type. Convergent validity was assessed using the average variance extracted (AVE), with values expected to be >0.5. Discriminant validity was evaluated through the heterotrait-monotrait (HTMT) ratio of correlations, with a threshold of <0.85 [40]. Composite reliability (CR) was measured using Raykov's rho (ρ) statistic, expecting values equal to or greater than 0.7 [41].

For the SEM models, the model fit indices were verified using standard criteria in literature: χ^2/df<3.0-5.0, RMSEA/SRMR<0.06-0.08, CFI/TLI>0.90-0.95, normed fit index (NFI)>0.9, parsimony normed fit index (PNFI)>0.5, Akaike information criterion (AIC) and Bayesian information criterion (BIC) [42]. The explained variance for endogenous variables inside SEM was assessed using the R^2 statistic, and the residual variance (or measurement error of the model) as $1 - R^2$. To determine the unique contribution of each predictor, we calculated the change in variance ΔR^2 by comparing the full model ($R^2{}_{\text{final}}$) against a reduced model ($R^2{}_{without}$) excluding the specific predictor [43]. The effect size was estimated using Cohen's

$f^2 = \frac{(R^2\text{final} - R^2_{without})}{(1-R^2\text{final})}$, interpreted as follows: f^2≥0.02=low effect, f^2≥0.15 = medium effect, and f^2≥0.35=high effect [44].

Finally, the factor invariance of the predictive model was also tested according to the differences obtained in the main goodness-of-fit indices at multiple levels of restriction (configurational, metric, scalar, and strict), expecting Δχ2 with non-significant p-values (p>0.05), ΔCFI≤0.01 (or>-0.01), and ΔRMSEA<0.015 to assure its invariance. Subsequently, Wald tests were used to examine whether the direct path coefficients differed significantly between groups (gender and school type).

3. RESULTS AND DISCUSSION

3.1. Descriptive results and correlations

For more than 30 years, researchers in virtual education have raised the need to create theoretical models for assessing digital competencies in schoolchildren [45], [46], including psychological factors that are always present in online education, such as MOT and INT. Due to the educational challenges arising from the pandemic and the growing number of empirical studies on virtual education, there is a recognized theoretical challenge in explaining the conditions that favor the development of digital skills, including DIC.

As descriptive results, the distributions of the variables for the SEM model have a mean and median that are relatively close to each other, although with a slight negative trend in all variables. The average score for the overall DIC was 30.9 out of 42 points (73% of the total expected performance). Students obtained an average of 24.8 points (77.5% of the total score) in the attitude dimension (ATTI), but their average score in the knowledge and ability dimension (KN_AB) was only 6.1 out of 12 points (50.83% of the total). That is, they are just below the passing score for the Peruvian education system (55%). These results are consistent with those of students in other countries in the region, such as Colombia [35], where students obtained even slightly lower average scores (KN_AB=5.44, ATTI=23.61).

When performing the correlation analysis between the variables of the proposed model (including the observable variables), it was determined that there is a positive and significant relationship between DIC and MOT and INT, as well as with EDU_MOTHER, EDU_FATHER, DEVICES, and ICT_TASKS, as shown in Table 3. However, DIC does not correlate significantly with AGE_MOTHER or AGE_FATHER. Thus, we can reject hypotheses H_5 and H_6, since if there is no relationship between the variables, theoretically and empirically there cannot be a predictive factor for the variable of interest during the subsequent SEM estimation.

Table 3. Descriptive statistics and correlation with DIC

Variable name	Mean	Median	SD	Skewness	Kurtosis	Correlation with DIC
DIC	30.94	32	4.954	-0.995	1.735	
KN_AB	6.133	6	2.191	-0.056	-0.404	0.778***
ATTI	24.807	25	3.561	-1.541	4.379	0.888***
MOT	124.084	127	22.038	-0.678	0.187	0.224***
Intrinsic value (INTR_VAL)	54.51	56	10.061	-0.694	0.255	0.229***
Extrinsic motivation (EXT)	22.317	23	4.697	-0.909	0.68	0.152***
Self-efficacy (SELF_EF)	47.257	49	10.834	-0.808	0.434	0.185***
INT	82.169	83	13.545	-0.268	-0.043	0.211***
Interactions with teacher (TEA)	33.165	33	6.283	-0.178	-0.272	0.114*
Interactions with materials (MAT)	26.673	27	4.145	-0.645	0.763	0.300***
Interactions with other students (STU)	22.331	23	6.233	-0.464	-0.434	0.163***
AGE_FATHER	4.275	4	1.273	-0.076	-0.812	0.061
AGE_MOTHER	4.757	5	1.259	-0.229	-0.798	0.072
EDU_FATHER	6.195	7	2.072	-0.927	-0.185	0.147**
EDU_MOTHER	6.297	7	1.913	-0.835	-0.407	0.190***
ICT_TASKS	3.082	3	1.116	0.665	0.263	0.180***
DEVICES	1.709	2	0.773	0.886	0.242	0.177***

Note: correlation coefficients were calculated using Spearman's rho (ρ) with listwise deletion. * p<0.05, **p<0.01, ***p<0.001.

This finding is consistent with the results derived from data collected by the Organisation for Economic Co-operation and Development (OECD) in 78 countries between 2003 and 2022, which showed that although younger parents tend to possess stronger digital skills, the children of older parents do not necessarily achieve lower scores [47]. As noted by García *et al*. [48], younger parents have more resources to foster the attitudinal component of digital competence (promote engagement with ICT), though this does not necessarily translate into an increase in knowledge or abilities.

3.2. Predictive model estimation

Moving on to the SEM model, an initial measurement model was created with the three main variables, which yielded positive and significant covariances between DIC and MOT (β=0.323, p<0.001), DIC and INT (β=0.282, p<0.001), and between MOT and INT (β=0.487, p<0.001), which is consistent with the previous result of the statistical correlations. CR coefficients (based on ρ) demonstrate high internal consistency: DIC (CR=0.778), MOT (CR=0.872), and INT (CR=0.775). Furthermore, convergent and discriminant validity reached adequate levels, as detailed in Figure 2.

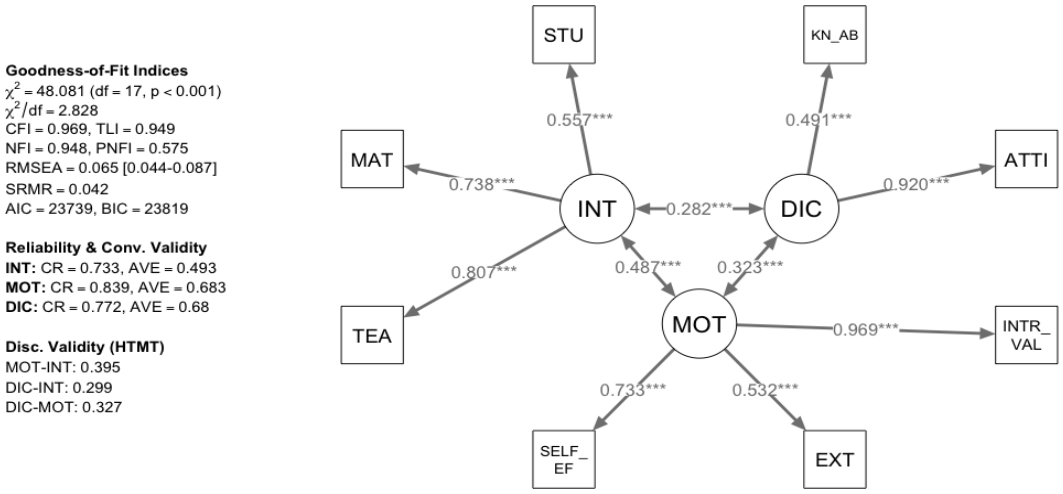

Figure 2. Measurement model

Upon estimating the structural model based on the proposed theoretical framework, we observed that the structural coefficients of EDU_FATHER (β=0.079, p=0.257), and DEVICES (β=0.076, p=0.135) were not significant, and most goodness-of-fit indices (CFI, TLI, NFI, RMSEA, SRMR) were outside the expected range. Due to this result, the model was re-specified, eliminating the insignificant variables (EDU_FATHER and DEVICES) with the DIC, as shown in Figure 3. Then, the largest modification index (MI) found between the INT and MOT variables was analyzed (MI=78.510, p<0.001).

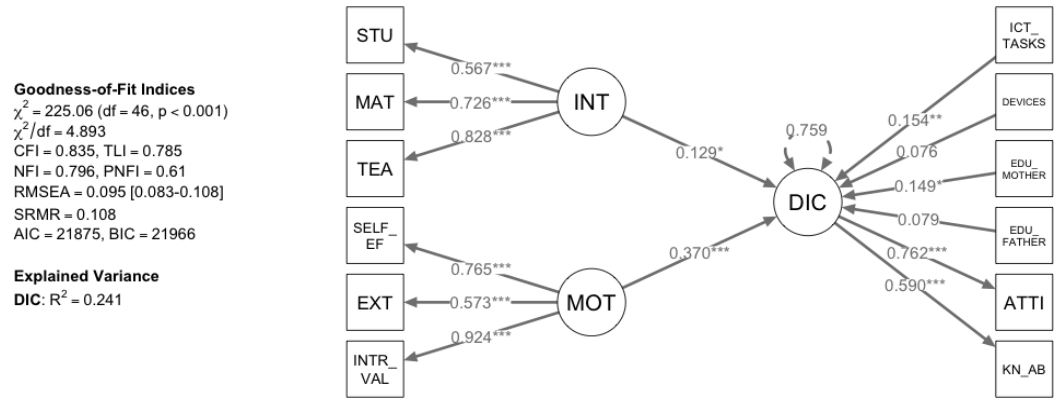

Figure 3. Initial SEM model

The effect of INT on MOT has been demonstrated in recent research. Thanasi-Boçe [49] found that INT with instructors and classmates account for 46.2% of the variance in MOT among undergraduate students. On the other hand, Hernández-Sellés [50] found INT linked to cognitive activities, MOT and well-being is generated. In addition, the lack of INT creates poor learning experience, loneliness and demotivation. Based on these findings, the initial SEM model was re-specified, adding an effect relationship from the INT variable to MOT, as illustrated in Figure 4.

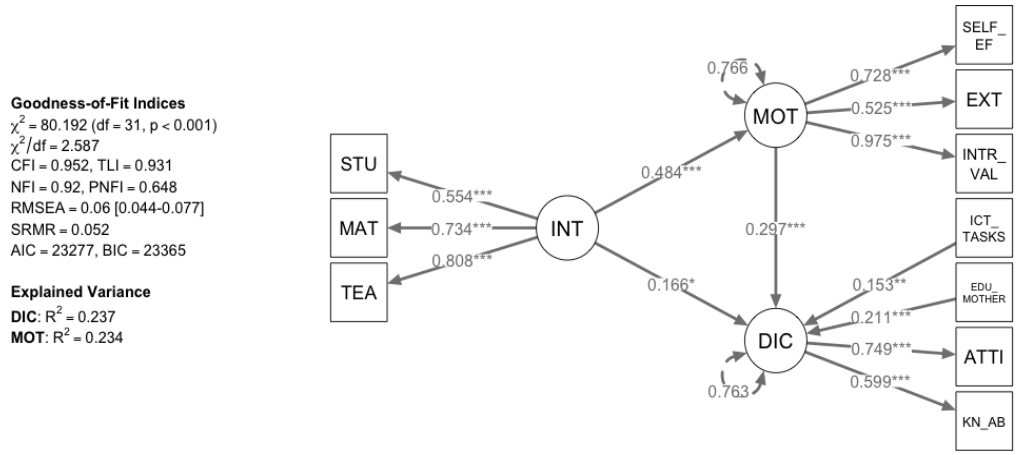

Figure 4. Final SEM model

With this new relationship, the structural model was re-estimated, revealing that INT, MOT, EDU_MOTHER, and ICT_TASKS showed a direct, positive, and significant effect on DIC, as shown in Table 4. Additionally, INT has a direct effect on MOT, while MOT functions as a mediator between INT and DIC, accounting for an indirect effect and resulting in a total (direct and indirect) effect of INT on DIC. Collectively, the structural model accounts for 23.7% of the total variance in DIC (R^2=0.237), which represents a modest yet significant explanatory power expected for social sciences [51].

Nevertheless, a substantial portion of the variance remains unexplained ($1 - R^2 = 0.763$), suggesting that additional latent and observed variables could help provide a more comprehensive explanation of the phenomenon, such as teacher digital competence, peer influence and access to broadband. It is recommended to examine the ITU's manual for measuring access to and use of ICTs by households and individuals [52] for more granular indicators that could further reduce residual variance in future structural models.

Table 4. Standardized structural coefficients and effect sizes of the respecified SEM model

Variables	β	CI (95%)		SE	z	p	R^2_{final}	$R^2_{without}$	ΔR^2	f^2
DIC ← INT (direct)	0.166	0.03	0.303	0.07	2.395	0.017	0.237	0.223	0.014	0.019
DIC ← INT (indirect)	0.144	0.074	0.214	0.036	4.012	< 0.001	0.237	0.216	0.021	0.028
DIC ← INT (total)	0.31	0.192	0.428	0.06	5.151	< 0.001	0.237	0.228	0.009	0.012
DIC ← MOT	0.297	0.166	0.428	0.067	4.456	< 0.001	0.237	0.17	0.068	0.089
DIC ← EDU_MOTHER	0.211	0.11	0.312	0.052	4.099	< 0.001	0.237	0.176	0.062	0.081
DIC ← ICT_TASKS	0.153	0.053	0.254	0.051	3.002	0.003	0.237	0.195	0.042	0.055
MOT ← INT	0.484	0.391	0.577	0.047	10.21	< 0.001	0.234	0.000	0.234	0.306

Note: R^2_{final}=variance explained by the full model; $R^2_{without}$=variance explained excluding the predictor; and ΔR^2=unique contribution. f^2 effect sizes: $f^2 \geq 0.02$ (small), $f^2 \geq 0.15$ (medium), and $f^2 \geq 0.35$ (large).

In this SEM model, it was determined that MOT is the most important predictor of DIC, uniquely explaining 6.8% of its variance, situating it between a small and medium effect size (f^2=0.089). This confirms H_1 and is noteworthy because in remote education during the pandemic, schoolchildren had to study alone and without contact with their teachers and classmates, which would have required a significant psychological effort in which MOT has been crucial, requiring self-efficacy, task value, intrinsic motivation, and beliefs about learning. On this point, recent studies found that when students are independent and have greater self-efficacy in using the internet, they are also better at searching for information, even when the space is disorganized [53]. Similarly, MOT has been proven to be the variable with the greatest predictive capacity for general digital competence [54].

Similarly, INT (with teachers, materials, and students) is a direct and stable predictor of DIC with a small effect size (f^2=0.019) which confirms H_2. In countries like Sweden, researchers found that due to a sudden and emergency shift to remote teaching, secondary school students expressed difficulties with collective learning, mutual interaction, group work, and comparing their performance with that of their peers [55]. In contrast, a study in a Mexican secondary school showed that synchronous and asynchronous communication was important for teachers to interact with their students and for students to develop their overall digital competence [56].

It was found that EDU_MOTHER is positively associated with DIC, leading to the acceptance of H_8. Conversely, EDU_FATHER does not emerge as a significant predictor in the model, resulting in the rejection of H_7. Previous data from Peru showed that the wealth index and the mother's educational level increase the probability that the student will frequently use a computer and the Internet [57]. Another study with primary school students found greater digital competence in those whose mothers had a higher level of education, which was not the case when the father's education was considered [58]. In contrast, some authors found greater digital competence or greater self-perception of this competence in schoolchildren when both parents had formal education [23], [59].

Also, ICT_TASKS is directly and significantly related to DIC, thus confirming H_3. Its small effect has also been reported in multiple studies, where the frequency of use of digital devices influenced digital competence in schoolchildren [60] and university students [61]. Similarly, "e-activities" are crucial in virtual education, both for digital competence itself and for other academic courses [62]. For example, students with low digital competence perform less well in reading and mathematics when they use ICT more [63]. On the other hand, DEVICES do not appear to be a crucial predictor in understanding the development of DIC, so H_4 is rejected. Although the presence of electronic devices allows the student to engage in spontaneous use, our findings coincide with Spanish students, where the acquisition of digital devices does not impact the level of other kinds of digital competence [10].

A critical finding lies in the direct and strong effect from INT to MOT (f^2=0.305). INT proved to be the fundamental driver of MOT in students, explaining 23.4% of its variance (with a residual variance of $1 - R^2$=0.766). These results suggest that INT is the primary catalyst of the motivational states necessary for developing DIC. The evidence from other low- and middle-income countries (LMICs) during the pandemic highlights that MOT is the result of a learning environment that provides well-being through social and education connections with teachers and peers [64].

Finally, a sensitivity analysis was performed according to Matsunaga [65] to evaluate the impact of our parceling strategy by comparing the measurement and structural model with a version that explicitly integrated measurement error. The results confirm the robustness of the proposed theoretical model, evidenced by the stability and significance of INT-DIC and INT-MOT paths. In contrast, the DIC-MOT relationship showed greater sensitivity to error treatment ($\beta_{measurement}$=0.17, p=0.057; $\beta_{structural}$=0.142, p=0.182). This phenomenon, which is common in the discipline [66], suggests intrinsic conceptual complexity rather than methodological deficiency, reaffirming that error handling is a crucial analytical component in SEM. Although certain relationships require cautious interpretation, the model maintains a solid theoretical and empirical consistency that underpins the validity of the findings. For future research, it is recommended to further investigate alternative parceling strategies to test the stability of the structural coefficients.

3.3. Factor invariance

The subsequent statistical analysis examined factor invariance, which reflects the extent to which the underlying construct functions equivalently across comparison groups. Measurement invariance followed a hierarchical procedure for both gender and school type, as shown in Tables 5 and 6. Initially, measurement invariance by gender was achieved at the configural and metric level, which means that both category groups have an equivalent factorial structure, as well as unit metric for its components. However, full scalar invariance was not achieved, suggesting significant differences in item intercepts across gender. To address this, modification indices were consulted, where "Interactions with teacher" (TEA) appeared as the primary source of non-invariance. By relaxing the intercept constraint for this specific indicator, partial scalar invariance was successfully established.

Table 5. Factor invariance analysis by gender

Model	χ^2(df)	CFI	RMSEA	Model comp.	$\Delta\chi^2$ (df)	ΔCFI	ΔRMSEA	Decision
Configurational (M1)	111(62)	0.957	0.057	-	-	-	-	-
Metric (M2)	118(67)	0.956	0.055	M1-M2	6.24(5), p = 0.284	-0.001	-0.001	Accept
Scalar (M3)	134(72)	0.946	0.059	M2-M3	16.23(5), p = 0.006	-0.010	0.004	Reject
Partial scalar (M4)	127(71)	0.951	0.057	M2-M4	9.07(4), p = 0.059	-0.004	0.001	Accept
Partial strict (M5)	133(79)	0.953	0.053	M4-M5	5.87(8), p = 0.661	0.002	-0.004	Accept

Table 6. Factor invariance analysis by school type

Model	χ^2(df)	CFI	RMSEA	Model comp.	$\Delta\chi^2$ (df)	ΔCFI	ΔRMSEA	Decision
Configurational (M1)	107(62)	0.961	0.054	-	-	-	-	-
Metric (M2)	118(67)	0.955	0.056	M1-M2	11.1(5), p=0.049	0.001	-0.005	Reject
Partial metric (M3)	115(65)	0.956	0.056	M1-M3	8.31(3), p=0.039	-0.005	0.002	Accept
Partial scalar (M4)	122(68)	0.953	0.057	M3-M4	6.45(3), p=0.092	-0.003	0.001	Accept
Partial strict (M5)	147(76)	0.938	0.062	M4-M5	25.15(8), p=0.002	-0.015	0.005	Reject

When comparing students by school type, full measurement invariance was only achieved at the configural level. Partial metric invariance was established by constraining the factor loadings of TEA and Interactions with other students (STU) within the INT factor. Subsequently, partial scalar invariance was achieved by further constraining the intercepts of these same indicators (TEA and STU).

The lack of full measurement invariance suggests that TEA and STU from the INT construct does not represent an identical experience for all students; rather, it reflects distinct dimensions of engagement depending on gender and school type. Consequently, the unequal conditions for INT during the pandemic appear to have generated varied psychological and practical meanings related to the development of DIC.

Following the establishment of partial scalar invariance, latent mean differences were examined across both grouping criteria. Regarding gender, the analysis revealed that female students exhibited significantly higher latent means in DIC ($\Delta M=1.079$, $p=0.032$) and INT ($\Delta M=1.323$, $p=0.028$) compared to their male counterparts. No significant differences were found in MOT ($\Delta M=-1.180$, $p=.204$). On the other side, students from private schools had a significantly lower latent means in MOT ($\Delta M=-4.721$, $p<0.001$) than those from public schools, with no significant differences in DIC ($\Delta M=0.799$, $p=0.241$) and INT ($\Delta M=0.271$, $p=0.724$).

To further explore the predictive dynamics of the model, structural coefficients were compared across groups using the partial scalar invariance SEM, as shown in Table 7. In male students, MOT and EDU_MOTHER have a stronger path coefficient over DIC, while female students INT and ICT_TASKS stands out. The highest discrepancy was observed in the path from MOT to DIC ($W=7.837$, $p<0.001$), which was markedly stronger in male students.

Table 7. Comparison of direct paths and Wald tests by gender and school type

Variables	Gender comparison			School type comparison		
	β_{Male}	β_{Female}	W	β_{Public}	$\beta_{Private}$	W
DIC ← INT (direct)	0.099	0.257*	0.386	-0.072	0.218*	4.422*
DIC ← INT (indirect)	0.043**	0.016	-	0.039*	0.049**	-
DIC ← MOT	0.409***	0.163	7.837**	0.410**	0.316***	0.005
DIC ← EDU_MOTHER	0.220**	0.129	2.021	0.265**	0.044	1.609
DIC ← ICT_TASKS	0.100	0.191*	0.100	0.123	0.187**	0.805
MOT ← INT	0.399***	0.576***	4.652*	0.506***	0.514***	1.675

Note: the indirect effect was estimated using 5000 bootstrap samples. W=Wald test statistic. * $p<0.05$, **$p<0.01$, ***$p<0.001$.

These findings suggest that while both genders share comparable motivational profiles, the mechanisms through which they develop digital competence differ. According to expectancy theory [18], cultural beliefs influence skill acquisition and performance. Current shifts driven by gender equality policies, evolving perspectives on gender, and the inclusion of women in the workforce could be modifying women's ideas about their own abilities, leading them to further develop their academic skills in general [67], including DIC.

Although national literature on this topic remains scarce, it is plausible to infer that cultural beliefs and stereotypes about women and their abilities in science, technology, engineering, and mathematics (STEM) fields are constantly changing, reflecting changes in women's self-perception and, ultimately, their performance in DIC. Applied to our sample, the mandatory nature of remote education likely minimized traditional face-to-face gender comparisons (such as exposure to disruptive peers, mainly men) and better self-control over their own activities [68]. The shift to a virtual classroom may have allowed female students to build self-confidence through INT and practical engagement with ICT_TASKS, resulting in significantly higher latent DIC means compared to male students.

Regarding the comparison of path coefficients between school types, MOT emerged as a significant predictor of DIC in both public and private schools. However, for students in public schools, DIC was directly predicted by EDU_MOTHER and indirectly influenced by INT. Conversely, for those in private schools, INT and ICT_TASKS served as the primary direct predictors of DIC. The most notable discrepancy between the groups was the direct path from INT to DIC, which reached statistical significance only within private schools ($W=4.422$, $p=0.036$). However, these structural findings must be interpreted with caution due to the previously noted limitations in achieving full measurement invariance across comparison groups.

This structural difference in the role of interaction can be understood through the lens of the digital divide exacerbated during the pandemic. Peruvian schools faced challenges mirrored in other Latin American countries. In Argentina, for example, WhatsApp was the technological medium used for most educational activities in primary and secondary schools [69]. Virtual or remote learning during the pandemic was

characterized by the use of the camera being turned off, which reduced or eliminated interaction through facial and body expressions [70].

Our results suggest that these limitations did not affect all students equally. As shown by the Peruvian Institute of Statistics and Informatics [71], there is a wide difference in Internet access depending on the device (86.6% of women and 87.4% of men use phones, but only 12.4% of women and 16.6% of men use a computer), which may partly explain the differential weight of INT in each group. In this context, the behavioral and cognitive effort required for learning is hampered, reducing MOT [72]. The reliance on asynchronous messaging apps further exacerbated these limitations, creating an environment where the conditions for INT were systematically unequal [73], [74].

This context could also explain the lack of full measurement invariance. The digital divide and remote learning constraints fundamentally altered the nature of digital engagement. Consequently, INT became intrinsically distinct across groups, reflecting how structural inequities reshaped the psychological and behavioral meaning of TEA and STU.

Overall, the findings support the idea that variables in the model may represent distinct aspects for each group, depending on gender and type of school, and consequently exhibit different structural coefficients within the SEM model [75], confirming H_9 and H_{10}. It is also important to acknowledge that the current theoretical frameworks on motivation do not fully account for the role of autonomy, self-efficacy, and persistence in virtual learning contexts during the pandemic. Likewise, existing theories of interaction fall short in explaining how students' online interactions have been transformed and how these changes affect both learning processes and the development of digital competence. The findings of this study therefore provide a valuable contribution to the ongoing reflection on these aspects, emphasizing the need to revisit and expand motivational and interactional theories in the context of digital education.

In summary, this study provides empirical evidence that motivation, virtual interaction, ICT-related tasks, and the mother's educational level are significant predictors of DIC among Peruvian secondary school students. From a theoretical perspective, these findings refine the application of the DIGCOMP 2.0 framework within the Latin American context by identifying specific sociocultural and psychological mediators. Also, it highlights the relevance of considering both psychological and educational factors to better understand and promote students' digital skills in increasingly complex learning environments. Although the study is limited by its focus on a specific age group and two urban contexts, the predictive model contributes to the field by integrating multiple variables that had previously been studied in isolation. Furthermore, this research was conducted in a context in which pandemic restrictions were still in place, for example, the heterogeneity of platforms for distance or virtual learning, such as the use of Zoom vs. WhatsApp, which could have introduced some bias in the results.

Future research should extend this approach to diverse regions and educational settings, incorporating additional socio-cultural and technological factors to strengthen the generalizability and applicability of the model. Moreover, these novel approaches must explicitly consider how inequitable access to devices, connectivity, and supportive learning environments shapes students' capacity to participate in virtual interactions and to develop their digital skills, especially in settings marked by structural socioeconomic disparities.

4. CONCLUSION

The findings of this research provide a robust structural model for understanding the psychological and contextual determinants of DIC among secondary school students. The final SEM analysis INT, MOT, ICT_TASKS, and the EDU_MOTHER as the fundamental pillars of DIC. Critically, the model highlights a sophisticated mediation effect: while INT directly predicts DIC, it also serves as a catalyst that enhances student MOT, which in turn significantly boosts DIC. Among these, MOT emerged as the most powerful direct predictor, suggesting that it is the primary driver of information competence in the digital age.

Finally, the multigroup analysis underscores a digital divide shaped by gender and socioeconomic disparities. Among male students, MOT and EDU_MOTHER significantly predict DIC, whereas for female students, INT and ICT_TASKS emerge as the primary predictors. In public schools, DIC is predominantly predicted by MOT and EDU_MOTHER; conversely, in private schools, MOT and ICT_TASKS stand out as the most significant predictors.

The theoretical model validated in this study provides a robust foundation for national policies and programs focused on digital competence development and assessment. To operationalize these findings, it is essential to integrate ICT_TASKS into the curriculum and promote digital literacy programs for mothers, thereby addressing the structural socioeconomic disparities that shape DIC.

At the institutional level, our findings highlight the need for tailored pedagogical strategies that account for gender and school-type variations, as these dynamics may differ across countries depending on

cultural norms and institutional resources. In parallel, sustained efforts must be made to promote the equitable use of digital technology between men and women.

Regarding the family environment, it is crucial to recognize the influence of parental involvement by providing guidance on home-based digital learning, particularly the instructional role of mothers for male students in public schools. Finally, for future research, the scope should be extended to rural populations to explicitly address how inequalities in device access and connectivity influence virtual interaction. Such efforts would be further enriched by incorporating qualitative methods to explore the relationships between INT, MOT and DIC.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by Institutional Review Board (IRB) “Comité Institucional de Ética en Investigación (CIEI)” from the Cayetano Heredia Peruvian University (research project no. 206148). This IRB is affiliated to the Office for Human Research Protections (OHRP) International Program with the following codes: IORG0000671 and IRB00001014 (valid until March 21st, 2025). Federal wide Assurance code: FWA00000525 (valid until January 23rd, 2028).

DATA AVAILABILITY

The data and analysis code that support the findings of this study are openly available in the Open Science Framework (OSF) at https://osf.io/ebrgd. Supplementary materials are available on request from the corresponding author, [TF-B].

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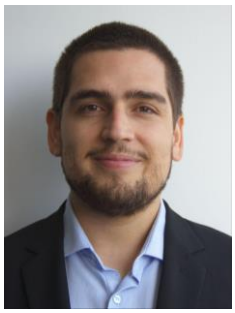

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