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RESEARCH ARTICLE

REVISED Students' Digital Competence and Perceived Learning: The mediating role of Learner Agility [version 2; peer review: 1 approved, 3 approved with reservations]

Vidya Patwardhan [ID]1, Jyothi Mallya [ID]1, Rahul Shedbalkar[1], Sandeep Srivastava[1], Kartikeya Bolar [ID]2

1Welcomgroup Graduate School of Hotel Administration, Manipal Academy of Higher Education, Manipal, Udupi, Karnataka, 576104, India
2T A Pai Management Institute, Manipal Academy of Higher Education, Manipal, Udupi, Karnataka, 576104, India

Abstract

Background: The ravages of COVID-19 escalated the penetration of online education and usage of digital technologies. While educational institutions across the globe adopted different forms of computer-mediated communication, the institutes in India have gradually attuned to the new normal, notwithstanding the initial glitches of adopting new technology and shifting to blended. It became increasingly significant to gain a better understanding of students' perspectives of newly emerged learning environment. This motivated the researchers to study the digital competencies (DC) and their impact on students' learning agility (LA) and perceived learning (PL) in professional/technical education.

Methods: In this cross-sectional study, a DigiComp 2.1 framework was attempted to investigate the relationship between DC and PL among higher education students in India. The data from 359 graduate and post-graduate students were analyzed using Structural equation modelling and Process Macro 4.0.

Results: The findings of this study revealed that DC has a significant positive impact on PL (b = 0.33; p < 0.001), indicating that higher learners' DC leads to higher learning outcomes. Similarly, DC also had a significant positive impact on LA (b = 0.59; p < 0.001), suggesting that the higher DC of learners leads to higher learning agility. Further, a positive significant relationship was also found between LA and PL (b = 0.21; p < 0.001). This significant positive path reveals that higher

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1. **Ramachandran Sivakumar** [ID], Sri Ramachandra Medical College and Research Institute (Deemed to be University), Chennai, India

2. **Heliona Bellani (Miço)** [ID], Universiteti Epoka, Tirana, Albania

3. **Ahmad Samed Al-Adwan** [ID], Al-Ahliyya Amman University, Amman, Jordan

4. **Mahboobe Mehrvarz**, Carnegie Mellon University, Pittsburgh, USA

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learners' agility leads to higher student learning outcomes.

Discussion: Post-COVID, DC, a technology-related skill set is linked to the academic performance of teachers and students. Our findings reveal that DC significantly positively impacts PL and LA. Therefore, we recommend that the higher educational institutes in India consider the inclusion of DC in their curriculum as a fundamental competence for a better learning outcome for learners.

Keywords
Digital competence, learners' agility, perceived learning

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Corresponding author: Jyothi Mallya (mjyothimallya69@gmail.com)

> **REVISED** **Amendments from Version 1**
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> In this revised version, we have expanded the concept of online education and added more content on perceived learning. Further, we have now explained the proficiency levels of digital competency in the research methodology section. Accordingly, new references have also added to the reference list. We believe that the manuscripts' readability is increased by incorporating the changes recommended by the reviewers. The Methodology section has been expanded as suggested. A brief outline of the measures taken to orient the respondents to the terminologies used in the survey has been explained. Similarly, an explanation of the usage of items related to DC, the levels, and justification for using the items in a Likert scale form is provided. More information on the analysis is provided to make the results section clearer to the readers. We have strengthened the conclusion part of the article by justifying the necessity to enhance digital initiatives in higher education in India.
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Introduction

With the unprecedented entry of COVID-19 into our lives, digital technologies are re-evolving and emerging as one of the most potent tools even in the most non-volatile ecosystem of education. Today, education is broken, and we are trying to fix it with technology (technologization) (Teräs *et al.*, 2020). This profound change toward democratization of education expects high levels of digital competence (DC) from teachers and students. Though it started as a stopgap solution due to the COVID crisis, the technology dependence spearheaded the abrupt shift toward full-fledged online education (OECD, 2020). The educational institutes in India have gradually attuned to the new normal, notwithstanding the initial glitches of adopting new technology and shifting to blended learning (IBEF, 2021; India Today, 2021). As an outcome of this, today, students are a community disconnected physically and broadly connected virtually. The ubiquitous use of virtual teaching-learning to maintain continuity in education stimulated innovative teaching-learning practices (Lockee, 2021). In higher education institutions, the hybrid shift is a new way forward and the acceleration of blending in-person and online learning has become the new normal (Selingo & Clark, 2021). Online education has paved the way for complete integration of Internet and education and acquisition of necessary skills.

This shift necessitates proficiency in a series of DC for learning and performance in digital formal and informal learning environments (Elstad & Christophersen, 2017; Heidari *et al.*, 2021; Mehrvarz *et al.*, 2021). Critical to the success of the transition to online education is the inevitability of attaining the requisite knowledge, skills, and attitudes to embrace digital technologies constructively (Coman *et al.*, 2020; OECD, 2020). It is a tectonic shift (Govindarajan & Srivastava, 2020) featuring hybrid or blended classrooms, collaboration, equity, experimentation, and innovation that may continue to be an effective learning ecosystem (Miroshnikov, 2021). Numerous online resources facilitated students to access, create, and share digital content for collaborative education. The role of DC has become more critical due to its holistic emphasis on the ethical, safety, and social dimension and the inclusion of diverse knowledge, abilities, and desires of individuals (Falloon, 2020; Foulger *et al.*, 2017). Parallel direction is apparent within the education domain, where the focus should be on enhancing the learner's capabilities for better participation in digital society (Martzoukou *et al.*, 2020).

The development of digitally competent, able, and skilled professionals within the ever-changing technological and online environment expect learners to be agile in their ability to learn, adapt, unlearn, and relearn to keep up with the frequently changing learning environment (Fulton & McGuinness, 2016; Martzoukou *et al.*, 2020). The digitally literate generation must remember the three vital components of learning agility (LA): 1. Potential to learn, 2. Motivation to learn, and 3. Adaptability to learn (Amato & Molokhia, 2016). Agile learners are willing to learn continuously and apply the knowledge in new situations (De Meuse *et al.*, 2010; Kim *et al.*, 2018). In a post-COVID academic environment, it is extremely important to be agile in the adoption of technologies that allow for flexible and personalized learning (OECD, 2020). Today, governments, institutions, educators, and students have experienced the need for digital literacy and generic digital skills. However, past research shows that undergraduate students need intense training in digital technologies as they do not effectively attempt to integrate them into their educational experiences (Piotrowski, 2015; Strømsø *et al.*, 2013).

The key terms used to explain digital technologies in digital parlance include information and communication technology (ICT) literacy, Internet skills, Information literacy, media literacy, digital literacy, and DC (Chetty *et al.*, 2018). Among these, DC, an emerging concept that describes technology-related knowledge and skills, has been acknowledged as a critical competence vital for enduring learning (Falloon, 2020; Iordache *et al.*, 2017). In the higher education research context, it is defined as "the ability to explore and face new technological situations flexibly, to analyze, select and critically evaluate data and information, to exploit technological potentials to represent and solve problems and build shared and collaborative knowledge, while fostering awareness of one's responsibilities and respect of reciprocal rights/obligations" (Scuotto & Morellato, 2013; Spante *et al.*, 2018). Due to the advent of continued online learning, DC has

become a buzz term that resonates explosion of digital information, communication, and interaction among people, especially the academic fraternity. According to the European DC framework for citizens (DigComp 2.1), the five key components of DC are; 1. Information and data literacy, 2. Communication and collaboration, 3. Digital content creation, 4. Safety, and 5. Problem-solving (Ferrari et al., 2013a). Experts opine that the key components of DC are fundamental to supporting an individual's lifelong learning and employability (Guitert et al., 2021; Zhao et al., 2021). Therefore, the student perspectives of cognitive, emotional and social aspects of the learning process in a digital environment require special attention.

In India, Ministry of Human Resource Development (MHRD) launched various digital initiatives to address the challenge of remote learning to build the future of 25 crore students (MHRD, 2020). It is time to develop systematic approaches to map the DCs of students in higher educational institutions as a coherent learning continuum. Despite its importance, many higher education institutions in India have not yet developed an organized method to map the DCs of students as a priority. Today, the development of digital skills from the point of view of employability is a baseline requirement. Universities have to design resources to support students to develop digital skills. Using the DigComp 2.1 framework, this study tries to report students' current DC profile and learning agility that might help bridge the digital divide in institutions of higher learning in India. It is presumed that the extent to which students benefit from digital learning depends on students' competence in utilizing these environments. As propagated by the developers of DigComp, we need a tool to enhance learners' DC as a pointer for policymakers to formulate guidelines to improve the DC of specific target groups (Vuorikari et al., 2016).

Alongside, understanding self-perceived DC levels by the students would facilitate learning as students have diverse digital experiences based on their background characteristics. Hence, the LA of students is taken as a mediator to investigate the effect of DC on students' PL. In the digital learning environment, factors related to the nature and content of learning affect the perceived learning of students (Blau et al., 2020). Past research indicates that perceived learning is considered an indicator to measure the effectiveness of online and blended learning environments (Akyol & Garrison, 2011; Harrell & Wendt, 2019). Therefore, the student perspectives on cognitive, emotional, and social aspects of the learning process in the digital learning environment (Richardson, Maeda, & Lv, 2017) require special attention. It is felt important to examine the linkage between the issues explained in the preceding paragraphs and the perspectives of students i.e. their perceived learning experiences. It is assumed that LA stimulates the student's motives to enhance digital skills. This quantitative study aims to test the conceptual framework highlighting the positive relationship between DC, LA, and PL using structural equation modelling and mediation analysis. To the authors' knowledge, this is an under-researched domain and could be an addendum to continue efforts towards creating a digital society by developing novel DC frameworks specific to the needs of Indian higher education students. Throughout this paper, the term 'DC' will be used as an umbrella term for various key terms related to digital skills.

Literature review
Digital competence and Perceived Learning
DC is a multi-faceted concept (Sánchez-Caballé et al., 2020) that evolved from diverse backgrounds (Gallardo-Echenique et al., 2015; Lucas, 2019). The UK higher education context proposed Digital Capabilities Framework having six elements (Biggins et al., 2017) that can be used to enhance students' ability to steer self-learning for continuous development. Likewise, the European Commission developed the DC framework (DigComp2.1) to respond to the ever-increasing need to operate effectively in a knowledge-intensive society (Sillat, Tammets, & Laanpere, 2021). With five dimensions and 21 elementary competencies, this framework was first published for European citizens in 2013 and renewed in 2017. This framework highlights the significance of digital creation, innovation, communication, collaboration, engagement, and digital identity (Lucas, 2019; Sillat et al., 2021). Later it was adopted within the education sector to create a standard for evaluating the DC of educators and students (Lucas, 2019). Experts predict that acceleration in edutech growth will sustain, and DC training in higher education (MHRD, 2020) will profoundly shift the focus towards using digital technologies to enhance students' learning experiences and facilitate the development of their DC.

Regrettably, in a traditional learning environment, similar instruction styles are followed regardless of the individual learning abilities of students. The digital resources are designed at baseline, ignoring individual learners' present DC levels (Martzoukou et al., 2020). As students belong to different demographics, the requirement of levels of support for DC may vary (Martzoukou et al., 2020). The diversity in socio-demographic characteristics may widen the digital divide (Moore et al., 2018). Hence, it cannot be presumed that all students arrive at university with the same levels of DC. Some studies suggest that students develop DC spontaneously in digital learning environments through active engagement and self-motivation (Heidari et al., 2021; Lucas, 2019; McGuinness & Fulton, 2019). At the same time, few others emphasize the close linkage between well-founded pedagogy, didactics, and DC (Sung et al., 2016; Tamim et al., 2011). In the digital learning environment, it is argued that meaningful learning occurs when students are active,

constructive, intentional, authentic, and cooperative (Howland *et al.*, 2012). The above standpoints deliberated by researchers with diverse backgrounds invite the inquiry of learning processes from students' perspectives (Blau *et al.*, 2020).

Theoretically PL consists of cognitive, emotional, and social aspects that deal with understanding new insights, feelings and experiences during learning and inter-personal interactions through the learning sessions (Blau *et al.*, 2020; Rockinson-Szapkiw *et al.*, 2016). It primarily relates to two predominant aspects of learning: knowledge acquisition and knowledge transfer (Barbera *et al.*, 2013) which are projected to be essential to acquire DCs. However, the prediction of DC having a significant relationship with PL has largely remained unexplored. There is no evidence thus far investigating this relationship in the extant literature related to online education. Hence, we propose the following research hypothesis:

H1: There is a significant positive relationship between students' Digital competence and perceived learning in an online learning environment.

Digital Competence, Learner Agility, and Perceived Learning

The researchers in the field of digital literacy and competence feel that mere usage of digital tools will not automatically make students digitally competent (González & Martín, 2017; Sánchez-Caballé *et al.*, 2020). There is a gap between formal (e.g. educational software, technology theory) and informal (e.g. multimedia tools) digital skills and abilities of university students (Flores & Roig, 2016; Parvathamma & Pattar, 2013; Prieto *et al.*, 2020; Purushothaman, 2011). In the formal setup, students lack experience in e-learning skills and abilities (Poulová *et al.*, 2011). Research studies have revealed that undergraduate students need extensive training in digital technologies (Kim *et al.*, 2018). This training is essential when students enter a blended learning environment, primarily pointing to the post-COVID education scenario. To moderate the gap, in institutions of higher learning, both learners and educators need to develop technology-related knowledge, skills, and attitudes through ongoing learning programmes (Kim *et al.*, 2018). Only agile ("agile" as used in the domain of technology) methodology and development referring to iterative processes and continuous improvement by building a culture of constant growth (Himmelsbach *et al.*, 2019) seems to be the viable solution. Students must embrace an agile mindset to meet the demands of digital innovations.

LA is an essential factor that integrates digital technologies into student learning and engagement in academic life. The theory of Learning Agility emphasizes that "individuals who have performed well in the past will not necessarily perform well in the future in a new job" (Connolly, 2001). It is believed to significantly influence learners' ability to progress to more complex and challenging learning assignments (Almeida, 2019). Similarly, it can be presumed that students living in an era of transition may find it challenging to adapt to new learning situations with the present DC levels. Therefore, they are anticipated to be flexible and fast learners amid a high level of knowledge uncertainty posed by COVID-19 and evolving digitalization as prerequisites to seize new opportunities. The construct LA is more appropriate for consideration in this research context as its basis is rooted in adult learning and self-regulated learning (Allen, 2016). Students perceive that agile practices have a great potential to enhance their learning experiences (Melnik & Maurer, 2002). The definition of perceived learning, i.e. "changes in the learner's perceptions of skill and knowledge levels before and after the learning experience", as given by Alavi *et al.* (2002), is appropriate in this context to ensure the quality of learning and improvement in the learning experience. Hence, as a predictor of students' enriched learning experience, we hypothesize that LA mediates the relationship between DC and PL.

H2: There is a significant positive relationship between students' Digital competence and learning agility in an online learning environment.

H3: There is a significant positive relationship between students' learning agility and perceived learning in an online learning environment.

H4: The learning agility of students mediate the relationship between students' Digital competence perceived learning in an online learning environment.

Based on the above literature, the following model (Figure 1) is proposed.

Methods
Ethics and consent
Ethical approval was obtained from the Institutional Research and Ethical Committee of Welcomgroup Graduate School of Hotel administration (WGSHA), Manipal Academy of Higher Education via Reference No. WGSHA–IRC-2021-02
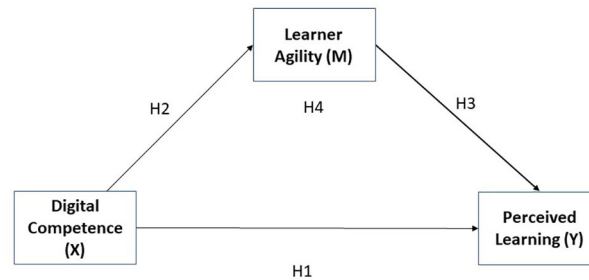
Theoretical Framework

Figure 1. Proposed model.

dated 14-08-2021. The committee waived the written consent since there was no risk involved for the participants, and most participants were above 18 years of age. Parental consent was also waived for a few participants of 17 years because of the no-risk nature of the study, and these underage participants were in the same cohort as the other participants, i.e., university students. Additionally, one of the authors visited the classrooms to explain the objectives and informed the participants that participation in the survey is voluntary. Thus, verbal consent was obtained before distributing the online survey form.

Data collection and sample profile

Data was collected from 359 full-time students across professional disciplines of a well-known private university in India. This university offers higher education in Medical, Paramedical, Allied Health, Health Science, Pure Science, Technology, Management, Hospitality Management, Commerce, Media, Humanities, Geopolitics, and few other disciplines. The diversity in the background was considered adequate to represent the different proficiency levels in DC among the student community. The questionnaire was developed in Microsoft Forms, and the web link of the online questionnaire was emailed to 1,200 students with an explanation on the constructs as well as study objectives. Though online, the researchers circulated the questionnaire to the students in the classroom. The research team members were present to explain the constructs of the study variables. The majority of the students filled out and submitted the questionnaire in the presence of the researchers. The data was collected in May 2021 and August 2021. A week after this, a follow-up email was sent as a reminder to expedite the data collection process. The data was collected in the month of May 2021 and August 2021.

In this cross-sectional research, the respondents were selected based on purposive sampling. The respondents have attended a minimum of 12 months of online classes. In total, 359 valid responses were received yielding a response rate of 30%. The sample included among the respondents, 224 (62.4 %) male and 135 (37.6%) female students. Among the respondents, 315 (87.7%) were undergraduates, and 44 (12.3%) were postgraduates.

Measurement of constructs

The measuring instrument was developed after an in-depth literature review. The DC survey instrument was borrowed from (Ferrari *et al.*, 2013b). DigComp 2.1 provides a set of proficiency levels ranging from basic to advanced and is intended to provide a common understanding of what individuals should be able to do at each level. For example, at the basic proficiency level, individuals should be able to perform simple tasks such as sending and receiving emails, using search engines to find information, and creating simple documents. At the advanced proficiency level, individuals should be able to perform more complex tasks such as programming, data analysis, and creating interactive digital content. The proficiency levels are intended to provide a common understanding of what individuals should be able to do at each level and to help educators and trainers design learning experiences that are appropriate for the level of the learners. The 21 items were measured on a 5-point Likert scale where 1 represents "very low", and 5 represents "very high". A higher value would indicate a higher level of DC. Though the original DC framework is based on three levels, we have adopted a 5-point Likert scale (Mehrvarz *et al.*, 2021) to have uniformity in measuring all constructs. A higher value would indicate a higher level of DC. The LA (five items) was measured based on the scale of Kim *et al.* (2018). Respondents were requested to rate their agreement or disagreement with the statements on a 5-point Likert scale where 1 representing strongly disagree and 5 representing strongly agree. The outcome variable's PL scale (six items) was adopted from the study by Narayan *et al.* (2021). These variables were operationalized using a 5-point Likert scale ranging from 1 (strongly disagree) and 5 (strongly agree). The respondents' demographic details such as age, gender, and education were also included in the survey instrument. The full questionnaire can be found in the Extended data (Mallya & Patwardhan, 2022b).

Sampling adequacy

The Kaiser-Meyer-Olkin (KMO) test was used to test the sample adequacy. The KMO value is above the recommended value of 0.6 (0.93), and Bartlett's test of sphericity is significant (χ^2 (210) = 4478, p < .001), thus confirming the suitability of data for factor analysis (Kline, 1994).

Psychometric properties of the first-order factors

Reliability and validity (together known as psychometric properties) of the constructs (or factors) are the two prerequisite features in evaluating the measurement scale. This ensures the integrity and quality of a measurement scale. Before assessing the structural model, the first-order factor's measurement model's psychometric properties were assessed using the confirmatory factor approach. The model displayed good model fit indices (CFI = 0.95; TLI = 0.94; RMSEA = 0.05; SRMR = 0.05; x2/df = 2.64). The model was further tested for its reliability and convergent validity (Table 1). Reliability was assessed based on the composite reliability (CR), and convergent validity was assessed based on the average variance extracted (AVE) values. According to Hair *et al.* (2014), the value of CR and AVE should be more than 0.70 and 0.50, respectively. All these values were above the recommended value (Table 1), suggesting the constructs' reliability and convergent validity. Further, except for the factor "Communication", the model achieved discriminant validity (Table 2). However, this is common due to the high correlation between the manifest indicators (Koufteros *et al.*, 2009; Marsh & Hocevar, 1985).

Table 1. Psychometric properties of the first-order factor measurement scale.

Factors and their indicators	SL	t-value	CR	AVE
Information and data literacy				
INF1	0.756	1	0.836	0.630
INF2	0.811	14.718		
INF3	0.813	14.747		
Communication				
COM1	0.731	13.069	0.874	0.536
COM2	0.729	13.354		
COM3	0.727	12.871		
COM4	0.756	12.904		
COM5	0.739	12.927		
COM6	0.711	1		
Content Creation				
CON1	0.811	1	0.866	0.619
CON2	0.850	14.454		
CON3	0.760	15.057		
CON4	0.720	13.570		
Safety				
SAF1	0.823	1	0.856	0.600
SAF2	0.859	12.324		
SAF3	0.765	12.620		
SAF4	0.632	11.733		
Problem-solving				
PRO1	0.823	1	0.868	0.623
PRO2	0.859	14.608		
PRO3	0.765	17.480		
PRO4	0.632	16.203		

SL – Standardized loadings; CR – Composite reliability; AVE – Average variance extracted.

Table 2. Discriminant validity analysis of first-order factor.

	INF	COM	CON	SAF	PRO
INF	0.794				
COM	0.745***	0.732			
CON	0.645***	0.648***	0.787		
SAF	0.440***	0.482***	0.327***	0.775	
PRO	0.649***	0.719***	0.743***	0.595***	0.789

***Significant at 0.001 level.

Table 3. Comparison between the four models.

Fit indices values	Model 1	Model2	Model 3	Model 4
X2	1585.849	1251.59	502.65	547.288
CFI	0.680	0.751	0.926	0.917
TLI	0.645	0.730	0.913	0.905
RMSEA	0.144	0.125	0.071	0.0704
x2/df	8.391	6.622	2.808	2.974
AIC	1669.89	1335.58	606.651	641.288
BCC	1832.95	1498.68	808.58	823.80

CFI – Comparative fit index; TLI – Tucker–Lewis index; IFI – Incremental fit index; RMSEA – Root mean square error of approximation; SRMR – Standardized root mean square residual; AIC – Akaike information criterion; BCC – Browne–Cudeck criterion.

Model comparison

After achieving reliability and validity for the first-order factors model, the performance of the second-order factor model of DC was tested. Generally, first- and second-order CFA are conducted to validate the multi-dimensional scale. Specifically, when first-order factors act as indicators of second-order factors. Since DC comprises five sub-dimensions, the development of four models using a hierarchical approach was adopted to validate the second-order factor model (Rindskopf & Rose, 1988). First, the single first-factor model with 21 items of DC was loaded (Model 1). The second model hypothesized that all the five dimensions of DC were separate and unrelated (Model 2). The third model (Model 3) hypothesized that all the five dimensions of DC were distinct but correlated. The fourth model (Model 4) was the second-order factor model of DC.

The hypotheses were tested using confirmatory factor analysis. The results are presented in Table 3. Table 3 shows that Model 1 and Model 2 did not have acceptable model fit indices. Further, Model 3 had marginally better model fit indices than model 4. Though model 3 had better fit indices, model 4, which hypothesizes a second-order factor model, was considered since it also had an acceptable fit.

Results

Measurement model

The overall measurement model was tested using CFA after achieving desired model fit for the second-order factor. The purpose of the measurement model is to examine the relationship between the latent variables and their measures. The model indices values as per the recommended values (CFI = 0.94; TLI = 0.94; RMSEA = 0.04; SRMR = 0.05; x2/df = 2.37). The second-order factor model of DC was further tested for convergent and discriminant validity. The CR and AVE values were above 0.7 and 0.5, respectively (Hair et al., 2014) (Table 4). The discriminant validity of the constructs was tested by comparing the square root of AVE to bivariate correlation values between the constructs (Table 5). According to (Fornell & Larcker, 1981) square root of all measuring constructs should be greater than the bivariate correlation values between the constructs. The overall measurement model achieved discriminant validity.

Structural model and hypotheses testing

After establishing the reliability and validity of the measurement model, the model fit indices of the structural model were tested (Table 6). The purpose of the structural model is to test the proposed hypotheses in the study. The fit indices were within acceptable range (CFI = 0.928; TLI = 0.922; RMSEA = 0.0544; SRMR = 0.0604; x2/df = 2.04).

Table 4. DC as a second-order factor.

Factors and their indicators	SL	t-value	CR	AVE
Digital competence			0.889	0.619
INF	0.82			
COM	0.859	10.396		
CON	0.858	9.782		
SAF	0.587	7.804		
PRO	0.776	11.161		
Learning agility			0.809	0.515
LEA1	0.655			
LEA3	0.76	11.332		
LEA4	0.693	10.639		
LEA5	0.757	11.301		
Perceived Learning			0.88	0.571
PEA1	0.7			
PEA2	0.732	12.795		
PEA3	0.794	13.788		
PEA4	0.833	14.39		
PEA5	0.667	11.719		
PEA6	0.792	13.763		

SL – Standardized loadings; CR – Composite reliability; AVE – Average variance extracted.

Table 5. Discriminant validity Analysis of second-order factor.

	DC	LA	PER
DC	0.787		
LA	0.592***	0.718***	
PER	0.455***	0.402***	0.755***

DC – Digital Competence, LA – Learners' Agility, PER – Perceived Learning.

Table 6. Model fit indices of the measurement and structural models.

Model	x2/df	CFI	TLI	RMSEA	SRMR
Measurement model	2.239	0.915	0.907	0.059	0.0605
Structural model	2.043	0.928	0.922	0.0544	0.0604

The structural model assessment was used to test the hypothesized relationship as conceptualized in the proposed model. This included the relationship between DC, LA, and PL. The R^2 values (the coefficient of determination) and beta values (path coefficients) were the parameters used to determine the strength and magnitude of the relationship between the constructs. All path relationships were statistically significant (Figure 2).

Hypothesis 1 (H1), proposing a significant positive relationship between DC and PL, was accepted (b = 0.33; p < 0.001), indicating that higher learners' DC leads to higher learning outcomes. Similarly, hypothesis 2 (H2), which postulated the significant positive relationship between DC and learners' agility also found support (b = 0.59; p < 0.001), suggesting that the higher DC of learners' leads to a higher level of learning agility. The third hypothesis (H3) that proposed the positive relationship between the learners' agility and PL also found support (b = 0.21; p < 0.001). This significant positive path reveals that higher learners' agility leads to higher student learning outcomes.
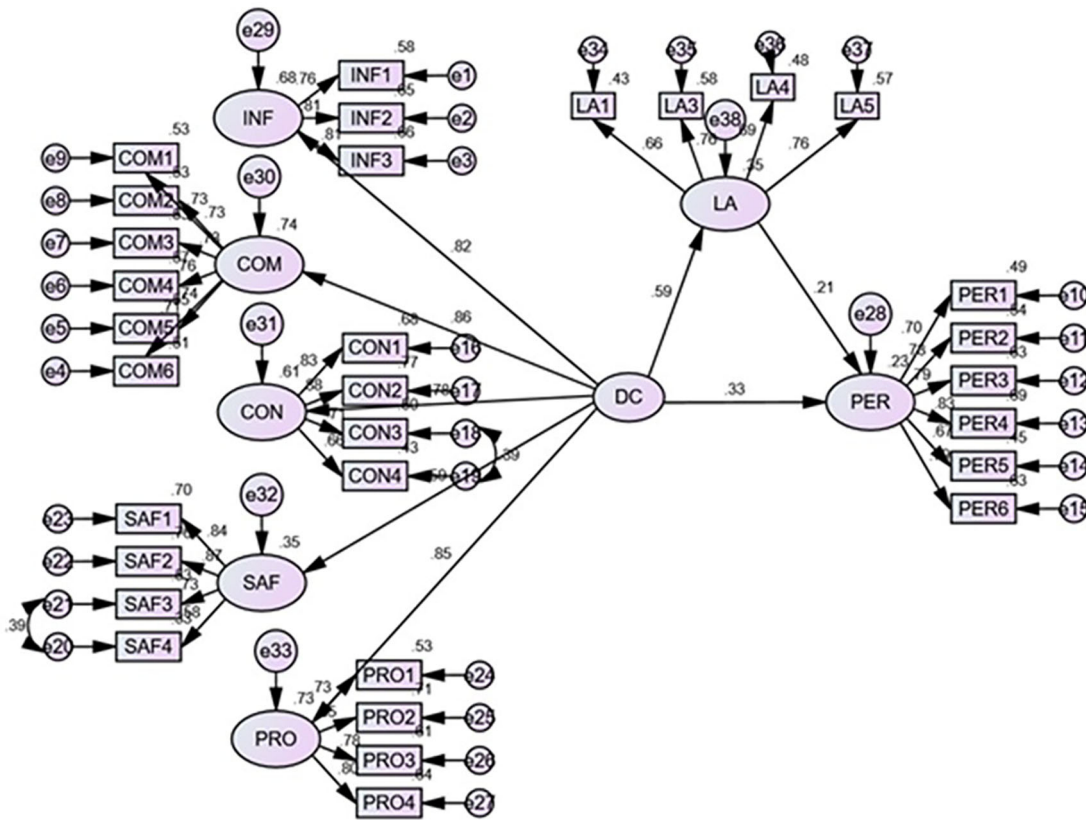
Figure 2. Structural model.

Mediation analysis

The mediating effect of learning agility between DC and PL was analyzed using PROCESS macro model 4 (Hayes, 2018). We have used the bootstrap method with 5000 re-samples to test the indirect effect as the sample size was adequate (Zhao *et al.*, 2010). It is found that LA has a mediating effect between their DC and PL (H4MFE-SAT-SWL: β= 0.1238, 95%, CI [0.0381, 0.216]).

Discussion

Today higher education is becoming learner centric. The teacher assumes the role of a facilitator and catalyst to engage students in active learning with the support of innovative online teaching-learning tools and high-tech, content-rich instructional resources. Blended learning has emerged as a viable solution to manage the rapid shift to online education. In such an environment, DC plays a crucial role in students' academic life (Alexander *et al.*, 2016; Olszewski & Crompton, 2020). In this environment, LA (the ability to learn from the experience and adapt to new circumstances) becomes essential for integrating digital technologies into student learning and engagement in academic life.

The overarching aim of this study was to investigate the postulated association between students' DC, LA, and PL in institutions of higher learning. To do this, we proposed four hypotheses, and the findings supported the proposed hypotheses. First, DC of students positively impacts their PL (H1). In other words, the greater the DC higher the self-perceived learning among students. E.g. the greater the self-perceived DC of students while dealing with daily digital tasks, the more likely they are to develop high self-perceived DC in areas related to their education (Martzoukou *et al.*, 2020). However, thus far, no empirical studies in the literature have established the direct relationship between DC and PL. Second, DC significantly influences LA (H2), and the LA positively impacts students' PL. Per the preceding statement, Kim *et al.* (2018) argued that their agility mediates the college student's perception of DC (ability to learn and readiness to apply the acquired knowledge). The additive results revealed that LA mediated the relation between DC and PL (H4), primarily an unexplored relationship predicted in this study. In all, the findings of our study is in line with few of the past research findings (Blau *et al.*, 2020; Heidari *et al.*, 2021; Himmelsbach *et al.*, 2019; Kim *et al.*, 2018; Mehrvarz *et al.*, 2021).

As the introduction and literature review mentioned, DC is a complex and multi-faced concept that spans several social, motivational, personal, cultural, and technical understandings. First, in the remote learning environment, students must be strongly encouraged toward self-directed learning. Researchers have a consensus that students are reflective of their learning (Miller & Mushfiq Mobarak, 2015; Plaza-De-La-Hoz et al., 2015). Their efforts in developing DC by becoming agile learners are a value addition (Kim et al., 2018). Second, in higher educational settings, educators' technology-related knowledge, skills, and attitudes become important to improve students' DC (García-Vandewalle García et al., 2021; Mishra & Warr, 2021). The importance of DC in students is also mirrored in the educator's attitudes, beliefs, and professional development (Spante et al., 2018). When an educator assigns a low value to DC, students do not appreciate or acquire the soft competencies. Educators must develop a positive attitude toward imparting the digital knowledge to students (Miller & Mushfiq Mobarak, 2015; Plaza-De-La-Hoz et al., 2015) at different levels to promote a culture of information-seeking. Third, students must be encouraged to develop self-efficacy in a safe atmosphere through the trial and error method. While researchers are investigating to develop an efficient method for improving DC among students, for a student, educators must open up for the adoption of new technologies and pedagogies. Lastly, the inclusion of course/s on DC in the higher education curriculum of all professional programs can become a 'best practice' of education. The dimensions of DC and their respective elements are undoubtedly applicable to a multitude of subject-specific areas (Karsenti et al., 2020), which is essentially to be adopted in present day higher education. DC can become an empowering agent to transform students into digitally literate by increasing awareness, safety behavior, digital tools, resources, and interfaces (Alt & Raichel, 2020). As students advance through the different levels of education, DC will support students to become more autonomous in using digital technologies in academic, professional, and daily lives.

Conclusion

Critical to the success of the transition to online education is the inevitability of having the requisite knowledge, skills, and attitudes to embrace digital technologies in a most productive manner (Coman et al., 2020; OECD, 2020). Numerous online resources facilitated students' access, creation, and digital content sharing for collaborative education. However, every student may not possess the digital skills and competence for a seamless changeover. Though today's learners are digitally enriched, it is evident that they are not entirely competent and agile in using the digital resources offered by the institutions. The convergence of technology, pedagogy, and an inclusive online or hybrid learning environment will push students to develop critical DC that fosters active learning and participation. Students' prior experience with DC, where they can use a full range of digital technologies for information, communication, creation, safety, and problem-solving, will take centre stage in learning in this environment. It is documented that DC development should be initiated at an early age. Introducing a DC-based curriculum at the secondary-school level education would be ideal. However, to address the immediate needs in the post-COVID world, the integration of components of digital technologies within the higher education curriculum would support the transformation of students as "digitally literate natives". In India, with the 'youth bulge' (UNFPA India, 2021), to advocate the livelihood skill education of youth, digital enablement is vital in creating a digitally inclusive society. Towards this end, our study throws light on the necessity of developing a DC framework as a policy document that can be used in various disciplines within the landscape of higher education. This framework's orientation should be towards using digital technology in professionally purposeful ways for lifelong learning. As given in the NMEICT manual by the MHRD, India, "to reach out to Higher Educational Institutions (HEIs) in such regions and states which may not be much aware of these digital initiatives, an attempt is being made in the form of a Handbook on Digital Initiatives in Higher Education" (MHRD, 2018). The findings and the framework of this research will support such initiatives of the department of higher education in improving digital education solutions.

Limitations and further research

Though this study attempted to comprehend how DC and learning agility relate to and predict perceived online learning, some limitations must be noted. First, a quantitative survey is a self-report of perception of DC and learning agility. Other methods such as focus group interviews and different experimental designs can be utilized for future research. Second, a broad-based teacher DC framework must be introduced as educators have an indispensable role in implementing digital initiatives. Therefore, further studies could investigate the teaching fraternity's DC levels and learning agility. Third, this research focused on the students in only one large private university; hence, the results may not be generalizable. Inclusion of students in diverse learning settings may be undertaken to compare the perceptions. Fourth, the demographic variables should be considered to compare the results in future investigations. Finally, this article argues the need to expand students' understanding of the variety of DC necessary to function productively, safely and uprightly in diverse and progressively digitally mediated learning environments.

Data availability
Underlying data
Figshare: Students' Digital Competence and Perceived Learning: The mediating role of Learner Agility, https://doi.org/10.6084/m9.figshare.20423496.v3 (Mallya & Patwardhan, 2022a).

This project contains the following underlying data:

- Data.xlsx (the data set consists of four constructs: digital competence, perceived learning, learners' agility, and self-efficacy).

Extended data

Figshare: Digital competency_questionnaire.docx, https://doi.org/10.6084/m9.figshare.20423364.v2 (Mallya & Patwardhan, 2022b).

This project contains the following extended data:

- Digital competency_questionnaire.docx.

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

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Open Peer Review

Current Peer Review Status: ❓ ✔️ ❓ ❓

Version 2

Reviewer Report 02 January 2024

❓ **Mahboobe Mehrvarz**

Human-Computer Interaction Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA

Dear Authors,

Thank you for submitting your article. I appreciate the effort and work you have put into it. Overall, your paper demonstrates a well-executed and up-to-date research study.

In summary, your article titled "Students' Digital Competence and Perceived Learning: The Mediating Role of Learner Agility" addresses the relationship between digital competence, perceived learning, and learner agility. The study also aims to investigate the mediating role of learner agility in the relationship between digital competence and perceived learning.

I have reviewed the manuscript thoroughly and have prepared some comments and suggestions that I believe will contribute to further improving the quality and clarity of your work.

- In the abstract, you mentioned that digital competence (DC) has a significant positive impact on perceived learning (PL) and learner agility (LA). However, it is unclear whether the mediating role of learner agility between digital competence and perceived learning was found to be significant or not.
- On the fourth page of the article, in the last line of the first paragraph, the authors mention, "Therefore, the student perspectives of cognitive, emotional, and social aspects of the learning process in a digital environment require special attention." It is unclear how this sentence is directly connected to digital competence and why it is stated.
- The introduction primarily focuses on the importance and necessity of digital competence, while your paper encompasses three variables, and the aim of your research is to examine "Students' Digital Competence and Perceived Learning: The mediating role of Learner Agility." It would be beneficial to highlight the significance and necessity of the other two variables, "Perceived Learning & Learner Agility," in relation to digital competence to provide a more comprehensive understanding of the research objectives.
- In the literature review section, it would be valuable to clearly outline the research gap addressed by your study and highlight its novel contributions to the existing literature. Additionally, providing an overview of previous studies that have examined these variables, along with their findings, would be beneficial.
- In the methodology section, including a table summarizing the direct, indirect, and total effects of the proposed relationships would enhance the clarity and visual representation of

the findings.
- ○ The second sentence of the first paragraph in result, mentions "innovative online teaching-learning tools and high-tech, content-rich instructional resources" without providing specific examples or explanations. Clarifying these descriptions by providing concrete examples of these tools and resources would enhance the reader's understanding.
- ○ While the discussion mentions that the findings align with previous research, it would be beneficial to provide specific details or implications of these findings.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Educational Technology,Technology-Enhanced Learning, Artificial Intelligence in Education, Digital Games

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 20 December 2023

https://doi.org/10.5256/f1000research.144065.r228157

? **Ahmad Samed Al-Adwan** [iD]
Electronic Business and Commerce Department, Al-Ahliyya Amman University, Amman, Jordan

Thank you for submitting the revised version of your paper. The quality of this paper has increased significantly after addressing the reviewers' comments. However, the hypotheses development can be strengthen and benefit from well-established and related research. This includes but not limited to: (Al Adwan et al, 2020)[1]

References

1. Al Adwan Ahmad, Albelbisi Nour, Aladwan Shadia, Horani Omar, et al.: Investigating the Impact of Social Media Use on Student's Perception of Academic Performance in Higher Education: Evidence from Jordan dust. *Journal of Information Technology Education:Research*. 2020; **19**.
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Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Educational technology, computer-human interaction, e-commerce

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 15 March 2023

https://doi.org/10.5256/f1000research.144065.r163873

✔   **Heliona Bellani (Miço)** 🆔

Universiteti Epoka, Tirana, Tirana County, Albania

I saw the amendments to the first version of the article, the responses of the authors regarding the suggestions, and I have no further comments to make.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: The right to education, educational policy, teacher education, social inclusion

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

> Author Response 16 Mar 2023
> **Jyothi Mallya**
>
> Thank you so much for approving the manuscript. Thank you for your time and useful feedback as well.
>
> *Competing Interests:* No competing interests were disclosed.

Version 1

Reviewer Report 17 November 2022

? **Heliona Bellani (Miço)** 🆔

Universiteti Epoka, Tirana, Tirana County, Albania

The authors have addressed a very current topic, digital competence in education, which has been very sensitive in recent years, especially during the COVID-19 pandemic. Considering the need for digital competence in education, the article focuses on the connection between digital competence, perceived learning, and students' learning agility.

  ○ The authors are recommended to expand the concept of online education, which is touched on in the Introduction part.

  ○ The authors are recommended to dwell more on the concept of perceived learning presented in the literature review, as well as on the concept of students' learning agility as a skill inside the digital area.

  ○ In the framework of the analysis, there should be taken into consideration reasons that the students' DC is different. This can be related to the knowledge gained in pre-university education, which is addressed in the conclusions of the article but not during its analysis. Since the conclusions have affected the need for DC to be included in the curriculum of pre-university education, it is necessary to touch on how students have acquired these competencies. On the other hand, in the analysis, it is recommended to highlight the connection between digital competence and the study program followed by students, for example, the IT study program who may have higher DC than students from other fields.

  ○ The article used the DigComp 2.1 framework to evaluate the DC profile for students and learning agility. DigComp 2.1 provides the areas of digital competence and proficiency levels. Since the article referred to the DigComp 2.1 framework, it is suggested that this should be better evidenced in the methodology used.

  ○ It is necessary that the methodology used in the article be analyzed by psychometric experts.

The topic addressed in the article is current since society nowadays requires a set of competencies related to technology, which should start from school.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: The right to education, educational policy, teacher education, social inclusion

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 06 Feb 2023
Jyothi Mallya

The authors have addressed a very current topic, digital competence in education, which has been very sensitive in recent years, especially during the COVID-19 pandemic. Considering the need for digital competence in education, the article focuses on the connection between digital competence, perceived learning, and students' learning agility.
  ○ *The authors are recommended to expand the concept of online education, which is touched on in the Introduction part.*

Our reply: We have added more online educational content in the introduction.

  ○ *The authors are recommended to dwell more on the concept of perceived learning presented in the literature review, as well as on the concept of students' learning agility as a skill inside the digital area.*

Our reply: We have added this now.

  ○ *In the framework of the analysis, there should be taken into consideration reasons that the students' DC is different. This can be related to the knowledge gained in pre-university education, which is addressed in the conclusions of the article but not during its analysis. Since the conclusions have affected the need for DC to be included in the curriculum of pre-university education, it is necessary to touch on how students have acquired these competencies. On the other hand, in the analysis, it is recommended to highlight the connection between digital competence and the study program followed by students, for example, the IT study program who may have higher DC than students from other fields.*

Our reply: Thank you for this suggestion; since we did not measure the knowledge gained by the students during pre-university education, we can not perform this analysis now. However, we will keep this in mind and include it in future studies.

  ○ *The article used the DigComp 2.1 framework to evaluate the DC profile for students and*

> *learning agility. DigComp 2.1 provides the areas of digital competence and proficiency levels. Since the article referred to the DigComp 2.1 framework, it is suggested that this should be better evidenced in the methodology used.*

Our reply: We have briefly explained the proficiency levels of DC in the methodology section.

> ○ *It is necessary that the methodology used in the article be analyzed by psychometric experts.*

Our reply: We have consulted statistical experts about the methodology involved in the study. Further, we have also reported the psychometric properties of the constructs used in the study.

> *The topic addressed in the article is current since society nowadays requires a set of competencies related to technology, which should start from school.*

> ***Competing Interests:*** No competing interests were disclosed.

Reviewer Report 02 November 2022

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Ramachandran Sivakumar (iD)

Sri Ramachandra Medical College and Research Institute (Deemed to be University), Chennai, Tamil Nadu, India

The authors have taken a very relevant topic on digital competency for research. In the current development and use of digital tools and platforms, it is critical for the user to have an understanding of a few basic elements to explore the content, use it ethically, and explore without major limitations.

○ The authors could have expanded PL in the content of the article, though it is expanded in the abstract.

○ The authors have developed a measuring instrument for DC using the Digicomp manual. The manual itself does not use a Likert scale to measure the attributes of DC but used a three-level rubric with an operational definition. The attributes and Likert scale have been used in the survey for students to respond. Some of the attributes like 'Engaging in citizenship through digital technologies'', 'Netiquette', 'Managing digital identity', and 'Protecting health and well-being' needs an operational definition for the respondent/student to respond appropriately.

○ The authors have mentioned that oral informed consent has been obtained, but not detailed about any measures taken to orient the responders to the terminologies used in

the survey and grading used. This step is likely to cause bias or median responses like moderate. However, the survey items for PL and LA were clear to read.

- ○ As the statistical methods used were not common, a brief outline for using them in the analysis could help the reader to understand the data analysis better.

- ○ The discussion has been to give a way forward to introduce DC in the learning environment.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Physiotherapy, Education technology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 06 Feb 2023
Jyothi Mallya

The authors have taken a very relevant topic on digital competency for research. In the current development and use of digital tools and platforms, it is critical for the user to have an understanding of a few basic elements to explore the content, use it ethically, and explore without major limitations.
- ○ *The authors could have expanded PL in the content of the article, though it is expanded in the abstract.*

Our reply: Thank you for this advice; we have now added more content on the PL at the end of the introduction, as recommended by you.

> ○ *The authors have developed a measuring instrument for DC using the Digicomp manual. The manual itself does not use a Likert scale to measure the attributes of DC but used a three-level rubric with an operational definition. The attributes and Likert scale have been used in the survey for students to respond. Some of the attributes like 'Engaging in citizenship through digital technologies'', 'Netiquette', 'Managing digital identity', and 'Protecting health and well-being' needs an operational definition for the respondent/student to respond appropriately.*

Our reply: Since other constructs were on a 5-point Likert scale, we measured the DC on a 5-point Likert scale. The DC was measured on five levels instead of three: 1 being a low level and 5 being a high level of competence.

> ○ *The authors have mentioned that oral informed consent has been obtained, but not detailed about any measures taken to orient the responders to the terminologies used in the survey and grading used. This step is likely to cause bias or median responses like moderate. However, the survey items for PL and LA were clear to read.*

Our reply: Though online, the researchers circulated the questionnaire to the students in the classroom. The research team members were present to explain the constructs of the study variables.

> ○ *As the statistical methods used were not common, a brief outline for using them in the analysis could help the reader to understand the data analysis better.*

Our reply: We have added the purpose of using these statistical analyses.

> ○ *The discussion has been to give a way forward to introduce DC in the learning environment.*

Our reply: We have addressed this observation. Please refer to last paragraph of the conclusion section of the manuscript.

Competing Interests: No competing interests were disclosed.

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