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Online learning readiness in secondary education: validating the Online Learning Readiness Scale and examining the impact role of ICT familiarity

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Abstract

Online and blended learning have increased drastically during the pandemic, and their popularity has persisted as we emerge from this global crisis. This study aims to adapt and validate the Online Learning Readiness Scale (OLRS) to assess high school students. Secondary school students were recruited (n = 296) for the study. The OLRS scale included five components: Technology Readiness, Learner Control, Online Communication Self-efficacy, Self-directed Learning and Motivation for Learning. Results supported the OLRS scale in terms of reliability and internal construct validity in context of the study by confirmatory factor analysis and Rasch measurement with partial credit analysis. The differential item functioning analysis revealed no bias issues regarding gender, confirming the measurement invariance statistics achieved. The study also found that the majority of students (73.7%) engaged in online learning solely through their mobile phone. ICT familiarity, i.e., interacting with friends regularly, browsing online learning materials, and watching educational videos on YouTube, had a positive association with students' readiness for online learning. Students' access to social networks, online forums and online music did not have a significant effect on their readiness for online learning. The scale demonstrated the capacity to function as an assessment instrument for evaluating readiness for online learning in the context of secondary education. Educational implications were considered, including key requirements of supporting technology and pedagogical practice in online and blended learning environments.

KEYWORDS: Online Learning, Digital Readiness, Self-Directed Learning, ICT Familiarity, Secondary Education.

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1. Introduction

As online learning platforms developed suitable functionality and usability, researchers and educators have focused on the human factors that impact their effectiveness (Adedoyin & Soykan, 2020). Personal beliefs that impact engagement in online learning have emerged as a critical factor that is the subject of considerable research attention across multiple levels of education (Redmond et al., 2018). This topic is especially important as it has been linked to engagement and retention within online learning environments (Joosten & Cusatis, 2020). Understanding readiness of students in online learning plays an essential role in optimizing teaching and learning. In this manner, it can be considered a critical issue, as no matter how well-developed online pedagogies systems may be, they cannot benefit those who do not engage.

COVID-19 led to a rapid expansion of online and blended learning techniques. Around the globe educators and students rapidly transitioned to online learning as lockdown orders were issued to curtail contagion. Although information and communications technology (ICT) are becoming an essential component of educational curricula and learning environments

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worldwide (Turgut & Aslan, 2021), numerous constraints, including disparities in digital resources, insufficient access to reliable internet, limited preparedness and technological proficiency both at university (Hunt et al., 2022) and secondary school level (Perifanou et al., 2022). For many high school students and teachers, this was their first exposure to online learning (Maheshwari, 2021). Though internet and app use has become ubiquitous within school aged children, this should not be conflated with a general capacity to use online learning systems (Creighton, 2018). This appears to be a false assumption and further highlights the need for educators to understand not only student capacities, but their perceptions of ability within these environments. A study by Power et al. (2022) found that, after a rapid transition to online learning, the cohort with greater levels of online learning experience reported lower perceptions of readiness. This reflects the naïve initial beliefs that being generally competent in terms of social app use and basic ICT had adequately prepared them for this new learning experience.

Research on readiness for online learning has typically been examined at university level (i.e., Alqabbani et al., 2020; Peechapol et al., 2018; Tang et al., 2021). However, there is a lack of research discussing how to examine secondary students' readiness to study online and whether the ICT familiarities impact their readiness in the online learning environments in secondary education contexts. The pandemic situation has opened a space for online learning research among younger students. This research is anticipated to provide valuable insights by validating the scale's structure in secondary schools in a Viet Nam context. As experience with ICT resources has been previously identified as critical to adequate engagement with online learning (Power et al., 2022), this study also considers prior experience alongside reports of learner readiness to identify the potential for optimization and to generate practice recommendations grounded in empirical evidence.

Readiness for Online Learning

Readiness for online learning is defined as multi-dimensional in previous studies. It may involve a two-factor structure: comfort with e-learning, linked to cognitive style and resource-based learning materials, and self-management of learning (Smith et al., 2003). Pillay et al. (2007) defined online learning readiness as a construct that includes the dimensions of technical skills, computer self-efficacy, learner preferences, and attitudes towards computers. Hung et al. (2010) created a scale to assess readiness for online learning, defining it as being comprised of self-directed learning, motivation, computer/internet self-efficacy, learner control, and online communication self-efficacy. Meanwhile, Dray et al. (2011) argued that readiness for online learning could be assessed via subscales of learner characteristics, digital divide, and ICT engagement. These instruments were originally designed for higher education students. The recent study by Ramazanoglu et al. (2022) proposed an online learning readiness scale for high school students that involved three dimensions of internet self-efficacy, computer self-efficacy, and self-learning. Overall, the literature review (e.g., Farid, 2014; Tang et al., 2021; Yalley, 2022) revealed that the online learning readiness scale (OLRS) with five components (Technology readiness, self-directed learning, learner control, online communication self-efficacy, and motivation for learning) demonstrated suitable fit characteristics and was the most widely used.

Technology Readiness

Technological Readiness refers to the necessary skills and knowledge to use online learning platforms, tools, hardware (e.g., computers, tablets) and software to participate in online learning (Al-araibi et al., 2019; Singh & Thurman, 2019). Students' attitudes toward technology-based applications in learning contexts reflect their technical readiness (Farid, 2014; Shirahada et al., 2019).

Self-directed Learning

Self-directed learning requires students to manage their own engagement with various learning activities and also to consider their own performance within these activities (Farid, 2014). The Self-directed Learning subscale emphasizes student initiative in goal setting and decision-making (Geng et al., 2019). Self-directed learners actively seek knowledge and resources online (Geng et al., 2019). Suitably designed online systems and collaborative pedagogies can foster self-directed learning (Farid, 2014).

Learner Control

The Learner Control subscale measures students' ability to manage media systems in online learning (Scheiter & Gerjets, 2007). Well-designed online learning structures can enhance learner control, interest, motivation, and adaptive learning, while allowing customization to individual preferences (Scheiter & Gerjets, 2007). Lin and Chang (2011) found that higher learner control correlated with increased learning and more positive attitudes towards technology.

Online Communication Self-efficacy

The Online Communication Self-efficacy definition relates to students' capacity to establish unique and meaningful interactions, such as communicating successfully during group discussions (Alqurashi, 2016). Self-efficacy has been linked to successful learning outcomes across a wide range of learning settings and systems (Smith, 2003). Students' interpersonal skills help them connect with teachers and other students to achieve learning goals. Effective interaction in a technological environment has a significant impact on the success of the teaching process, as well as student learning outcomes (Farid, 2014).

Motivation for Learning

Learning motivation was crucial for student achievement and a predictor of learning outcomes and attitudes (Code, 2020; Nasir Ansari & Khan, 2020). Social settings influence whether individuals were proactive or passive in achieving goals (Ryan & Deci, 2000). Students' readiness to learn online significantly affected their class participation and interaction quality (Kauffman, 2015). Therefore, it is essential to examine factors influencing online learning readiness.

Students' ICT Familiarity and Online Learning

The rapid evolution of ICT, with widespread smartphone and internet access, reshaped how students study, communicate, and collaborate (Wright et al., 2022). Rangel-de Lazaro and Duart (2023) found that 56% of reviewed studies reported mobile phone use in online learning activities. ICT resources enhanced communication and resource access in distance and blended learning environments (Madadi et al., 2011).

Familiarity with ICT positively influences its use in online learning (Madadi et al., 2011). However, students often lack the necessary technology or digital literacy for effective online learning (Wright et al., 2022). Peechapol et al. (2018) reviewed studies showing a strong impact of online learning experience and knowledge on self-efficacy. Computer experience significantly enhances computer self-efficacy (Kim & Park, 2018). Reychav et al. (2016) found that peer interactions in mobile collaboration leverage network reciprocity. Conversely, Power et al. (2022) revealed that students with more prior online learning experience had lower perceptions of readiness, indicating that basic social app and ICT skills are insufficient preparation for online learning.

Research questions

This study aimed to adapt and validate the OLRS scale to assess students in secondary education contexts. We examine the structure of the adapted OLRS scale with a focus on its psychometric properties. The study also investigated the influence of students' ICT familiarity on their readiness to learn online. Thus, the present study addresses the following research questions:

1. What is the structure of the adapted instrument to measure students' readiness for online learning?
2. Does the instrument demonstrate suitable validity and reliability in the given context?
3. Does the adapted scale achieve equal invariance regarding gender?
4. Does students' familiarity with ICT affect their readiness for online learning?

2. Procedures and methods

2.1 Adaption the Online Learning Readiness Scale

The suitability if the scale to the given unique context was considering in light of rigorous psychometric standards (Kane, 2016; Messick, 1995) for adapting educational research instruments. The OLRS is adapted from the original OLRS by Hung et al. (2010). The questionnaire measures five components of students' readiness to learn online: Technology Readiness, Learner Control, Online Communication Self-efficacy, Self-directed Learning and Motivation for Learning. The original questionnaire covered five components with 40 items (8 items for each). The questions are constructed in the 5-point Likert format, with anchors ranging from 1 (strongly disagree) to 5 (strongly agree). The questions are adjusted and translated into Vietnamese from the original English version following the standard translation procedure.

2.2 Validity of the adapted questionnaire

Initial content validity

The adapted questionnaire underwent a review process involving two education experts and two high school educators. Following this, an independent researcher back translated the Vietnamese version into English, which was then compared with the original English version to ensure accuracy. After resolving translation issues and assessing content validity, a revised version was piloted with five high school students. The objectives were explained, and the students completed the questionnaire with guidance. Post-survey, students were asked about language and content concerns.

Participants

The study assessed 296 students (girls: 62.5%, boys: 37.5%) in two public schools in the southern of Vietnam. There were 106 10th-grade students (35.8%), 103 11th-grade students (34.8 %), and 87 12th-grade students (29.4%). Participants were provided with suitable information regarding the purpose of the project and their role, should they choose to participate. The voluntary nature of their participation and right to withdraw were clearly communicated in verbal and written form prior to participation.

Google Meet was the main platform for online teaching. Students who agreed to the survey received a Google Forms link from their school office. The online survey took 15 to 20 minutes and did not affect their school performance.

Questions related to students' familiarity with ICT were adapted from the ICT Familiarity Questionnaire (OECD, 2014), in which students were asked about three aspects related to digital devices, average times using the internet and activities using the internet on a typical day.

The background questionnaire was adapted form PISA 2015 and translated into Vietnamese (OECD, 2014).

Statistical analysis

Confirmatory factor analysis (CFA) was employed to evaluate the construct validity of the adapted instruments as a criterion for further analysis. CFA was employed with Mplus 7 (Muthén & Muthén, 2017) to assess the fit of the model. The weighted root mean square residual (WRMR), the comparative fit index (CFI) and the root mean square error of approximation (RMSEA) were considered when evaluating model fit. In educational research, the cut-off criterion can be accepted with RMSEA < 0.06, CFI > 0.90 (Hu & Bentler, 1999). The Mplus manual (Muthén & Muthén, 2017) suggested values below .90 for the WRMR, Angeles (2002) recommends a slightly higher cutoff of 1.0 with categorical data for an acceptable model.

Rasch measurement is a psychometric modelling measurement based on the item response theory. In the present study, the Rasch model in ACER ConQuest software was employed for polytomous items with partial credit analysis (PCA) (Adams & Wu, 2010). An item in the Rasch model fits well if its infit index is between 0.77 and 1.30, according to Griffin (2010).

The differential item functioning (DIF) analysis was utilized to examine statistical characteristics of an item. To test measurement invariance for polytomous items, we used the R lordif package (Choi et al., 2011), after testing the presence of DIF under the logistic regression framework. Pseudo R^2 statistics were used as magnitude measures and classified DIF as negligible (< 0.13), moderate (between 0.13 and 0.26), and large (> 0.26).

In this study, we referred internal consistency measured through Cronbach's alpha (α) and omega (ω) to examine interitem reliability (Gliner et al., 2016). The common statistical tests such as Pearson's correlations were applied. To calculate and visualize the findings, we employed the R psych package (Revelle, 2019) and the ggplot2 package (Wickham, 2016).

3. Results

3.1 Confirmation of construct validity of the five-dimensional model

We employed CFA to weigh fit model for the readiness for online learning with a five-factor model, involving Technology Readiness (TR), Learner Control (LC), Online Communication Self-efficacy (OC), Self-directed Learning (SL) and Motivation for Learning (ML). The CFA identified two items that did not fit the model. The modified model with 38 items was used for further analyses. The results showed marginal cut-off indices (CFI = .924, RMSEA = .066, WRMR = 1.470), suggesting that the model fit is acceptable, but not excellent. Significantly high and identical correlations were found among pairs of the components, ranging from .678 to .901.

Furthermore, Rasch measurement with the PCA revealed that the adapted OLRS model fit the data well. Generally, all items in the five subscales fit well to the present dataset. For the TR scale, the infit indices ranged from 0.91 to 1.11. All infit indices of the other subscales met quite well to the cut-off standards, excepting item of LC7. The highest means of person response were ML (Mean = 0.349, SD = 0.776), followed by SL (Mean = 0.294, SD = 0.692) and TR (Mean = 0.262, SD= 0.617), indicating that students have positive dispositions for these components. Students reported lowest scores in the OC and LC subscales.

The whole questionnaire results showed indicators of reliability with a Cronbach's alpha of .95 (ω = .95). For individual subscales, alpha values were .75 (ω = .81) for TR, .84 (ω = .88) for LC, .86 (ω = .90) for OC, .85 (ω = .89) for SL and .86 (ω = .91) for ML. According to Taber (2018), these levels of internal consistency reliability were satisfactory.

Readers can access supplementary materials at https://doi.org/10.17605/OSF.IO/342NG.

3.2 The DIF analysis for examining equal invariances

We implemented DIF analysis with respect to gender and grade levels by using logistic ordinal regression methods in R lordif package (Choi et al., 2011). The likelihood ratio χ^2 test is considered as the detection criterion at the α level of 0.01, while the change in McFadden's R^2 of 0.01 as a criterion for rejecting the null hypothesis of no DIF. All pseudo R^2 values were below 0.01, and p-values of the goodness-of-fit statistics above 0.05, indicating no item were flagged as DIF item regarding gender. Overall, these results suggest that the models were well supported by the empirical data.

3.3 Students' ICT familiarity and its effects on online learning readiness

Students can participate in online lessons via different devices such as desktop computers, laptops, tablets or smartphones. Regular use of these devices can affect the quality of learning in virtual space. Understanding the familiarity of using devices in online learning plays an important role in both designing lesson plans and practicing in an online environment. Figure 1 presents the proportion of technology devices that students were directly using for learning online lessons. Surprisingly, the desktop computer is almost absent from the students' homes in this survey. Tablets (i.e., iPads, Samsung Galaxy Tab or similar devices) were rarely used for online learning, with only about 5.0% of students using these kinds of electronic device, while about 16.1% of students used laptops to access the online courses. Up to 73.7% of students participated in online classes on mobile phones. The results showed that online learning seemed to be a big challenge for both teachers and students in the current condition where many students use mobile phones as their main means for joining online classroom activities.

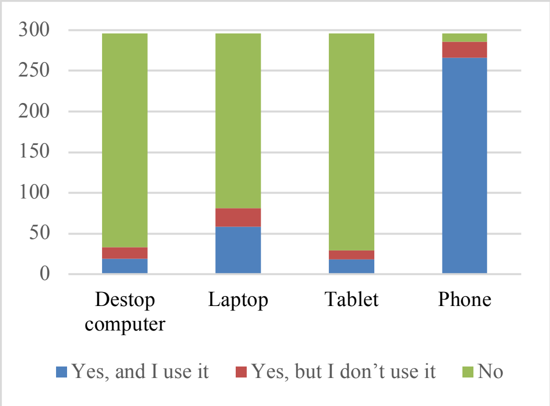

Figure 1 - Proportion of the common devices available for accessing online lessons.

To examine the familiarity of Internet usage, a question "How often do you use digital devices for the following activities?" was also conducted in the study. There were five levels of the frequency, which were coded as follows: 1: "Never or hardly ever", 2: "Once or twice a month, 3: "Once or twice a week", 4: "Almost every day", 5: "Every day". In the study, we included Send or read email inboxes (Email), chat with friends (Chat), search and collect information via the Internet (Search), join social networks or online forums (Facebook), online call with friends (Call), access online documents (Docs), submit work on the school's online learning management system (Assignment), watch videos or materials related to learning (Video), watching movies, listening to music and other recreational activities (Music).

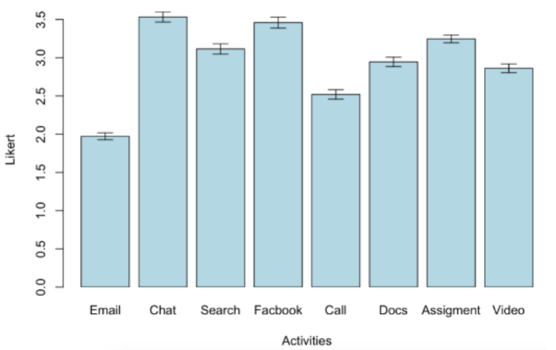

Figure 2 - The frequency of accessing online activities of students.

As depicted in Figure 2, students accessed the internet quite often for both daily life and recreational activities. In particular, Chat and Facebook variables were reported from "frequently" to "almost daily" in the majority of children surveyed. A positive finding is that Search and Docs (using online resources) were also considered by students as fairly regular activities. In general, students seemed to be quite proficient and experienced in using and exploiting the internet for learning and other leisure activities in life. This is a fundamental advantage as the basic understanding required for accessing the various learning systems appears to be adequately developed.

	TR	LC	OC	SL	ML	RO
Email	.05	.04	.09	.15**	.07	.10
Chat	.05	.05	.02	.10	.05	.07
Search	.13*	.13*	.06	.19**	.12*	.15*
Facebook	.13*	.08	.05	-.01	.01	.06
Call	.25***	.15**	.16**	.20***	.17**	.22***
Docs	.20**	.12*	.13*	.18**	.20***	.20***
Assignments	.17**	.12*	.11	.12*	.09	.14*
Video	.20***	.24***	.24*	.26***	.30***	.30***
Music	.05	.01	.02	.00	-.04	.01

Note. *p < .05, ** p < .01, ***p < .001.

Table 1 - Relationships between ICT familiarity and Readiness for Online Learning.

Furthermore, we investigated the relationship between ICT familiarity and the Readiness for Online Learning. Table 1 outlines Pearson's correlation values for ICT Familiarity and the components of Readiness for Online Learning. Some activities were positively associated with online learning readiness, but not very strongly. These more formal uses of ICT also demonstrated significant correlations with the majority of Readiness for Online Learning components. ICT familiarity with activities that were typically more associated with casual and personal web use demonstrated small, and typically non-significant correlations with the components of Readiness for Online Learning.

4. Discussion and Conclusions

The majority of research examining online learner readiness to date has focused on university cohorts. In the context of a rapid and sustained increase in online learning at secondary schools, a clear need for research examining the role of individuals' beliefs and associated impacts on online and blended learning within school age populations is evident. The current study offers a unique evaluation of the widely used the OLRS in secondary education settings. The psychometric properties of the adapted questionnaire appear to be acceptable. However, using the CFA, two items, were removed from the OLRS, while the Rasch measurement advised that one item in the LC scale was not fit the model. These items need to be revised for future studies. There are no gender-related bias concerns, which confirms the successful attainment of measurement invariance statistics. Generally, the findings demonstrate comparability with the results on the original scale development study by Hung et al. (2010). The OLRS demonstrated suitable levels of reliability within the current empirical data. This evaluation is presented as essential due to the markedly different socio-cultural context of the current study and the previous uses of this questionnaire (Farid, 2014; Hung et al., 2010; Tang et al., 2021). This implies that the OLRS could serve as an potential evaluation tool to assess students' readiness for learning in a virtual setting, which is anticipated to become increasingly common in schools in the future. Researchers also anticipate that blended learning will be increasingly incorporated in schools, and global distance learning programs will become more common (Sharadgah & Sa'di, 2021).

The results suggest that previous experience of ICT activities is linked to student perceptions of readiness for online learning in a secondary school context. The experience of ICT processes that are typically associated with personal or leisure use demonstrated small and mostly insignificant relationships with the components of OLRS. The factors related to Internet usage habits, social media use and online entertainment (e.g., listening to music, playing online games) did not have a significant effect on students' readiness for online learning. Conversely, interacting with friends regularly, browsing study materials, and watching videos of lectures had a positive association with students' readiness for online learning.

From a practical perspective, this has immediate consequences for the design of resources, accessibility considerations and platform selection. The results highlight the need for increased awareness among parents and teachers about social network usage among secondary school students. The students apparently spent much of their time chatting and networking on social platforms, which were indicated to have no impact on their online learning readiness. Teachers and parents should advise students on how to ultilize the virtual environment in effective ways. Additionally, as students reported that they faced most challenges in their learning control and self-efficacy in online communication, it is essential for teachers and parents to provide assistance in these matters. Schools need to implement comprehensive strategies, including providing training for both students and teachers on digital tools, creating engaging and accessible online curricula, and offering resources and guidance to help students adapt to the virtual learning environment.

Moreover, the findings exposed that mobile phones were the primary means of accessing online learning for most students. The dominance of this electronic device selection aligns with previous studies (i.e., Arthur-Nyarko et al., 2020), which found that most students at university level accessed online learning courses via smartphones. Integrating mobile technology allows educational institutions to create distance learning systems that enable students to be highly flexible with their schedules and locations (Eom, 2022), but for students, displaying a lesson on a phone screen, especially during a long study session, is a significant challenge due to its size. This learning condition may lead to various undesirable long-term effects (e.g., eye strain), which should be considered more carefully in educational settings. This issue needs to be addressed not only by online educators and program designers but also by teachers who create online lectures to ensure that all students can access them suitably. Media and interaction platforms must be optimized for the platform on which it is consumed. While modern learning management systems and associated platform are designed at their core to be suitable for multiplatform use, it is essential that educators consider the accessibility of the materials they create and use on these platforms in order to enhance the student learning experience.

The results and conclusions of this paper should be considered in light of its limitations. The data was drawn from a relatively limited population in the southern part of Viet Nam, so there is a possibility of a Type II error. Data sharing using Open Science principles has the potential to alleviate this issue and potentially build insights of variance across socio-culturally diverse settings and potentially support future meta-analytic studies (Power, 2021). Future research aiming to explore potential differences across grade or age groups should take into account power calculations appropriate for a medium effect size (McCrum-Gardner, 2010). This is the first application of the self-report adapted questionnaire in a secondary school context. Future research employing this modified scale should consider potential impacts of the translation process and associated content validity assessment. Most main psychometric indices of the adapted instrument were acceptable, but the WRMR value slightly greater than 1 typically indicated that the model's fit to the data was still poor, and next steps may be needed to improve model specification. Incorporating a parallel qualitative approach could potentially provide further insight in future. Additionally, this study used a self-report questionnaire to measure familiarity with various online activities, which may not fully capture digital proficiency. Future research needs a more comprehensive assessment consisting of items with interactive scenarios may provide deeper insights into students' preparedness for online learning.

Nevertheless, the current findings offer valuable insights for educators, stakeholders, and policymakers in enhancing online learning environments. As blended and fully online elements continue to be integrated into secondary education systems, it becomes increasingly crucial to deepen our understanding of the personal factors influencing student engagement and performance within these systems.

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Instruments for measuring Digital Citizenship Competence in schools: a scoping review

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Abstract

The integration of digital technology into the teaching and learning process has both good and negative consequences. Several schools have incorporated digital citizenship to teach the responsible use of technology. The purpose of this scoping review is to provide an overview of research on tools for measuring digital citizenship competency among school children. This scoping study focuses on three main areas: (a) defining digital citizenship and competency; (b) instrument development and characteristics; and (c) key findings. The main outcomes of this research may help students, teachers, and school administrators implement digital citizenship education programs in schools.

KEYWORDS: Digital Citizenship; Measuring Instrument, School Students, Education Programs, Digital Technology.

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1. Introduction

The word "citizenship" comprises rights and duties based on geographic, cultural, and political limits (Mulyono et al., 2021). The term "citizenship" has obvious geographical bounds. The old definition of citizenship is criticised for neglecting current diversity and globalisation trends. According to Choi (2016), real citizenship is more closely linked to identity and community. Traditionally, Marshall (1950) defined citizenship as a status granted to complete community members. The term "community" is crucial in discussing citizenship, since it stems from people' natural desire to unite and serve others.

The internet may improve society by facilitating membership and involvement, known as social inclusion (Mossberger et al., 2008) . Online group formation with sufficient emphasis and cohesiveness leads to citizenship difficulties (Ohler, 2011); Mossberger et al. (2008) defines it as a digital community. This method connects "citizenship" and "digital" to each other. The blend of offline and online interaction creates a daily emotional, behavioral, and experiential encounter in the virtual world (Mulyono et al., 2021). Digital citizenship cannot be divorced from the broader notion of citizenship. Choi (2016) defines digital citizenship as including social duty, informed awareness, and active involvement. The issue of digital citizenship is interdisciplinary and complex. Some sources define digital citizenship as a foundation for digital literacy that emphasises (1) online behaviour respect and (2) citizen involvement (Jones & Mitchell, 2016). Digital citizenship, a prevalent idea in education, refers to responsible technology usage (Ribble & Bailey, 2004b; 2007).

The fast progress of technology has had a huge influence on education, especially since the COVID-19 Pandemic. This transition has boosted chances for learning and cooperation in school education while also introducing new problems and concerns.

One of the most pressing challenges is the growth of cyberbullying, which has grown increasingly common as a result of greater internet connection. Cyber etiquette, privacy, and protection have become more important as students traverse digital places where personal information may be subject to misuse.

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Table 1- Digital citizenship frameworks from various research studies.

Author/ Institution	Factors/Dimension	Target group
Ribble, 2009	1. Digital Access 2. Digital Commerce 3. Digital Communication 4. Digital Literacy 5. Digital Etiquette 6. Digital Law 7. Digital Rights and Responsibilities 8. Digital Health and Wellness 9. Digital Security	Teachers and students
ISTE 2019	1. Inclusive 2. Informed 3. Engaged 4. Balanced 5. Alert	Teachers and students of all grades
iKeepsafe	1. Use of digital balance 2. Ethical digital use 3. Protection of personal information 4. Maintaining healthy and safe relationships 5. Building a positive reputation 6. Achieving digital security	School students
Choi, Glassman, & Cristol, 2017	1. Self-identity 2. online activity 3. Fluence in digital environment 4. Ethics of digital environment	College students and adults
Jones & Mitchell, 2016	1. Online respect 2. Online civic engagement	Adults and students above 11
Common sense and media, 2019	1. Media balance and well-being 2. Privacy and security 3. Digital footprint and identity 4. Relationships and communication 5. Cyberbullying, digital drama and hate speech 6. News and media literacy	Students of all ages
Lindsey, 2015	1. Copyright 2. Digital footprints / social media 3. Acceptable use policies 4. Promoting responsible student behavior	Teachers and students
Payne, 2016	1. Internet Ethics 2. Information Security 3. Cyber Security	Teachers

The digital literacy gap, sometimes known as the digital divide, has grown as schools increasingly depend on technology for instruction. Students from marginalized families may not have access to required technology or internet connection, aggravating educational inequities. Bridging the gap and providing fair access to technology has become a top priority for educators and governments.

Digital citizenship education has grown in popularity because it provides students with the information, skills, and attitudes required to navigate the digital world responsibly and ethically. It covers issues such as online safety, responsible internet usage, critical thinking in digital settings, and respect for others' digital rights. Incorporating digital citizenship education into the curriculum helps students become responsible digital citizens. Educators play an important role in passing on these lessons, developing critical thinking skills, encouraging empathy and respect in online interactions, and discussing the ethical implications of technology usage. Collaboration between schools, parents, and communities is critical for reinforcing these skills and providing consistent assistance in navigating the digital world. Schools throughout the world are implementing "Digital Citizenship Education" to help students improve their online skills, creativity, and legal awareness. Digital citizenship education aims to educate students how to work, live, and contribute constructively in digital environments (Pandian et al., 2023).

Students, teachers, school administrators, and parents have a limited understanding of the various strategies that schools can implement to promote digital citizenship education. The aim of this scoping review is to provide a comprehensive overview of research on the framework and instrument used to measure digital citizenship competency among school students. This study focuses on three main areas: the definition of digital citizenship and its competence; the characteristics of the instruments used to measure digital citizenship in schools; and key findings. In short, our goal in this scoping review is to summarize and analyse the digital citizenship assessment techniques used to assess students' digital citizenship skills.

The findings of this review and suggestions may eventually benefit students, educators and school management in implementing and executing educational programmes that promote students' digital citizenship competencies in schools.

2. Defining Digital citizenship and competency

Mike Ribble is an early author who established digital citizenship competencies for education He defines digital citizenship as norms for the appropriate and responsible use of online technologies. Its digital citizenship competencies include nine elements: digital access, digital commerce, digital communication, digital literacy, digital etiquette, digital law, digital rights and responsibilities, digital health and well-being, and digital security (Ribble & Bailey, 2004a; 2004b; 2007). According to Mossberger (2008), digital citizenship is the ability to participate in an online, digital society. Alberta Education (2012) defines citizenship as belonging to a national, political, or social group. The community is the focus. Community shapes citizenship. Community members have rights and obligations, coupled with accountability. Community members must follow their duties. Digital citizenship fits within this concept with few modifications. Mitchel defines digital citizenship as respectful and tolerant behaviour that promotes civic involvement. He focuses on two elements: online respect and online civic engagement (Jones & Mitchell, 2016). Choi (2016) introduces four digital citizenship (DC) teaching methods; first, the ethical approach teaches basic digital society skills, second. the media literacy approach develops critical information access and use skills, third, the participation/engagement approach encourages citizens to create content and contribute to social, cultural, and economic life online, and fourth, the critical resistance approach encourages DC to choose platforms that promote values and participate in creating an online community. Choi's digital citizenship competencies includes internet political activism, technical skills, local and global awareness, critical perspective, and networking agency (Choi, 2017). Kim and Choi (2018) argue that digital citizenship education extends beyond obligations or duties and established SAFE Framework: self-identity in the digital environment, activity online, fluency with digital tools, and ethics for the digital environment. Martin et al. (2020) define DC as a set of responsible habits on how to function in a digital and offline space, which consists of five aspects: cyberbullying, digital footprint, digital privacy, digital netiquette, and digital identity (Kim & Choi, 2018).

Chen et al. (2021) conceptualised digital citizenship largely in terms of competency and participation. The competence view focuses on citizens' online skills in using technology and the Internet for social, cultural, and economic participation, such as accessing the Internet, evaluating information, communicating, and collaborating with people from various backgrounds (Choi, 2016; Ribble & Bailey, 2007). This competence-based approach divides digital citizenship into several components, including digital literacy, digital interaction, digital communication, digital safety, digital ethics, digital rights and responsibilities, digital law, digital commerce, and digital health (Ribble & Bailey, 2004b; 2007). Alternatively, Kim and Choi (2018) offered a digital citizenship framework based on individual competency, emphasising "ethics for the digital environment, fluency for the digital environment, rational and active activities, and establishing self-identity in a digital world" (Kim & Choi, 2018). Researchers have mostly employed competency frameworks to assess or evaluate, particularly in education. Fewer studies employ the participation perspective of digital citizenship, which connects it to any economic, social, or political involvement in the digital/online environment (Harrison & Polizzi, 2022; Mossberger et al., 2008)

2.1 Frameworks of digital citizenship competency

The various global institutes are also enlisted digital citizenship competencies. The International Society for Technology in Education (ISTE), based on the research of Ribble and Bailey (2011), has identified five specific competences for digital citizenship: Inclusive, Informed, Engaged, Balanced, and Alert. The Council of Europe has divided digital citizenship competencies into three groups, consisting of ten competencies in total; being online, wellbeing and right online. The concept of being online consists of three elements: access and inclusion, learning and creativity, and media and information literacy. Wellbeing online consists of three components: ethics and empathy, health and well-being, and e-presence and communication. Right online consists of four elements: active participation, rights and responsibilities, privacy and security, and consumer awareness (Mulyono et al., 2021). The DQ Institute (DQI), a global organization dedicated to digital education, has enlisted eight elements for digital citizenship competencies; these include digital citizen identity, screen time management, cyberbullying management, cyber security management, privacy management, critical thinking, digital footprints, and digital empathy (DQI, 2017). Common Sense Media, a non-profit organization, has enumerated six digital citizenship competencies: media balance and well-being, privacy and security, digital footprint and identity, relationships and communication, cyberbullying, digital drama and hate speech, and news and media literacy (James & Weinstein, 2019; Mulyono et al., 2021). Most of the above frameworks makes use of Ribble and Bailey's (2011) works.

3. Method

A scoping review is a type of literature review that aims to map out and summarize the existing literature on a particular topic or research question (Davis, 2019). It is based on Arksey and O'Malley's (2005) framework. There are five steps in the method: "1) Identifying the research question; 2) Identifying relevant studies; 3) Study selection; 4) Charting the data; 5) Collating, summarizing, and reporting the results" (Arksey & O'Malley, 2005, p. 22).

A scoping review studies was conducted to gain knowledge on measuring instruments of Digital Citizenship Competence in Schools. Inclusion and exclusion criteria are shown in Table 2.

The criteria used to select the final databases for this scoping review included the relevance of the topic, the type of articles available, and the accessibility of the databases. Ultimately, the scientific databases included in this review were Google scholar, ERIC, Pubmed, Science direct, Proquest, and Jstor.

The search for research articles was conducted using Boolean connectors with the following keywords: digital citizenship, school, students, learners, education, citizenship, competency, measurement. We used the following search string: (digital citizenship OR cyber citizenship OR e-citizenship) AND (competence OR skills OR competencies) AND (measurement OR assessment OR evaluation) AND (learners OR education OR students) AND (elementary schools OR middle schools OR secondary schools OR schools).

4. Results

A search turned up 309 articles. After the identification process, 98 duplicate articles were eliminated. Next, after running keyword filters through the titles of the 220 studies that were still in the database, it was found that 210 of them did not meet the inclusion criteria for the following reasons: 71 papers did not resemble the search term; 47 titles and abstract criteria were deemed irrelevant; 33 studies did not belong to the population; 36 studies did not have any context-relevant information; 7 books; 5 conference papers; and 10 papers were not peer reviewed. Due to their compliance with all inclusion criteria, the remaining 12 articles were found appropriate for the study. Ultimately, these articles underwent a thorough review process, and their relevance to the study was confirmed by obtaining the full versions. The articles were chosen using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement as a guide, as shown in Figure 1 (Moher et al., 2009).

Table 3 lists studies on digital citizenship at the school level, including the author, year of publication, title, purpose of the theoretical or conceptual framework, participants or sample, methods, and key findings. We identified three data collection methods: test-type assessment, self-assessment, and performance-based assessment. In addition to other frameworks, schools widely use Ribble's and ISTE frameworks for assessment instruments to measure digital citizenship competence.

In our scoping review, we found other digital citizenship conceptual frameworks (shown in Table 1). In this review, we identified various assessments that evaluated digital citizenship competence among school students. A Likert-type scale questionnaire was used to measure participants' digital citizenship competency across different levels. Alazemi (2019) used a quasi-experimental study design was used to measure achievement levels, providing insights into the effectiveness of digital citizenship educational programs. Several researchers have used survey method to assess students' knowledge in specific areas of digital citizenship competence, covering a range of relevant topics. Instruments consisted several factors or dimensions covering the various aspects of digital citizenship competence shown in Table 3.

Table 2 - Inclusion and exclusion criteria.

Criteria	Included	Excluded
Time frame	2012 - 2023	Before 2012 and after 2023
Publication type	Online peer – reviewed articles	Policy documents, books, Theses, working papers, reports, conferences
Focus	Studies focused on Digital citizenship for schools	Articles focusing on other topics
Languages	English	Other Languages
Target population	Studies focused among school students and digital citizenship competence measurement	Studies focusing on students' other population (preschool, adults, university students, special needs)
Articles	Empirical papers with research design, participants, data sources, data collection techniques, analysis procedures, and key findings	Review article, articles with no empirical studies, positioned papers

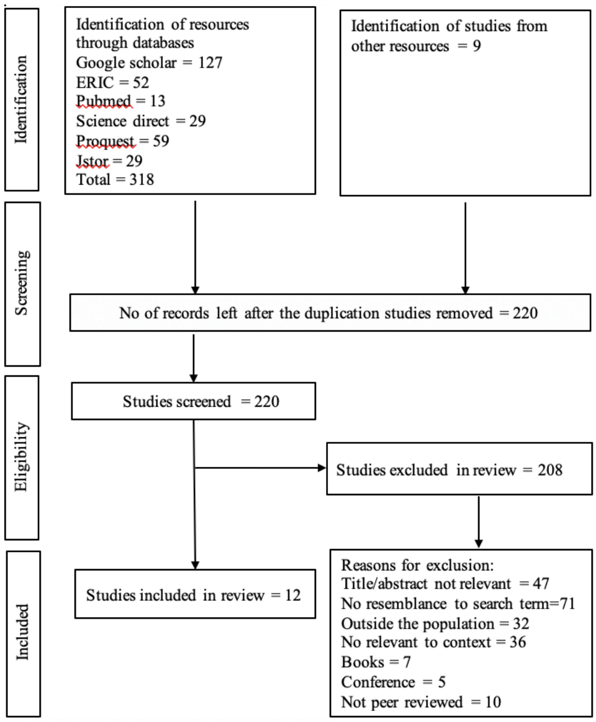

Figure 1 - PRISMA flow chart for inclusion criteria.

5. Discussion

A literature review was conducted to explore assessment tools for measuring students' digital competence. The review revealed that existing tests primarily focused on examining students' digital citizenship skills, abilities, and perception. Most assessment tools cover multiple competency dimensions and cover the various aspects of digital civic literacy listed in Table 3, including areas such as digital literacy, digital commerce, online etiquette, privacy and protection, etc. The majority of studies utilize self-assessment questionnaires with multiple-choice items to evaluate digital competence. The research findings indicate that the Ribble and Bailey's (2004a) framework for digital citizenship is the most frequently used framework in this context. Students often define digital citizenship as engaging in digital groups or activities, providing knowledge, and being ethically and socially accountable.

These notions are often expressed through digital abilities, such as reading online, sharing personal experiences on social media, and other digital activities. In addition, students practise many sorts of digital citizenship via language usage in digital citizenship activities (Alazemi et al., 2019).

The results of this study reveal students need help on the greater knowledge of appropriate online behaviour and develop or enhance a broad range of digital communication skills for a variety of purposes, informal and formal education, social networking, and digital wellbeing in social and cultural contexts. Studies have shown digital citizenship programmes have improved the students' perception of digital citizenship elements (Alazemi et al., 2019). So, digital citizenship programmes can shape students' attitudes and habits towards digital citizenship activities. These results demonstrate that many students may utilise social media and their academic, social, and digital communication skills to make use in digital environment to facilitate socialising, studying, and personal growth. However, the advantages that young people get from utilising digital media might range greatly because everyone has varying access to technology and experiences with digital communication.

With regard to the critical aspects and social justice, this research review has revealed most of the students have hesitated to speak and share anything on social and political concerns. Moderate usage of technology could be one of the reasons why students do not discuss any political issues (Ananto & Ningsih, 2023). Social media has potential to attract cyber trolling and humiliations. So, such negative experience may hamper the political and social engagement of students in the digital environment.

The review is also has shown the fact that high use of technology leads to misuse of it. Digital technology misuse can lead to cyberbullying, addiction, false information dissemination, privacy invasion, and illegal activities. The widespread availability and accessibility of digital technology make it easy for students to engage in harmful activities. The anonymity provided by online platforms can encourage harmful behaviour, such as cyberbullying and trolling. The addictive nature of digital technology, particularly social media and online gaming, can lead to compulsive behaviour and excessive use, negatively impacting mental health, relationships, and overall well-being. The rapid spread of false information on digital platforms can exacerbate societal issues and undermine trust in institutions. The commodification of personal data and erosion of privacy rights raise concerns about surveillance, data breaches, and exploitation by corporations and governments. Therefore, it is crucial for students to be aware of their digital behaviour and use technology responsibly and ethically.

This review reaffirms how important it is for parents to teach their students responsible online behaviour and to keep them safe from online threats. Unmonitored smartphone use can put students at risk for cyber trolling, exposure to unhealthy content, hacking, and excessive screen time, among other negative outcomes. Their development, academic performance, and physical and mental well-being may all suffer as a result.

Excessive screen time can also impair mental health and sleep. Additionally, it can impair social abilities like creativity, and problem-solving. Parental supervision is essential to lowering these risks and teaching children appropriate online behaviour. Parents can monitor their children's online activity, set age-based computer time limits, and have conversations with their children about internet safety.

Table 3 - Characteristics students digital citizenship competence assessment.

	Author	Theoretical/Conceptual framework	Purpose	Participants/ sample	Methods	Key findings
1	Ananto & Ningsih, 2023	Five Dimensions proposed by Choi et al (2017): internet political activism, technical skills, local/global awareness, critical perspective, and network agency	To assess the perceptions and levels of digital citizenship among Indonesian educators and students.	157 participants (39 teachers and 118 secondary students)	Self-assessment report questionnaire with a five-point Likert scale ranging from strongly disagree (scored 1) to strongly agree (scored 5).	The study found that while internet usage helped understand social and political issues, teachers and students were less active in discussing them, and their political activity varied by age
2	Alazemi et al., 2019	Ribble & Bailey (2007): Digital Access, Digital Commerce, Digital Communication, Digital Literacy, Digital Etiquette, Digital Law, Digital Rights and Responsibilities, Digital Health and Wellness, and Digital Security.	To incorporate digital citizenship elements into language classes and assess the impact of exposure to these elements through interactive online international English content on tenth-grade writing performance	40 students selected from a basic school in Kuwait as two intact sections	A quasi-experimental followed by pre and post test-type assessment	The study found that students were uninformed about digital citizenship and its nine elements. The training improved writing performance, increased interaction, and participation
3	Purwanti et al., 2023	Ribble & Bailey (2005) and its nine dimensions: Digital Access, Digital Commerce, Digital Communication, Digital Literacy, Digital Etiquette, Digital Law, Digital Rights and Responsibilities, Digital Health and Wellness, and Digital Security.	tT evaluate students' perspectives regarding the integration of digital citizenship principles at the secondary school level	120 students from Middle Schools	Self-assessment questionnaire consisting of ten questions for students' attitudes towards the use of technology in school with a Likert scale from 1 to 5	The findings show that while digital citizenship is being implemented in secondary schools, moderate to high levels of technology usage are preferred by students. Increases in the use of digital media are correlated with higher levels of misuse
4	Aldosari et al., 2020	ISTE (2019) Dimensions: Digital identity, Ethical behavior, Intellectual property, and Digital privacy and security.	To assess the availability of ISTE Digital Citizenship standards among middle and high school students in Riyadh, Saudi Arabia	394 male middle and high school students in general education from the Riyadh Region	A self-assessment survey was used to collect data on the perceptions of students in	Students demonstrated high availability of digital citizenship in the first and second domains, as well as high level of Internet self-efficacy
5	Harmanto et al., 2022	Ribble & Bailey (2005) and its nine dimensions: Digital Access, Digital Commerce, Digital Communication, Digital Literacy, Digital Etiquette, Digital Law, Digital Rights and Responsibilities, Digital Health and Wellness, and Digital Security.	To examine Indonesian junior high school students' comprehension of Digital Citizenship	200 junior high school students in Indonesia	Quantitative, with a self-assessment survey design	The study highlights the need of including digital citizenship education into the curriculum. This education empowers students with the skills to navigate the digital world responsibly, comprehend online ethics, and promote a balanced use of technology
6	Martin et al., 2020	DC dimensions. Cyberbullying, Digital footprint, Digital privacy, Digital netiquette, and Digital identity	To assess middle school students' perspectives of digital citizenship components centred on online behaviour.	237 middle school students of United States	Survey Method with self-assessment	Students are increasingly using mobile devices, emphasising the need of parents monitoring their children's internet activity
7	Komalasari et al., 2023	Dimensions: Civic knowledge, Cognitive civic skills, Participatory civic skills, and Civic disposition	To explain the digital citizenship practices that junior high school students in digital citizenship	260 VIII grade students in Indonesia	Survey Method with self-assessment	Awareness and comprehension of digital citizenship of students are rated as "Extremely Good"
8	Prasetiyo et al., 2021	Ribble (2015) and its nine dimensions: Digital Access, Digital Commerce, Digital Communication, Digital Literacy, Digital Etiquette, Digital Law, Digital Rights and Responsibilities, Digital Health and Wellness, and Digital Security.	To study the digital citizenship competence of senior high school students	581 students from from 12 public and private senior high schools of Indonesia	Self-assessment survey method with 5-point Likert Scale (5 = Strongly Agree, 1 = Strongly Disagree).	Measured digital citizenship readiness of students was very high. The study data could be used in future

(continue)

	Author	Theoretical/Conceptual framework	Purpose	Participants/ sample	Methods	Key findings
9	Çepni et al., 2014	Ribble & Bailey (2007) and its nine dimensions: Digital Access, Digital Commerce, Digital Communication, Digital Literacy, Digital Etiquette, Digital Law, Digital Rights and Responsibilities, Digital Health and Wellness, and Digital Security.	To explore the perspectives of elementary school students concerning internet usage (digital citizenship)	557 8th grade students of 6 primary schools	Survey model with self-assessment	The study revealed that internet availability, email address, mother's education, family income, internet use history, and father's education significantly influence primary school 8th graders' digital citizenship attitudes
10	Çebi & Özdemir, 2019	Dimensions 1. Digital communication and literacy 2. Digital Security 3. Digital etiquette and law	To explore how digital nativity and digital citizenship relate to strategies used for online information searches	331 high school students	Self-assessment with a 7-point Likert scale	The study found that online information search strategies were mainly influenced by "digital communication and literacy" levels, with "digital security" being important across all sub-dimensions. However, "digital etiquette and law" were not statistically significant predictors. Additionally, "comfort with multi-tasking" and "reliance on graphics for communication" significantly determined behavioral domain strategies
11	Ahmed Hassan, 2021	Three dimensions: 1. the respect values 2 the values of educating 3. dimension measures protection values	To examine how secondary schools in Saudi Arabia are promoting the principles of digital citizenship among students during the Coronavirus outbreak	3591 boys and girls, students from private secondary and government schools	Questionnaire Design with 5-point Likert Scale	Secondary schools significantly promote digital citizenship values, preparing students for the digital society and its technologies, with private schools playing a greater role in this. Male students are more aware of secondary schools' role in promoting digital citizenship.
12	Hassan et al., 2023	Ribble & Bailey (2007) and its nine dimensions: Digital Access Digital Commerce Digital Communication Digital Etiquette Digital Health & Wellness Digital Law Digital Literacy Digital Rights & Responsibilities Digital Security	This research assesses Malaysian students' perceptions of their digital citizenship practices in nine elements	398 high school students	Survey design with self-assessment	The study found that students are moderately practicing digital citizenship, with Digital Access and Digital Health and Wellness being the least frequent elements, and frequent practice significantly contributes to their overall wellness.

However, because technology is changing so quickly, many parents might not know how to keep an eye on their children's online activity. Educational initiatives can help with this problem by giving parents the knowledge and resources they need to keep their kids safe online. Classes, lectures, online courses, and instructional materials covering subjects like setting up parental controls, promoting safe online behaviour, and fostering positive digital habits are some examples of these programs. By giving parents the knowledge and resources they need, we can make sure that students can navigate the digital world in a responsible and safe manner (Martin et al., 2020).

6. Conclusion

Students' screen time is increasing every day. By and large, students have access to digital technologies in schools and at home. Many schools have strict policies on how to use smart phones on campus. However, parents often fail to adequately monitor their children at home. One of the main reasons could be that many parents, who are digital immigrants, lack knowledge about how to use smart phones effectively. They rely on their children for online activities such as shopping, bank transactions, booking tickets, and so on. Therefore, it is crucial to educate parents on the fundamentals of digital literacy and citizenship. Society's use of digital and internet technologies is increasing day by day. Therefore, schools must find ways and means to adapt curriculum to changing technologies. Schools must systematically implement digital citizenship programmes. The main idea behind digital citizenship is that everyone who lives in the digital world should make it a better place. This includes having good interactions online, following the rules that apply in the digital world, and learning how to keep yourself safe online. This review shows students by and large do not have sufficient knowledge on cyberbullying and proper internet behaviour (Komalasari et al., 2023). This supports Martin's (2020) assertion that many public schools fail to teach digital citizenship (Martin et al., 2020). Therefore, we need to do more to prepare students for appropriate and responsible behaviour in an online environment.

7. Recommendations

The results of this research have far-reaching implications for everyone involved in the education system, such as parents, teachers, students, and administrators. With the increasing adoption of digital technologies and social media among students, it is critical for all groups to take the lead in promoting responsible digital citizenship behaviour. The results of this research highlight how important it is for students to understand the basics of digital citizenship while interacting with others online. Students need to be aware of the ethical issues, privacy issues and social media standards associated with online communication as they frequently use digital technologies and social media platforms. Students can navigate the digital environment safely and ethically by developing their knowledge as digital citizens, reducing the likelihood of disinformation, cyberbullying and data breaches. The results of this research also have implications for teachers, as they contribute significantly to students' learning and development in the area of digital citizenship. Teachers can successfully address these gaps in students' digital citizenship knowledge and skills by identifying the areas in which students are deficient. This could include using technology to promote digital literacy, combining interactive activities and conversations on online safety and ethics, and incorporating the ideals of digital citizenship into existing curriculum topics. To encourage students to practice digital citizenship, parents are also essential. Parents should actively monitor their children's online activities and encourage an honest dialogue about internet safety and appropriate digital behaviour. Parents can help reduce the dangers associated with excessive screen time, cyberbullying, and exposure to inappropriate information by keeping an eye on their children's online activity and offering advice and support when needed. Additionally, school administrators are critical in driving initiatives to support digital citizenship in learning environments. By implementing a comprehensive digital citizenship curriculum that covers all grade levels and subject areas, administrators can ensure that every student receives consistent and relevant education in this important area. Administrators can also help teachers integrate the ideals of digital citizenship into their lesson plans, provide professional development opportunities for teachers, and form alliances with community organizations and parents to promote digital citizenship education.

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Predicting student specializations: a Machine Learning Approach based on Academic Performance

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Abstract

Education is a cornerstone of societal progress, equipping people with essential skills and knowledge. In today's dynamic global society, personalized learning experiences are crucial. Data-driven methodologies, especially Educational Data Mining (EDM), play pivotal roles. This study employs machine learning algorithms to predict specializations for Greek high school students based on their previous grades. The aim is to provide a practical tool for educators and parents, aiding in the optimal selection of specializations. The paper outlines the methodology, presents comparative study results, and concludes with insights into the potential impact on educational decision-making. This research advances the integration of data-driven approaches in education, enhancing students' learning experiences and prospects.

KEYWORDS: Machine Learning Algorithms, Educational Data Mining, Prediction, High School.

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1. Introduction

One of the primary foundations of society development is education, which gives people the knowledge and abilities they need to function in a constantly changing environment. It is universally acknowledged as the essential component of economic progress (Chang, Chen, & Xiong, 2018; Alani, Yawe & Mutenyo, 2022), societal improvement and personal development (Zheng, 2023), making it a fundamental human right. It is more than just a process of acquiring information, but mostly a transformative journey that enables people to think critically, to confront complex problems and generally, to make significant contributions to their communities (Kurnia, 2021). In today's interconnected global society, the role of education has become even more pivotal, as it equips people with the tools they need to navigate a complicated and rapidly evolving environment (Schleicher, 2018). Owing to these conditions, teachers are required to modify the curriculum and address the particular requirements and learning preferences of a broad spectrum of students (Kilag, Comighud, Amontos, Damos & Abendan, 2023). As a result, dynamic, customized learning experiences replace conventional, one-size-fits-all methods. This shift is supported by the integration of data-driven methodologies, which provide valuable insights into how students learn, what interests them, and where they may need additional support, which lead educators and institutions to increasingly using innovative technologies and approaches in their quest to optimize learning experiences and outcomes (Siemens & Long, 2011). Data mining is one such effective technique (Romero & Ventura, 2007).

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Data mining is the process of discovering valuable patterns, dependencies, insights, and knowledge from datasets that contain large amount of data (Chen, Abtahi, Carrero, Fernandez-Llatas & Seoane, 2023). More precisely, it involves employing a variety of computer tools, statistical algorithms, and machine learning approaches that facilitate the extraction of information, hidden relationships and correlations from raw data, that at first glance may not be immediately apparent (Mittal, Shuja & Zaman, 2016). Data mining encompasses a wide range of techniques to extract valuable insights from large datasets such as classification (Dol Aher & Jawandhiya, 2023;Tsimpiris & Kugiumtzis, 2012a; Kaur, Singh & Josan, 2015), association (Antonello et al., 2021), decision trees (Jin, Li, Ma & Wang, 2022), clustering analysis (Romanazzi, Scocciolini, Savoia & Buratti, 2023; Papaioannou et al., 2023b; Hartigan & Wong, 1979; Correa-Morris, Urra Yglesias & Puente, 2023), neural networks (Papaioannou et al., 2023a; Rutkowska et al., 2023), random forest (Schnitzler, Ross & Gloaguen, 2019), k-nearest neighbors (Tsimpiris, Vlachos, & Kugiumtzis, 2012b) etc. In general, this process is essential in diverse fields such as business (Wang, Omar, Alotaibi, Daradkeh & Althubiti, 2022), healthcare (Jothi, Abdul Rashid & Husain, 2015), finance (Jin & Hu, 2022), and education,(Altabrawee, Ali, & Qaisar, 2019; Strikas, et al., 2023; Amelia, Gafar Abdullah, Mulyadi & Ijost, 2019; Ordoñez-Avila, Reyes, Meza, & Ventura, 2023; Aldowah, Al-Samarraie, & Fauzy, 2019; Rodrigues, Zárate, & Isotani, 2018), as it enables informed decision-making, prediction (Sultana, Rani, & Farquad, 2019), and optimization. The part that pertains to education is known as educational data mining.

Educational Data Mining (EDM) refers to the application of data mining techniques in the field of education (Mohamad & Tasir, 2013). EDM aims to extract, evaluate, and comprehend knowledge from massive datasets related to the teaching and learning process (Baker & Yacef, 2009). Information about student performance, teaching methods, educational materials, and other elements that influence the learning process may be included in this. By using data analysis techniques such as predictive models and clustering algorithms, EDM can provide valuable insights into how the teaching and learning process can be improved (Peña-Ayala, 2014). Furthermore, it may anticipate the needs of the students (Shaik et al., 2022), recommend customized strategies, and assist in decision-making to improve the learning environment (Chalaris, Gritzalis, Maragoudakis, Sgouropoulou, & Tsolakidis, 2014).

Educational data mining offers a range of impactful applications in the field of education such as personalized learning paths by analyzing students' learning patterns and preferences (Gobert, Kim, Pedro, Kennedy & Betts, 2015), predicting student's performance that enabling the educators to provide targeted support and resources (Amrieh, Hamtini & Aljarah, 2016; Nabil, Seyam & Abou-Elfetouh, 2021; Sandra, Lumbangaol & Matsuo, 2021), and finally feedback and assessment improvement by examining how students respond to one another and their interactions (Gushchina & Ochepovsky, 2020).

In this paper we will use machine learning algorithms to predict the specialization that Greek high school students will follow. In Greece, in the end of the first year of high school, students have the opportunity to select one of the available offered specializations. The specializations provide students with the ability to delve deeper into specific fields of knowledge and prepare them for the national examinations based on the subjects related to their chosen specialization. Each specialization includes different courses and leads to different career options. Here, we will focus on theoretical and practical specializations. The theoretical and practical specializations are two different directions within the educational system, during high school, that offer different courses and prepare students for different educational and professional paths.

The theoretical specialization focuses on theoretical knowledge and analysis. It includes subjects like Literature, History, Philosophy, Foreign Languages, Ancient Greek and it is suitable for students that are interested in humanities and social sciences and philosophy, as well as for those planning to pursue professional paths that require a strong understanding and analysis of theoretical principles.

The practical specialization emphasizes practical applications, mathematics and physical sciences. It includes subjects like Mathematics, Physics, Chemistry, Biology, Computer Science, and Technology. It is suitable for students interested in sciences and technology and who aim to pursue paths that require practical applications and data analysis.

The problem is that students often struggle with selecting the most suitable specialization, leading to choices that do not align with their strengths and interests. This misalignment can result in poor academic performance and decreased motivation. Research indicate that students typically struggle with this decision-making process, highlighting the necessity of a more supervised approach (Kallio, 1995).

To address this issue, machine learning is employed to develop a scalable and reliable system that can effectively generalize to new data and offer students tailored recommendations based on their academic performance. A variety of machine learning algorithms are utilized, including Random Forest, Naive Bayes, Support Vector Machines (SVM), Neural Networks, Logistic Regression, k-Nearest Neighbors (kNN), and CN2 Rule Induction. These algorithms will analyze students' previous grades, obtained when they all attended the same courses, in order to predict their future specializations. In summary, the primary aim of this article is to explore the potential of becoming a straightforward and valuable tool for educators and parents, that suggests the optimal choice of specialization for students, leveraging their performance in various courses from previous years. To the best of our knowledge, there is no existing literature specifically addressing this issue within the Greek educational system.

The rest of the paper is structured as follows: Section 2 introduces the fundamental elements of the theory and methodology employed. Section 3 presents the results of the comparative study and finally, Section 4 offers the conclusions.

2. Methods

The primary objective of this study is to develop a model for predicting the specialization that Greek high school students should pursue. This involves leveraging historical data from nine distinct courses and employing machine learning algorithms to identify the most effective approach. To achieve this, a variety of supervised machine learning algorithms including Random Forest, Naive Bayes, Support Vector Machines (SVM), Neural Networks, Logistic Regression, k-Nearest Neighbors (kNN) and CN2 Rule Induction, are utilized. The evaluation of the methods will be conducted using confusion matrices, accuracy, and additional metrics provided by Orange (described in detail below). The entire procedure is executed using the Orange machine learning software.

Orange is a platform of open-source machine learning and data mining tools (Demšar et al., 2013). Predictive modeling, data preprocessing, visualization and other data analysis tasks are all made possible by its comprehensive toolkit and user-friendly interface. Orange is made to be user-friendly for both beginner and experienced data scientists, enabling users to create machine learning models and deal with data efficiently, without requiring a deep understanding of programming. Additionally, Orange offers a visual programming interface that allows users to create data workflows and perform complex analyses with ease. A workflow in Orange is a sequence of interconnected data processing and analysis components, that are performed in a particular order on a dataset. These elements – also referred to as widgets – may comprise tools for evaluation, modeling, preprocessing, data loading, and visualization.

This process included projecting their distributions, identifying missing values, and calculating key metrics such as mean, median, dispersion, minimum and maximum values. Then, the data sampler split the dataset into training and testing subsets. This was crucial for evaluating the performance of the models on unseen data, ensuring that the models generalized well.

Subsequently, several supervised learning algorithms were employed to predict the students' future specializations based on their grades. Specifically, Random Forest (RF), Naive Bayes (NB), Support Vector Machines (SVM), Neural Networks (NN), Logistic Regression (LOGR), k-Nearest Neighbors (kNN), and CN2 Rule Induction (CN2) were employed (see Section 2.2 for a detailed description of the parameters used).

Finally, the models were evaluated using the 'Test and Score' widget. This step involved training each model on the training subset and testing it on the testing subset to assess its performance. The actual specialization chosen by each student, served as the target variable for the supervised learning models. This means that the models were trained to predict this specific outcome based on the input features, which were the grades from nine courses (Modern Greek Literature, Modern Greek Language, Ancient Greek Language, Algebra, Geometry, Physics, Chemistry, Biology, and History), serving as the independent variables. After training, the models could forecast the most probable specialization for new students, based on their grades in the same set

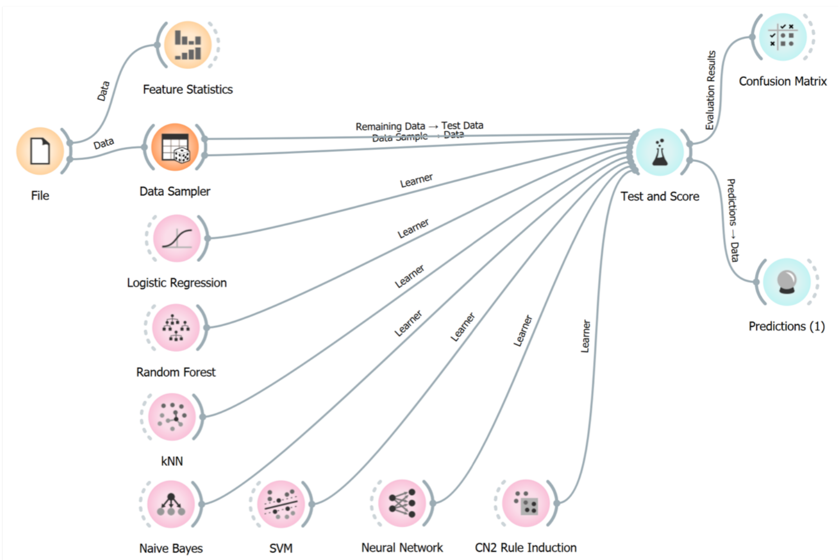

Figure 1 - Workflow in Orange.

of courses. To evaluate the performance of the models, metrics such as confusion matrix, area under ROC curve (AUC), classification accuracy (CA), F1, Precision (Prec), Recall and Matthews correlation coefficient (MCC) were employed.

2.1 Dataset

The Dataset in this paper consists of 530 records of 11 features each. Each record refers to a student. Specifically, they pertain to data from Greek students in the first year of high school from a High school in Serres, during the academic years 2013/2014-2021/2022. Each record has 11 features, such as the ID, the chosen specialization, and grades from nine courses, specifically Modern Greek Literature, Modern Greek Language, Ancient Greek Language, Algebra, Geometry, Physics, Chemistry, Biology, and History. These courses were selected because they are the subjects taken by students in Greece during the Panhellenic exams. The grades in these subjects ultimately determine their admission to university. While the focus was on the grades of these subjects, other potential features, such as attendance records, participation in extracurricular activities, and socio-economic background, were considered. However, these were either not available or not consistent across all records, leading to their exclusion from the current dataset. For each subject, the possible marks range from 0 to 20. The dataset was divided into training set and test set. The training set, which was used to train the different machine learning algorithms, consists of 530 instances randomly selected.

2.2 Machine Learning Algorithms

The machine learning algorithms employed, are discussed in this section. Each algorithm provides unique benefits and faces specific challenges, making them ideal for different aspects of prediction and analysis. The algorithms and the selected parameters and metrics for each algorithm are described below.

1) *Naive Byes*: in machine learning, Naive Bayes is a robust and popular classification algorithm (Zhang, 2004). Based on the Bayes theorem, it makes the assumption that the attributes/features utilized for classification are independent to one another. Naive Bayes classifiers are computationally efficient, quickly and able to achieve impressive results, especially when working with large datasets. However, circumstances in which the independence assumption might not hold true, can impact the accuracy of the model.

2) *Random Forest*: Random Forest is an ensemble learning method used for classification, regression and other tasks (Breiman, 2001). Decision trees are constructed using Random Forest. Each tree is developed from a bootstrap sample from the training data. The term “Random” refers to the arbitrary subset of characteristics that are pulled when creating individual trees, from which the optimal attribute for the split is chosen. The majority vote from each independently formed tree in the forest forms the basis of the final model. In this paper, the parameters are set as follows: the number of trees is set to ten, the minimum subset size for splits is five, and the number of attributes considered at each split is five.

3) *SVM*: Support Vector Machines (SVMs) are supervised learning algorithms used for both classification and regression tasks (Cortes & Vapnik, 1995). SVMs operate by finding the optimal hyperplane in a high-dimensional feature space that maximally separates the different classes of data points. This hyperplane is determined by selecting support vectors, which are the data points closest to the decision boundary. SVMs are unique in that they can handle data that is not linearly separable by using methods such as kernel functions, which convert the data into a higher-dimensional space where separation is feasible. Consequently, this makes SVMs adaptable and efficient for a wide range of applications. In this paper, the parameters for SVM are set as follows: the cost (C) is set to 1, regression loss epsilon to 0.1, numerical tolerance to 0.001, iteration limit to 100 and the kernel type is radial basis function (RBF).

4) *Neural Networks*: Neural networks are computational models that consist of interconnected nodes, or neurons, that process input data to make predictions and to help on decisions (Goodfellow, Bengio & Courville, 2016). A weight is assigned to each connection, and it changes as the connection is trained in order to take advantage of the data. Neural networks are organized in layers, including an input layer, hidden layers for complex pattern recognition, and an output layer for final predictions. In this paper, the parameters for the neural network are set as follows: the number of neurons in the hidden layer is 100, the selected solver is adam and the maximal number of iterations is 200.

5) *Logistic Regression*: Logistic regression is a statistical technique that predicts the probability of an event occurring by considering one or more independent variables (Hosmer, Lemeshow & Sturdivant, 2013). It employs the logistic function to constrain predictions between 0 and 1. In logistic regression, each independent variable’s impact on the probability of the event is represented by its coefficient. In this paper, the parameters for logistic regression are set as follows: the regularization type is ridge (L2) and the regularization strength (C) is 1.

6) *k-Nearest Neighbors*: the k-Nearest Neighbors (kNN) algorithm is a versatile and intuitive machine learning method (Cover & Hart, 1967). It functions according to the similarity principle, in which a new data point is categorized in the feature space according to the majority class of its k nearest neighbors. The value of k is a crucial parameter that determines the number of neighbors that will be considered. When decision boundaries are complex or hard to specify mathematically, k-Nearest Neighbors (kNN) is particularly useful. In this paper, the parameters for kNN are set as follows: the number of neighbors is 5 and the distance metric is Euclidean.

7) *CN2 Rule Induction*: CN2 Rule Induction is a machine learning algorithm that is used for classification tasks (Clark & Niblett, 1989). It is also particularly well-suited for generating rule-based models from data. In order to forecast the target variable based on the values of its attributes, CN2 builds rules iteratively. It adds conditions to the rule that maximize information gain, starting with the most influential attribute. Subsequently, by iteratively taking consideration of new attributes, the algorithm improves the rule. This process is carried out by CN2 until no further improvements are possible. In this paper, the parameters for CN2 Rule Induction are set as follows: rule ordering is ordered, the covering algorithm is exclusive, the evaluation measure is entropy, the beam width is 5, the minimum rule coverage is 1, and the maximum rule length is 5.

3. Results

In this section the results are presented. As mentioned above, the primary focus of this research is to evaluate various machine learning algorithms for assessing the selection of specialization of Greek high school students. To accomplish this, a variety of machine learning algorithms including Random Forest (RF), Naive Bayes (NB), Support Vector Machines (SVM), Neural Networks (NN), Logistic Regression (LOGR), k-Nearest Neighbors (kNN), and CN2 Rule Induction (CN2) were employed. Tenfold cross validation was used to evaluate the prediction accuracy. The dataset consists of records (greek high school students) of 11 features each. The performance of the model was measured from different metrics, using tenfold cross validation. In a 10-fold cross-validation with 530 records, each fold will have approximately 53 records (since 530 divided by 10 is 53). During each fold, one-tenth of the data will be used for testing, which means 53 records will be used as test set for each fold, while the remaining nine folds will be used as training set. This process is repeated for each of the folds. Metrics such as confusion matrix, area under ROC curve (AUC), classification accuracy (CA), F1, Precision (Prec), Recall and Matthews correlation coefficient (MCC) were employed to evaluate the performance of the model. During the development of the model, the grades of the courses (Algebra, Biology, etc.) were determined as independent variables, while the selected specialization was determined as the dependent one.

In Table 1, the predicted values of the examined models and the actual values are presented for five randomly selected students. The results for this sample of 5 students indicate that Neural Networks (NN) and Logistic Regression (LOGR) were the most successful, as they did not make any mistakes on their predictions for the selected instances, whereas all the other examined methods made a few mistakes.

Specifically, for students 1, 3, and 4, all methods performed admirably, accurately predicting their chosen specializations. Likewise, for students 2 and 5, Neural Networks (NN) and Logistic Regression (LOGR) excelled, while the other methods (Naive Bayes, k-Nearest Neighbors, Random Forest, Support Vector Machines, and CN2 Rule Induction) encountered challenges in accurately predicting the actual selected specialization of these students. Naive Bayes (NB) and k-Nearest Neighbors (kNN) notably underperformed, as they were unable to accurately predict the actual selected specialization for students 2 and 5. Random Forest (RF) inaccurately estimated the specialization for student 5, as while the student chose theoretical, the estimation of RF was practical. Similarly, Support Vector Machines (SVM) and CN2 Rule Induction (CN2) incorrectly predicted the choices for student 2, since they predicted theoretical while the student actually chose practical.

These findings are also supported by Table 2, which summarizes the success rates achieved by each algorithm, assessed through a range of performance measures employed in this study. Specifically, Neural Networks and Logistic Regression outperformed other machine learning methods across all metrics considered.

Table 1 - Predicted and Actual Specializations for a sample of 5 students. T refers to Theoretical, while P refers to Practical.

Student	**ID**	**LOGR**	**RF**	**kNN**	**NB**	**SVM**	**NN**	**CN2**	**Actual**
1	2058	T	T	T	T	T	T	T	T
2	2059	P	P	T	T	T	P	T	P
3	2061	P	P	P	P	P	P	P	P
4	2062	P	P	P	P	P	P	P	P
5	2066	T	T	P	P	T	T	T	T

Table 2 - Performance metrics for the examined machine learning algorithms.

Model	**AUC**	**CA**	**F1**	**Prec**	**Recall**	**MCC**
SVM	0.75	0.70	0.70	0.72	0.70	0.37
RF	0.76	0.72	0.72	0.71	0.72	0.36
NN	0.83	0.76	0.76	0.76	0.76	0.46
NB	0.70	0.67	0.68	0.69	0.67	0.31
LOGR	0.83	0.76	0.75	0.75	0.76	0.45
kNN	0.73	0.70	0.70	0.69	0.70	0.32
CN2	0.69	0.65	0.65	0.65	0.65	0.24

They performed equally well in terms of Area Under the ROC Curve (AUC), Classification Accuracy (CA), and Recall, achieving impressive scores of 0.83, 0.76, and 0.76, respectively. When it comes to F1, Precision (Prec), and Matthews Correlation Coefficient (MCC), Neural Networks exhibited a slight advantage over Logistic Regression, boasting a 0.01 improvement. Random Forest emerged as the third-best performer in terms of AUC, CA, F1 and Recall achieving 0.76 for AUC and consistently achieving 0.72 for the rest performance measures. Support Vector Machine (SVM) claimed the third spot in terms of Precision and Matthews Correlation Coefficient (MCC), achieving scores of 0.72 and 0.37 respectively, an incremental improvement of 0.01 over Random Forest. Additionally, it's worth noting that k-Nearest Neighbors (kNN) demonstrated a performance that closely aligned with Support Vector Machine (SVM) and Random Forest. However, it consistently lagged behind both SVM and Random Forest. Similarly, Naive Bayes showed performance closely aligned with kNN and both of them performed better compared to CN2, which performed less optimally for this specific task, registering the lowest scores across all performance measures employed in this study. Notably, CN2 consistently underperformed in this specific task, demonstrating scores that were 0.10 to 0.2 lower than the counterparts of Neural Networks and Logistic Regression in the examined measures.

From the Confusion matrix presented in Table 3, it is observed that Logistic Regression algorithm classifies correctly 401 from a total of 530 instances (76%).

Specifically, it accurately identifies 307 out of 351 students who have opted for practical specialization, demonstrating a strong accuracy rate of 87%. On the other hand, it exhibits a noticeably lower accuracy of 52% (94 out of 179) in correctly classifying students who have chosen theoretical specialization.

This suggests that the algorithm excels in predicting students inclined towards practical specialization, while facing relatively more challenge in accurately predicting those leaning towards theoretical specialization.

A similar trend is observed with the Neural Network algorithm (Table 4), as reflected in its confusion matrix, which closely resembles that of logistic regression. Notably, the Neural Network successfully classifies one additional student who has opted for theoretical specialization. A similar pattern is evident in the case of Random Forest, kNN, and CN2 rule inducer algorithms, as depicted in Tables 5, 6 and 7 respectively. These algorithms exhibit a comparable performance pattern to that of Logistic Regression and Neural Network, further emphasizing their effectiveness in predicting student that have chosen practical specialization.

This pattern experiences a subtle shift when considering the SVM and Naive Bayes algorithms, particularly in their accuracy in predicting students who have chosen theoretical specialization. Specifically, in Table 8, it is observed that SVM accurately identifies 253 out of 351 students who have opted for practical specialization, demonstrating an accuracy rate of 72%, while it exhibits a slightly lower accuracy of 61% (109 out of 179) in correctly classifying students who have chosen theoretical specialization. However, this percentage of accurate classification for students with theoretical specialization is comparatively higher than that achieved by other machine learning algorithms.

A similar trend is observed with the Naive Bayes algorithm (Table 9), as reflected in its confusion matrix, which closely resembles that of SVM.

Table 3 - Confusion matrix of the Logistic Regression algorithm.

Logistic Regression algorithm	**Practical**	**Theoretical**
Practical	307	44
Theoretical	85	94

Table 4 - Confusion matrix of the Neural Network algorithm.

Neural Network algorithm	**Practical**	**Theoretical**
Practical	307	44
Theoretical	84	95

Table 5 - Confusion matrix of the Random Forest algorithm.

Random Forest algorithm	**Practical**	**Theoretical**
Practical	303	48
Theoretical	89	90

Table 6 - Confusion matrix of the kNN algorithm.

kNN algorithm	**Practical**	**Theoretical**
Practical	295	56
Theoretical	94	85

Table 7 - Confusion matrix of the CN2 Rule Inducer algorithm.

CN2 Rule Inducer algorithm	**Practical**	**Theoretical**
Practical	280	71
Theoretical	84	95

Table 8 - Confusion matrix of the SVM algorithm.

SVM algorithm	**Practical**	**Theoretical**
Practical	253	98
Theoretical	70	109

Table 9 - Confusion matrix of the Naïve Bayes algorithm.

Naïve Bayes algorithm	**Practical**	**Theoretical**
Practical	252	99
Theoretical	70	109

4. Discussion and Conclusions

This study compared seven machine learning algorithms to investigate their accuracy in assessing the choice of specialization of Greek students in the end of the first year of high school. The data set used consists of 530 students that described by 11 features, such as id, chosen specialization and their final grades in nine core subjects in the first year of high school. Metrics such as confusion matrix, area under ROC curve (AUC), classification accuracy (CA), F1, Precision (Prec), Recall and Matthews correlation coefficient (MCC) were employed to evaluate the performance of the model. As for the results, on testing data, Neural Networks outperformed other machine learning methods across all metrics considered, followed by Logistic regression which was slightly worse when it comes to F1, Precision and Matthews Correlation Coefficient (MCC). In general, all the methods examined showed decent classification accuracy, as even CN2 rule inducer which was the worst compared to the other machine learning algorithms, achieved an accuracy of 65%. Neural Network which was the best overall achieved 76% accuracy.

Confusion matrices confirm that the class (Practical specialization) with larger sample size had improved classification accuracy, contrary to the class with fewer records (Theoretical specialization) for which the algorithms performed poorer. In summary, the results suggest that although challenging, automatic and accurate prediction of the specialization that students will select is feasible. Nevertheless, it could be further improved by using a larger and more diverse dataset, which could include additional relevant features such as attendance records, participation in extracurricular activities, and socio-economic background.

Additionally, examining other machine learning algorithms or even ensemble methods that combine multiple models could improve the prediction accuracy.

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Examining factors influencing the emergence of a knowledge society: an explorative study

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Abstract

This article addresses the contextual ambiguity prevalent in the literature surrounding the conceptualizations of a knowledge society. By identifying and clarifying these conceptual challenges, the research aims to provide a solid foundation for understanding the factors influencing the emergence of a knowledge society. The objectives include presenting a clear and comprehensive representation of the multifaceted elements that contribute to this societal transition. Methodologically, a quantitative approach is employed using a regression analysis.

The originality of this research lies in its endeavor to develop new perspectives and insights into the catalysts behind the emergence of a knowledge society. By addressing the existing gaps in the literature and employing advanced quantitative methods, the study contributes to the ongoing discourse on the transition to knowledge societies. Practical implications of the research are also developed. The findings offer guidance for policymakers, educators, and stakeholders involved in shaping societal structures, emphasizing actionable insights derived from the identified catalysts.

In terms of contribution, this paper provides a nuanced understanding of the factors influencing the knowledge society emergence. By synthesizing empirical evidence with theoretical frameworks, it not only advances academic discourse but also practitioners with valuable insights for informed decision-making in an era characterized by rapid societal transformation.

KEYWORDS: Knowledge Society, Technology Integration, Economic Performance, Knowledge Production, Social Transformations.

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1. Introduction

In the interconnected world of the 21st century, the concept of a knowledge society has gained immense significance as a driving force behind societal progress and development. According to Ranga and Etzkowitz (2015), a knowledge society is characterized by its ability to create, disseminate, and utilize knowledge as a key resource for innovation, economic growth, and social transformation. As scholars and policymakers endeavor to comprehend the intricate mechanisms driving the evolution of knowledge societies, it becomes imperative to dissect and evaluate the determinants that underlie this profound transition. Understanding the factors that contribute to the emergence of a knowledge society is not only crucial for policymakers and researchers but also holds profound implications for sustainable and inclusive development on a global scale (Simeoni et al., 2024).

While the concept of the knowledge society has attracted considerable attention in academic literature, the existing corpus is marked by a significant growth in theoretical definitions and conceptual models. This ambiguity represents a major challenge, as it prevents a comprehensive understanding of the factors that foster the emergence of a knowledge society. Our study aims to fill this critical gap in the literature by identifying and analyzing the specific factors responsible for the development of a knowledge society.

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To achieve this, we will explore the following research questions:

- what are the key theoretical definitions and conceptual models presented in the existing literature on the knowledge society?
- what factors are identified in the literature as potentially contributing to the emergence of a knowledge society?
- how do these factors interact and influence the emergence of a knowledge society?

By analyzing the complex interconnections among education systems, technological infrastructures, economic frameworks, and cultural dynamics, this study endeavors to unravel the complex web of factors that contribute to the emergence and advancement of knowledge societies. By scrutinizing empirical evidence and employing analytical framework, our research seeks to provide a comprehensive understanding of the key drivers that steer societies towards embracing knowledge as a foundational pillar. The article is structured into three sections. In order to assimilate the concept of the knowledge society from a theoretical point of view, the first section presents the fundamental and founding theories of the concept present in the literature. Then, the second section presents the hypotheses development. The third section represents the methodological framework of the study. Finally, the fourth section presents a discussion of the results of our study.

2. Theoretical foundations

The notion of a knowledge society has an extensive history that spans decades. Beginning in the 1960s, theorists delved into discussions about the trajectory of advanced capitalist nations, positing that the utilization of knowledge and information would shape their future. Consequently, various scholars introduced concepts such as the knowledgeable society (Lane, 1966), post-industrial society (Bell, 1973), information society (Umesao, 1963), network society (Castells, 1996), and learning society (Faure, 1972). Each of these concepts encapsulated distinct paradigms of societal evolution, all of which converged on the pivotal importance of knowledge, which in turn spurred continuous innovation as the foundation of societal development. In the intricate interplay of these concepts, we witness the dynamic synergy between historical insights, technological advances, and evolving societal norms – all converging into the tapestry of a knowledge society. This interconnectedness transcends individual paradigms, leading us to a comprehensive understanding of how knowledge serves as the catalyst for societal progression.

According to Nicolescu & Nicolescu (2005), the knowledge society is characterized by the conversion of knowledge into raw material, capital, products, elements of economic production and economic advances in which the generation, sale, purchase, learning, storage, development, sharing and protection of knowledge become predominant and condition the profit and economic sustainability. Moreover, Lytras & Sicilia (2005), argue that the knowledge society is built on the synergies of individuals, teams, organizations, social networks and communities that effectively exploit the flows of knowledge and learning. Furthermore, Fairclough (2012) presents knowledge societies as a qualitative change in economies and societies such that economic and social processes are knowledge-driven and change occurs, at an accelerated pace, through the generation, circulation, and operationalization of knowledge in economic and social domains. As outlined by Afgan and Carvalho (2010), a knowledge society is characterized by its reliance on the imperative of disseminating knowledge, converting information into actionable insights. The dissemination of knowledge is considered crucial for establishing a knowledge society (Znagui, 2021), emphasizing principles of justice, equality, and nondiscrimination.

Conceptually, the United Nations Educational, Scientific and Cultural Organization (UNESCO), contributed to the exploration of models specific to the knowledge society. In its report "Towards Knowledge Societies" published in 2005, UNESCO defines knowledge societies as those leveraging diversity for knowledge-sharing and human development. Embracing a participatory pluralist discourse, the report underscores freedom of expression, universal access to knowledge, and respect for linguistic and cultural diversity. The proposed conceptual framework for the knowledge society is detailed in Figure 1.

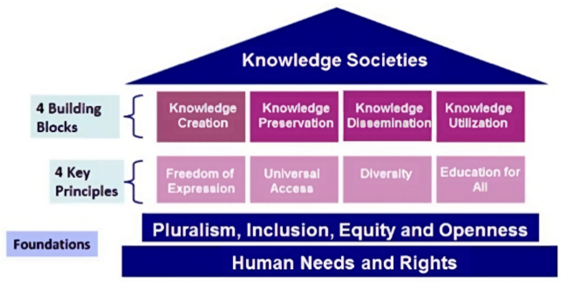

Figure 1 - Conceptual model of the knowledge society, UNESCO (2005).

Through its conceptualization, the vision of UNESCO for knowledge societies, promotes a social framework rooted in human rights principles, urging active participation in addressing societal challenges and promoting peace through fair and inclusive utilization of knowledge (Cummings et al. 2018; Mansell 2015). Building on this foundation, UNESCO has outlined essential foundations, key principles, and building blocks for the establishment of knowledge societies. The concept underscores that universal access to knowledge is crucial for the emergence and flourishing of knowledge societies, involving the creation of suitable infrastructure alongside legal and economic considerations (Mansell & Tremblay, 2013).

Critical analysis of the model present in the literature focuses on the exploration of its economic aspects, technological stance, and the basic principles of its inclusive framework. This discourse places a strong emphasis on problem-solving by critically questioning the role of knowledge in human development, integrating practical experimentation with theoretical knowledge, and establishing a knowledge hierarchy based on pluralistic principles with a focus on locally sourced endogenous knowledge (Souter, 2014). Furthermore, the economic dimension prioritizes collaborative, communal knowledge sharing over individual ownership, viewing knowledge as a non-rival public good, rejecting exclusive intellectual property claims (Mansell, 2013). The approach to technology emphasizes digital solidarity, fostering innovative partnerships across various entities, with the internet as a primary medium and recognition of the complementary nature of both old and new information and communication technologies (ibid).

Transitioning to the model of Sharma et al. (2008), a distinct perspective on knowledge societies emerges, offering additional insights into the intricate dynamics of this conceptual framework. According to Sharma et al. (2008), knowledge societies exhibit distinctive characteristics, including high knowledge and information absorption capacities, established governance structures, and a cultural ethos that prioritizes easy dissemination and sharing of knowledge. These qualities form the basis for active participation in intricate processes of knowledge collection, transformation, dissemination, and utilization. Moreover, the authors argue that knowledge societies emphasize sustainability, innovation promotion, and community learning. Consequently, these attributes foster an economic landscape where knowledge-based activities become pivotal drivers of growth, according to the authors. Figure 2 illustrates the model presented by Sharma et al. (2008).

The conceptual framework outlines four fundamental components integral to understanding and fostering a knowledge society: infrastructure and governance dimensions, collectively forming the structural capital of society; human capital, representing the cognitive capacities of citizens; and the culture of society, encapsulating relational capital. These components are systematically explained by the delineation of thirteen indicators, as visually depicted in Figure 2. As per the model, establishing a robust knowledge society necessitates a comprehensive examination of the interconnectedness of structures, individuals, and relationships, encompassing the multifaceted aspects contributing to knowledge creation. Evidently, the enduring sustainability of a knowledge society is contingent upon the cultivation of a culture that fosters learning, innovation, knowledge sharing, diverse perspectives, and leadership across various domains.

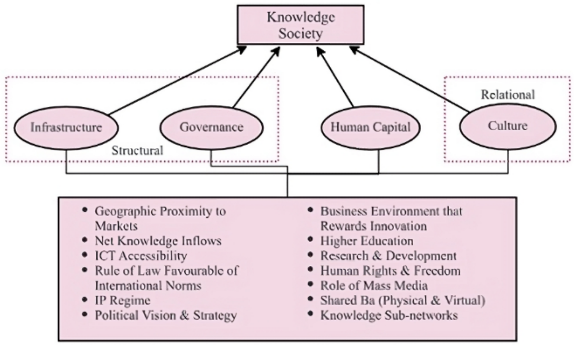

Figure 2 - Conceptual model of the knowledge society (Sharma et al., 2008).

Examining potential gaps between both models of UNESCO (2005) and Sharma et al. (2008) reveals distinctions that could guide the development of a more comprehensive framework. The model presented by UNESCO (2005) with its global focus and emphasis on pluralism and participation, contrasts with the one illustrated by Sharma et al. (2008) in a more specific approach, highlighting dimensions like infrastructure, human capital, and societal culture. While UNESCO (2005) underscores cultural diversity, Sharma et al. (2008) leans towards a potentially universal perspective. The differences in operationalization, temporal relevance, and stakeholder engagement also contribute to the identified gaps. In this context, the primary objective of our new model is to bridge these gaps by presenting a framework that integrates global principles with specific, practical indicators for the emergence of a knowledge society. Emphasizing both cultural inclusivity and universal applicability, the new model will incorporate dynamic variables responsive to contemporary socio-economic and technological dynamics, offering a comprehensive guide for understanding and fostering knowledge societies.

3. Hypotheses formulation

3.1 Information Technology Infrastructure in a society

The notion of Information Technology Infrastructure (ITI) encompasses an assemblage of technologies, tools, and assets employed for the acquisition, processing, storage, distribution, and utilization of information (Cassia et al., 2020). The robust foundation of ITI is intricately linked by the integration of various components, where technology integration, Information Technology (IT) planning, IT security, and technology management converge to create a comprehensive framework.

A number of studies suggest a reciprocal interaction between ITI and the emergence of a knowledge society determined by a selection of key variables (Bechmann, 2009; Balloni et al., 2012). At the core, technology integration emerges as a transformative force, seamlessly weaving technological advancements into the societal fabric (Sony & Naik, 2020). This integration extends beyond mere connectivity, fostering an environment where information flows effortlessly, enhancing efficiency, and enabling widespread access to knowledge (Fukuda, 2020). The interconnectedness of devices, networks, and systems becomes the conduit through which the knowledge society emerges (Anvarova, 2023).

Strategic IT planning acts as the architect of this transformation, orchestrating the alignment of technological resources with the overarching goals of the society. Through meticulous planning and foresight, IT infrastructure becomes a dynamic entity, capable of adapting to the evolving needs of the community (Borges et al., 2021). It anticipates technological shifts, ensuring that the society remains agile and responsive to harness the potential of emerging innovations. Amidst this transformative landscape, IT security assumes a critical role in safeguarding the integrity and confidentiality of information (Soomro et al., 2016). With the omnipresence of technology, ensuring robust security measures becomes imperative. The establishment of secure frameworks not only protects sensitive data but also nurtures a sense of trust within the society (Sanakulov, 2019). This trust forms the foundation for the unrestricted exchange of information, fostering a collaborative environment conducive to knowledge-sharing and innovation. Reinforcing these pillars is the strategic guidance of technology management, influencing the nuanced aspects of IT infrastructure. From the selection of technologies to the implementation and ongoing maintenance, technology management becomes the steward of a resilient and future-ready IT foundation (Siddiqui et al., 2020). This involves meticulous evaluations of technological options, prudent investments, and resource optimization, ensuring that the IT infrastructure evolves in tandem with the society's goals and aspirations (Yaras & Öztürk, 2022).

This leads us to formulate the following hypothesis:

Hypothesis 1: Information technology infrastructure influences the emergence of a knowledge society.

3.2 Knowledge production and dissemination within society

The impact of knowledge production dynamic within a society and its modernization has been the subject of a number of studies (Välimaa & Hoffman, 2008; Malik, 2018; Hopkins, 2011) and lead to present various variables that may potentially influence the emergence of a knowledge society. According to Jehanzeb & Bashir (2013), training represents the pivotal factor that enables individuals to acquire the skills and expertise they need to contribute to a knowledge-based community. Through targeted training initiatives, societies may cultivate a workforce adept at navigating the complexities of contemporary challenges and advancements.

Lifelong education stands as another pillar in the foundation of a knowledge society, emphasizing the continuous pursuit of knowledge throughout one's life (Ashour, 2024). This commitment to ongoing learning ensures that individuals remain adaptable and resilient in the face of evolving information landscapes, technological innovations, and societal shifts. Moreover, practical learning experiences bridge the gap between theoretical knowledge and real-world application, fostering a holistic understanding and mastery of skills that are directly applicable to the challenges and opportunities of the knowledge era (Eynon & Young, 2021).

Furthermore, Research and development (R&D) activities constitute a dynamic force propelling the knowledge society forward. By engaging in R&D endeavors, societies not only expand their collective knowledge base but also foster a culture of innovation. This culture is a catalyst for technological advancements, scientific breakthroughs, and the creation of novel solutions to complex problems (Aliu Mulaj & Dedaj, 2022). The ripple effects of R&D extend beyond intellectual enrichment, influencing economic growth through the development of new industries, products, and services.

In the collaborative form of a knowledge society, information-sharing and coordination serve as connective threads, weaving together insights, experiences, and expertise across individuals and organizations. A culture of open communication facilitates the free exchange of knowledge, accelerating the pace of discovery and innovation (Sayogo & Gil-Garcia, 2016). Coordinated efforts ensure that knowledge is strategically applied across various sectors, leading to synergies that contribute to comprehensive societal development.

This leads us to formulate the following hypothesis:

Hypothesis 2: Production and dissemination of knowledge within society influences the emergence of a knowledge society.

3.3 Economic performance within a society

Economic performance in a society represents an essential key measure of the vitality of its economic activities. Previous studies suppose that an economic growth in a modern society lead to transform it into a knowledge society (Baporikar, 2016; Stehr, 2012; Fukuda, 2020).

As a multifaceted concept, economic performance encompasses a wide array of indicators. Direct economic performance serves as a foundational pillar, offering a comprehensive overview of the financial vitality. Indicators such as GDP growth, employment rates, and overall economic output not only gauge the economic health of the society but also reveal its capacity to invest in knowledge-centric initiatives (Wang & Tan, 2021). Furthermore, market presence emerges as a dynamic force, influencing the societal narrative on the global stage (Enke, 2023). The competitiveness and visibility of a society in the international marketplace play a pivotal role in establishing its identity as a knowledge-driven entity. A strong market presence not only attracts foreign investment but also signals the society's prowess in generating innovative, knowledge-based products and services that contribute to the global intellectual landscape (Shorette, 2022).

Beyond the tangible metrics of direct economic performance and market presence lies the nuanced realm of indirect economic impact on society. This encompasses the profound ripple effects of economic activities, such as the creation of jobs, the invigoration of local economies, and the elevation of overall living standards (Fernández-Portillo et al., 2020). In the context of a knowledge society, these impacts extend beyond conventional economic indicators, influencing social mobility, inclusivity, and the overall quality of life (Botzen et al., 2019). The societal benefits derived from knowledge-driven economic activities transcend financial gains, permeating the very fabric of communal well-being.

Moreover, interdependent partnership between economic performance and a knowledge society represents a reciprocal relationship. The characteristics of a knowledge society, marked by a commitment to continuous learning and innovation, reciprocally enhance economic performance. A workforce steeped in knowledge becomes a catalyst for increased productivity, fostering economic diversification and sustainable growth. The generation of innovative solutions within a knowledge society further positions it as a hub for economic dynamism.

From the above approaches, we can pose the following hypothesis:

Hypothesis 3: Economic performance in a society influences the emergence of a knowledge society.

3.4 Social transformations

According to Stehr (2007), social transformations represent dynamic and complex processes through which societies undergo fundamental changes in their structures, institutions, values, and norms. At its core, the response to social challenges stands as a defining factor (Feola, 2015). Societal issues such as inequality, diversity, and social justice serve as crucibles, demanding innovative and knowledge-driven solutions. The ability of a society to meet these challenges not only shapes its character but also paves the way for a culture of continuous learning, adaptation, and the cultivation of intellectual resilience (Manda & Ben Dhaou, 2019).

Furthermore, social transformations are aimed to respond to the environmental challenges. As the global community confronts the profound impacts of climate change, resource scarcity, and ecological degradation, the imperative for knowledge-driven solutions becomes increasingly apparent (Oláh et al., 2020). In this context, a knowledge society becomes not just a repository of information but a proactive force in developing sustainable practices, leveraging scientific advancements and technological innovations to address pressing environmental concerns (Kraft, 2021).

Moreover, the transformative role of mass media in shaping cultural attitudes cannot be overstated. In the landscape of a knowledge society, the media serves as a powerful vehicle for information dissemination and the shaping of public opinion (Luttrell & Wallace, 2021). The democratization of information through various media channels fosters an environment where knowledge is not confined to academic institutions but is accessible to the broader population. This accessibility not only promotes informed decision-making but also cultivates a society where critical thinking and intellectual discourse thrive (Meier & Meier, 2012; Snellman, 2015). Cultural attitudes, deeply ingrained in societal norms and values, form the bedrock of a knowledge society. A culture that values education, embraces intellectual curiosity, and encourages continuous learning becomes a catalyst for progress (Lifintsev et al., 2019; Chwialkowska et al., 2020).

In light of the above, we can pose the following hypothesis:

Hypothesis 4: Social transformations influences the emergence of a knowledge society.

4. Methodology

4.1 Research design and variable measurement

Based on the above review of literature, the resulting model of hypothetical relationships explaining the influence on the emergence of a knowledge society is presented in Figure 3. Moreover, Table 1 presents the instruments for measuring the total five constructs.

In this study, we delineate the structure and dimensions of each construct as follows. The initial construct, ITI, is evaluated through the lens of four dimensions. These specific metrics have been previously employed in scholarly works, notably in the studies conducted by Lewis & Byrd (2003). The second construct encapsulates the production and dissemination of knowledge in society, assessed across four dimensions. This framework aligns with the established guidelines set forth by UNESCO (2005). The third construct pertains to the economic performance in society, gauged through three dimensions. Similar measurement criteria have been applied in prior research, as exemplified by Hussein et al. (2018).

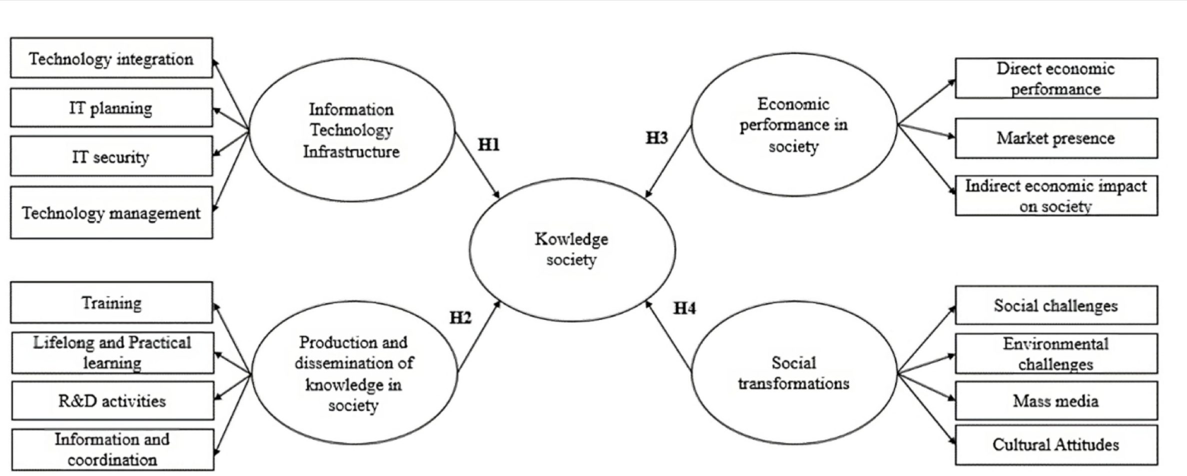

Figure 3 - Research model, Author.

Table 1 - Constructs measurement.

Variables	Items	Number of items	Authors
Information technology infrastructure	ITI1: Technology integration ITI2: IT planning ITI3: IT security ITI4: Technology management	4	Lewis & Byrd (2003)
Production and dissemination of knowledge in society	PROD1: Training PROD2: Lifelong and Practical learning PROD3: R&D activities PROD4: Information and coordination	4	David & Foray (2003), Darroch (2003), Loon Hoe & McShane (2010)
Economic performance in society	EP1: Direct economic performance EP2: Market presence EP3: Indirect economic impact on society	3	Hussein et al. (2018)
Social transformations	TRAN1: Social challenges TRAN2: Environmental challenges TRAN3: Mass media TRAN4: Cultural attitudes	4	Sharma et al. (2008)
Knowledge society emergence	KS1: Net knowledge inflows KS2: Political strategy KS3: Human rights and freedom KS4: knowledge sub-networks	4	Sharma et al. (2008)

The fourth construct encompasses social transformations, evaluated across four dimensions in accordance with the approach taken by Sharma et al. (2008). Finally, the last construct, the emergence of a knowledge society, is appraised through four dimensions, mirroring the methodology employed by Sharma et al. (2008).

4.2 Sample and data collection

The sampling frame represents actors of the regional innovation ecosystem in the Casablanca-Settat region in Morocco. This ecosystem, which consists of public and private organizations, professional associations, chambers of commerce and co-working spaces, aims to cover the entire innovation process, from ideation to development, validation and production.

In this study, the constitution of our sample is delimited using the stratified sampling technique. Given the heterogeneous composition of stakeholders within our chosen field of study, we assert that the implementation of the stratified sampling methodology is paramount. This approach is considered optimal as it guarantees the inclusion of all pertinent heterogeneous stakeholders, ensuring a comprehensive representation of the diverse elements within the field (Berndt, 2020). The variables used for stratification describe a set of heterogeneous entities, including Public-sector organizations, Private-sector organizations, Professional associations, Chambers of Commerce and Industry, and Co-working spaces. Total sample size is up to 331.

Data were collected using a questionnaire. Guided by the conceptual framework of our research, we structured the questionnaire into five distinct sections, aligning with the specific data requirements crucial for testing the hypotheses posited in our study:

In the first section participants were asked about the availability, integration, and utilization of digital technologies, as well as the institution's capability to support and enhance knowledge-based activities through its IT infrastructure. Moreover, questions in the second section explored the frequency and scope of research activities, the effectiveness of knowledge transfer strategies, and the extent of collaboration with other entities to ensure the widespread dissemination of knowledge. Furthermore, questions within the third section were designed to evaluate how knowledge production and dissemination contribute to economic outcomes. Respondents provided information on the economic benefits generated by their institution's activities, such as innovation-driven growth, job creation, and contributions to the regional or national economy. The fourth section included questions that explored the societal impacts of knowledge and technology generated by the institution. Participants were asked about the role their institution plays in driving social change, addressing societal challenges, and promoting inclusive development through knowledge-driven initiatives. The final section aimed to directly assess the indicators and manifestations of a knowledge society within the context of the study. Respondents were asked about the presence of knowledge-intensive activities, the level of societal reliance on knowledge, and the institutional and societal readiness for a knowledge-based economy.

Employing a five-point Likert scale as the primary question format, we complemented this with open-ended questions to ensure a comprehensive data collection approach.

To facilitate the administration of the questionnaire, we utilized Google Forms, leveraging the efficiency of electronic communication by distributing it via email to our selected sample. The data collection phase lasted 5 months. The ensuing response rate amounted to 70%, indicating a substantial and representative engagement from the participants.

Subsequently, the collected data was the subject of an in-depth analysis using SmartPLS V4 software, allowing for robust statistical examination and interpretation in accordance with the research objectives. This meticulous process ensures the reliability and validity of our findings, contributing to the overall rigor of our study.

4.3 Techniques and methods

In pursuit of the objective of our study, we used the partial least squares (PLS) technique, a variance-based method. PLS, recognized as a second-generation tool for multivariate analysis, proves particularly adept at estimating parameters in complex models. The rationale for opting for PLS stems from the exploratory nature of

Table 2 - Results of the Measurement Model, SmartPLS software.

Variables	Items	Loadings	Cronbach's alpha	Composite Reliability (CR)	Average variance extracted (AVE)
Information technology infrastructure	ITI1	0.873	0.948	0.900	0.751
	ITI2	0.803			
	ITI3	0.802			
	ITI4	0.873			
Production and dissemination of knowledge in society	PROD1	0.968	0.858	0.904	0.703
	PROD2	0.680			
	PROD3	0.957			
	PROD4	0.810			
Economic performance in society	EP1	0.792	0.884	0.919	0.743
	EP2	1.000			
	EP3	0.792			
Social transformations	TRAN1	0.877	0.893	0.920	0.744
	TRAN2	0.846			
	TRAN3	0.935			
	TRAN4	0.784			
Knowledge society emergence	KS1	0.873	0.858	0.904	0.703
	KS2	0.803			
	KS3	0.802			
	KS4	0.873			

the study. This approach demonstrates greater flexibility concerning minimum sample size prerequisites, the measurement scale's nature, and the distribution of observed variable indicators when compared to alternative covariance-based methods, as highlighted by Purwanto (2021). The calculation of the proposed research model was executed using SmartPLS version 4 software.

4.4 Assessment of the measurement model

When evaluating the measurement model, a critical step in empirical research, the accuracy and reliability of the selected measurements are closely examined. This process involves assessing the constructs and their respective indicators to ensure they effectively capture the intended concepts. Rigorous examination and validation of the measurement model are imperative for deriving meaningful and valid conclusions. Table 2 and Figure 4 present results of items loadings, Cronbach's alpha values, Composite Reliability (CR) and Average Variance Extracted (AVE).

Regarding the results, the factor loadings are above 0.5, which means that the convergent validity is reached. Moreover, Cronbach's alpha indicates values exceeding 0.7, all AVE values exceeded 0.5, and CR surpassed 0.7. These given results are showing that there is high reliability in the measurement model, and good consistency among all of the variables of the study.

We also examined the discriminatory validity of the constructs using the Heterotrait-Monotrait Ratio (HTMT) (Table 3). The values were below 0.9, which shows adequate discriminatory validity (Henseler et al., 2015).

4.5 Assessment of the structural model

The assessment of the structural model is a pivotal phase in research, where the relationships and interactions among constructs are examined for their significance and validity. This evaluation delves into the underlying mechanisms that link variables, offering insights into the theoretical framework's coherence. A thorough examination of the structural model ensures the reliability and generalizability of the study's findings. This critical analysis contributes to a comprehensive understanding of the dynamics and impact of the proposed relationships within the research framework.

The outcomes of the structural model evaluation are presented in Table 4. Moreover, the R^2 value is presented in Table 5. The result shows that all of the independent variables are expected to explain 85.2% of the variance in the knowledge society emergence.

Furthermore, effect sizes are calculated to assess the extent independent variable contributes to the R^2 value of a dependent variable. In this study, results of relative effect sizes (f^2) show that independent variables have a strong effect on the dependent variable (>.35) (Cohen 1988). Finally, we examine the quality of the model using predictive relevance (Q^2) (Chin, 1998). Results in table show that $Q^2 > 0$.

5. Research findings and discussion

The main objective of our study is to explore the possible factors influencing the emergence of knowledge society. The quantitative analysis has relied on t-values and a significance level for the acceptance or rejection of hypotheses. All hypotheses with t-values exceeding 1.64 and p-values below 0.05 have been deemed acceptable.

According to the results, there is a significant effect of information technology integration on knowledge society emergence ($\beta = .213$, $t = 3.620$, $p < .005$). Therefore, these results support that the interplay of technology integration, IT planning, IT security, and

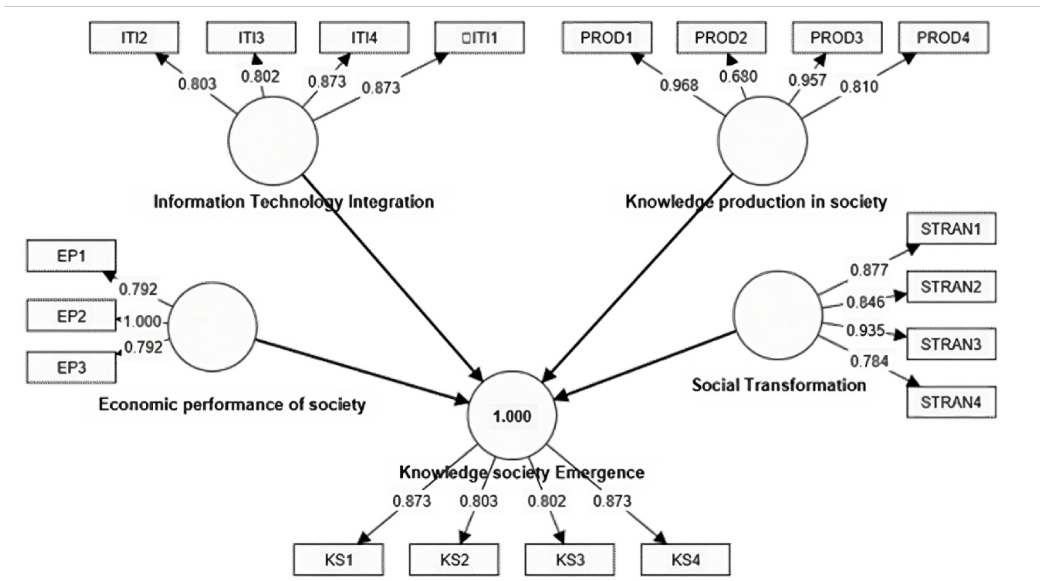

Figure 4 - Measurement Model Assessment, SmartPLS 4.

technology management forms the core of information technology infrastructure, acting as a key driver to the emergence of a knowledge society. Merging these essential elements not only establishes a solid technological framework, but also creates an environment conducive to the exchange and dissemination of knowledge. In addition to effective IT planning, societies can take strategic advantage of technological advances, while robust security measures guarantee the integrity and confidentiality of information, thus preserving the foundations of a knowledge-based society. Simultaneously, effective technology management ensures the optimal functioning and evolution of IT systems, enabling societies to navigate the complexities of the digital age. In this holistic integration, information technology becomes an indispensable catalyst, promoting the continual growth and transformation of societies into dynamic knowledge-based entities. Our findings are in line with the evidence from the literature that argues that the information technology, impact knowledge societies, and that even the society of knowledge depend on technology integration (Bechmann, 2009; Balloni et al., 2012). Moreover, some other studies have confirmed the current findings as Siddiqui et al. (2020) and Yaras & Öztürk, (2022) where authors affirm that technology integration has an impact on technologically progressive society and society 5.0.

Similarly, results show that there is significant positive and direct effect of knowledge production and dissemination in society on knowledge society emergence ($\beta = .361$, $t = 3.570$, $p < .005$). Indeed, the complex interplay between various dimensions of knowledge production and dissemination in society, encompassing Training, Lifelong and Practical learning, R&D activities, as well as Information and coordination, shows a significant positive and direct influence on the emergence of a knowledge society. As society actively engages in training programs, continuous and practical learning endeavors, and robust research and development initiatives, a multifaceted framework for knowledge cultivation is forming. The dissemination of information combined with effective coordination mechanisms further reinforces this transformation process. It is within the synergy of these components that the basis of a knowledge society is established,

Table 3 - Discriminant Validity HTMT of Measurement Model, SmartPLS 4.

Constructs	ITI	PROD	EP	TRAN	KS
ITI	-				
PROD	0.701	-			
EP	0.671	0.815	-		
TRAN	0.626	0.624	0.585	-	
KS	0.533	0.599	0.606	0.650	-

Table 4 - Hypothesis results, SmartPLS 4.

Hypothesis	Path coefficient (β)	Standard deviation (STDEV)	T Statistics (|O/ STDEV |)	P values	VIF	Decision
H1: ITI -> KS	0.213	0.061	3.620	0.001	1.260	Supported
H2: PROD -> KS	0.361	0.055	3.570	0.000	1.611	Supported
H3: EP-> KS	0.222	0.071	1.762	0.003	1.701	Supported
H4: TRAN -> KS	0.331	0.077	4.292	0.000	2.005	Supported

Table 5 - Variance Explained R², SmartPLS 4.

Dependent Variable	Variance explained (R^2)
Knowledge society emergence	85.2%

Table 6 - Effect sizes, SmartPLS 4.

Construct	f^2
ITI	0.490
PROD	0.355
EP	0.432
TRAN	0.505

Table 7 - Construct Cross-Validated Redundancy, SmartPLS.

Total	Sum of squared observations	Squared prediction errors	Q^2
Knowledge society emergence	249.000	89.002	0.721

where the exchange, creation, and application of knowledge become not only inherent but also pivotal to societal progress and development. The positive correlation between the comprehensive spectrum of knowledge-related activities and the evolution of a knowledge society underscores the indispensable role played by continuous learning, innovation, and collaborative information dissemination in shaping the dynamics of modern societal structures. The results of this study are supported by previous studies as Välimaa & Hoffman (2008), Malik (2018) and Hopkins (2011) where authors argue that knowledge production can influence the conceptualization of modern societies and that evidence shows that knowledge explosion has led to phenomenal changes in the modern society, therefore it represents one of the main pillars of knowledge society. Moreover, the study of Serpa et al. (2020) supports also our findings arguing that the process of knowledge production influence it impacts on a digital society.

Moreover, our results highlight that economic performance of a society on knowledge society emergence ($\beta = .222$, $t = 1.762$, $p < .005$). These results support that the emergence of a knowledge society is closely linked to the multifaceted dimensions of a society's economic performance. Comprising direct economic performance, market presence, and indirect economic impact on society, this composite framework plays a pivotal role in shaping the trajectory towards a knowledge-based paradigm. Direct economic performance reflects the efficiency and productivity of a society's economic activities, serving as a foundation for knowledge society emergence by providing the necessary resources and infrastructure. Market presence, on the other hand, underscores the global interconnectedness and competitiveness of a society, influencing its ability to participate in the exchange of knowledge on a broader scale. The indirect economic impact, encompassing factors such as social welfare and equitable distribution of resources, contributes to the inclusive nature of a knowledge society. In essence, the profound interplay between these components illuminates the intricate relationship between economic prowess and the unfolding of a society characterized by the cultivation, dissemination, and utilization of knowledge. This result is in harmony with a study by Ranga & Etzkowitz (2015), where authors argue that the triple helix thesis represent a potential for economic development in a knowledge society. Furthermore, our findings further support the work of Baporikar (2016), Stehr (2012) and Fukuda (2020) who affirm that the economic growth in a modern society lead to transform it into a knowledge society.

Our results also acknowledge the significant direct and positive effect of social transformations on knowledge society emergence ($\beta = .331$, $t = 4.292$, $p < .005$). Therefore, the emergence of a knowledge society is profoundly influenced by the dynamic contours of social transformations within a given community. Comprising social challenges, environmental challenges, mass media, and cultural attitudes, these interconnected components shape the fabric of societal evolution towards a knowledge-centric paradigm. Social challenges act as catalysts for change, driving adaptations and innovations in response to shifting dynamics. Environmental challenges, reflecting the interface between society and its environment, underscore the imperative for sustainable practices and the incorporation of ecological considerations into the knowledge society framework. Mass media serves as a conduit for the dissemination of information, fostering a culture of connectivity and shared knowledge. Cultural attitudes, deeply ingrained in societal values, play a pivotal role in shaping the receptivity and openness towards diverse forms of knowledge. In essence, the complex interplay of these elements illuminates the path of transformation towards a knowledge society, where the dynamism of social transformations becomes the driving force for the continuous cultivation, exchange, and integration of knowledge. The findings of this research further support the work of Stehr (2007) who argue that social transformations represent the foundation for the transformation of modern societies into knowledge societies. As well as by Meier & Meier (2012) and Snellman (2015) who argue that changes on the market, progress in the social transformations demand for setting out in the direction of a knowledge society. According to another study by Turnhout et al. (2020), the empowerment of societal transformation lead to strengthen politics of co-production within a society.

In order to contrast the research results with the sample studied, i.e. Moroccan innovation ecosystem, we can argue that this ecosystem, composed of public organizations, private organizations, professional associations, chambers of commerce, and co-working spaces, plays a pivotal role in fostering the emergence of a knowledge society. Public organizations lay the foundation by crafting and implementing policies that promote education, research, and innovation. These institutions provide the necessary funding and regulatory frameworks that not only encourage innovation but also facilitate collaboration across various sectors. By establishing and supporting educational institutions and research centers, public organizations ensure the continuous production of knowledge, which is essential for building a knowledge society.

This groundwork is complemented by private organizations, which inject capital, resources, and a market-oriented approach to innovation. By translating academic research into practical applications, products, and services, private organizations play a crucial role in making knowledge accessible and beneficial to society. Their partnerships with educational institutions and public research bodies further drive the commercialization of new technologies, bridging the gap between theoretical knowledge and its real-world applications.

Professional associations act as vital connectors within this ecosystem, linking academia, industry, and government. They facilitate the exchange of knowledge, skills, and best practices among professionals, ensuring that the workforce remains informed and aligned with global standards. Through their advocacy efforts, these associations also help shape policies that support the continuous professional development of their members, thereby enhancing the overall skill level within the society.

Chambers of commerce add another layer of support by fostering connections between businesses and academic or research institutions. They provide essential platforms for networking, knowledge exchange, and partnerships, which are crucial for the innovation process. By advocating for business-friendly policies and supporting entrepreneurial activities, chambers of commerce contribute to creating an environment that nurtures innovation and the dissemination of knowledge.

Co-working spaces further enhance this ecosystem by serving as dynamic hubs of creativity and collaboration. These spaces bring together a diverse array of individuals – entrepreneurs, freelancers, researchers, and startups – creating opportunities for the exchange of ideas and expertise. Through events, workshops, and mentoring sessions, co-working spaces accelerate the innovation process, facilitating the growth of knowledge-based initiatives.

Together, these components of Morocco's innovation ecosystem create a synergistic environment where knowledge is continuously generated, shared, and applied. This dynamic interplay supports the growth of a knowledge economy by fostering innovation, improving skills, and enabling the flow of information across different sectors. As a result, this ecosystem plays a crucial role in the gradual emergence of a knowledge society, where knowledge becomes the primary driver of economic development, social progress, and cultural advancement.

6. Concluding remarks

In conclusion, this article endeavors to formulate a conceptual framework elucidating the factors influencing the emergence of knowledge society. The study systematically examined the impact of indicators specific to various facets of knowledge society as delineated in the existing literature. After the development of a conceptual model as the foundation, a quantitative study was carried out to clarify the causal links between independent variables and the dependent variable. The questionnaire, tailored to expound upon the variables within the conceptual model, utilized items measured through categorical scales. Rigorous assessments of construct validity and content validity were then conducted to ensure the questionnaire's robustness. Our data analysis was based on a PLS Analysis. The findings of our study substantiate a noteworthy contribution from variables within the conceptual model. Results show that there is an influence of information technology integration, knowledge production and dissemination in society, economic performance of a society and social transformations on a knowledge society emergence. This research has two main theoretical implications. Firstly, it narrows existing conceptualizations by clearing up ambiguity in the literature; and secondly, it extends theoretical frameworks by incorporating validated relationships between different influencing factors. On a managerial level, the insights derived from this study offer actionable guidance for decision-makers tasked with navigating the multifaceted challenges posed by societal transitions, emphasizing the strategic leverage of technological innovation, educational paradigms, and societal dynamics. From a policy perspective, the findings underscore the imperative for adaptive strategies that harness the transformative potential of these identified catalysts. However, it is essential to acknowledge certain limitations, including potential challenges in generalizing findings to diverse contexts and the inherent dynamism of societal shifts. As a foundation for future research pursuits, this study advocates for further exploration into contextual nuances, encourages longitudinal analyses to capture evolving trends, and promotes interdisciplinary approaches to comprehensively enhance our understanding of the constantly evolving landscape of knowledge societies.

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Global perspectives on Teacher ICT Competencies: diversity and commonalities in eight representative frameworks

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Abstract

This study comprehensively compares and analyzes eight representative global frameworks for teacher Information and Communication Technology (ICT) competencies, each reflecting regional educational priorities and philosophies. The research aims to transcend geographical boundaries by identifying consensus on key areas of teacher ICT competencies and exploring unique characteristics of each framework within specific educational contexts and challenges. The findings indicate that despite diversity, global teacher ICT competencies represent an integration of knowledge, skills, and values, particularly in digital society building, digital career development, digital communication and collaboration, digital assessment, digital teaching and learning, and development of students' digital competencies. The study further highlights varying emphasizes among frameworks in core areas and competencies, accompanied by varying levels of implementation support. Ultimately, the paper provides recommendations to assist educators, policymakers, and digital leaders in understanding global standards for teacher ICT competencies, developing effective and inclusive frameworks, and exploring best practices for advancing teacher ICT competencies.

KEYWORDS: Teacher ICT Competencies Framework; Comparative Analysis; Information and Communication Technology.

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1. Introduction

The digital age has ushered in a new era of educational reform, especially in the post-pandemic period, where Information and Communication Technology (ICT) has become an indispensable part of the global teaching and learning process. As ICT permeates classrooms worldwide, the competencies required for teachers to effectively integrate ICT into their teaching have garnered widespread attention. ICT does not only impact teachers' professional capabilities but also significantly expands their scope of activities. Teacher ICT competencies has become an essential component of modern teacher qualifications (Skakun, 2021).

An ICT competencies framework is a tool designed to develop or assess the ICT competencies of a specific target group based on a set of interrelated competencies (Ferrari et al., 2012). To support the measurement of teacher ICT competencies, predict training needs and development requirements, or explore their application in specific contexts, various teacher ICT competencies frameworks have been designed by national education departments, supranational organizations, and professional bodies worldwide (Nguyen & Habók, 2023).

The development and formation of ICT competencies for students and teachers across all educational stages is a priority in new education standards. However, considerable debate in the literature about the precise definition, nature, and scope of teacher ICT competencies, and how best to develop it in initial teacher education were published.

According to the Technology, Pedagogy And Content Knowledge (TPACK) model, teacher knowledge is categorized into Technical Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK), as well as their intersections (Mishra & Koehler, 2006). It outlines what is taught and how the teacher

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delivers that content, and should form the basis of any effective integration of technology to enhance the student learning experience. The Substitution, Augmentation, Modification, and Redefinition (SAMR) Model illustrates how technology can be integrated into tasks to transform learning, progressing from a lower level of enhancement to a higher level of transformation (Puentedura, 2003). Pragmatists represented by these two models emphasize the ability to effectively integrate technology, pedagogy, and content knowledge to enhance subject knowledge outcomes. Other discussions include broader interpretations, encompassing personal "digital dispositions" and behaviors such as personal privacy, cyberbullying, and the impacts of ICT on human health, society, and the environment, called "digital wellbeing" (Falloon, 2020).

Some scholars have revealed the relationship between the development of teacher ICT competencies and the transformative activities within the school's informational and educational environment (Yuldasheva, 2021). Mastery of resources, participation in lifelong education systems, engagement in innovative activities, transformation of teaching systems, and the creation of local educational environments all influence the level of teacher ICT competencies. Yuldasheva (2021) identifies three components of teacher ICT competencies: (1) functional ICT literacy sufficient to support teaching; (2) the effective and informed use of ICT to achieve professional, social, and personal goals; (3) understanding ICT as a new educational paradigm These competencies involve cultivating learners capability in creating knowledge and knowing how to use vast amounts of information to achieve intellectual and active outcomes, thus becoming contributors to the society.

Based on those findings, our study conducts a comprehensive comparative analysis of eight representative teacher ICT competencies frameworks from various parts of the world and discusses their commonalities and diversities. These frameworks provide a structured approach in defining and assessing the ICT competencies needed for teachers to effectively fulfill their duties, reflecting the priorities and educational philosophies of their regions of origin. On the one hand, this study aims to reach a consensus on the main areas of teacher ICT competencies that transcend geographical boundaries, identifying the core and peripheral areas of current teacher education. On the other hand, this study explores the unique characteristics of each framework in specific educational environments and challenges, uncovering the complex interactions between local needs and global trends.

The purpose of these comparative analyses and discussions is not to undermine or question the validity and relevance of existing frameworks. On the contrary, this study aims to embrace the diversity to stimulate debate about the needs for teacher ICT competencies in an increasingly diverse society in terms of culture, language, and technology. We hope that this study can contribute to the educators, policymakers, and digital leaders, fully harnessing the potential of ICT in education.

2. Materials and Methods

This study employs a case-oriented comparative method and thematic analysis as the overarching qualitative methodology. The case-oriented comparative method can supplement comparative

No.	Name	Organization/Author	Country/Area	Publication Year	Accessibility
1	ISTE standards for educators: a guide for teachers and other professionals (ISTE Standard)	The International Society for Technology in Education (ISTE)	USA	2017	https://cdn.iste.org/www-root/Downloads/Downloads/Download-4070.pdf
2	Digital Competence Framework for Educators (DigCompEdu)	European Commission (EU)	International	2017	https://publications.jrc.ec.europa.eu/repository/handle/JRC107466
3	UNESCO ICT competency framework for teachers (ICT CTF) Version 3	UNESCO	International	2018	https://unesdoc.unesco.org/ark:/48223/pf0000265721
4	Professional Development Framework for Digital Learning (PDF-FDL)	Department of Basic Education (DBE)	South African	2018	https://www.education.gov.za/Resources/Publications.aspx
5	Digital literacy of teachers (DLoT)	Ministry of Education of the People's Republic of China (MOE of PRC)	China	2022	http://www.moe.gov.cn/srcsite/A16/s3342/202302/W020230214594527529113.pdf
6	Building digital capabilities framework (BDCF)	Joint Information Systems Committee (JISC)	UK	2022	https://repository.jisc.ac.uk/8846/1/2022_Jisc_BDC_Individual_Framework.pdf
7	Educators' Digital Competence Framework (EDC Framework)	UNICEF Regional Office for Europe and Central Asia (ECARO)	the Western Balkans	2022	https://www.unicef.org/eca/media/24526/file/Educators'%20Digital%20Competence%20Framework.pdf
8	Digital Teaching Professional Framework (DTPF) Version 2	Education and Training Foundation (ETF)	UK	2023	https://www.et-foundation.co.uk/wp-content/uploads/2023/06/ETF-DTPF-Full.pdf

Table 1 - Information on eight representative frameworks.

analysis that cannot be systematically monitored due to a lack of case numbers through logical reasoning (Porta & Keating, 2008). Thematic analysis focuses on identifying and refining themes, exploring the intrinsic connections within qualitative data, and Thomas (2006) proposed data summarization process provides effective guidance. These two methods complement each other, offering an in-depth perspective for understanding the connections between different frameworks.

2.1 Data Strategies

This study reviewed 35 national and international teacher ICT competencies frameworks and finally identified 8 representative frameworks for analysis. Table 1 describes their basic information and sources. The inclusion and exclusion criteria for the frameworks are as follows:

- Frameworks widely recognized and adopted in global education systems;
- Frameworks focusing on a comprehensive view of teacher ICT competencies;
- Frameworks published or continuously updated after 2017;
- Frameworks published in English or Chinese.

2.2 Topic Setting

This study utilizes the computer-assisted qualitative analysis software NVivo for coding, conducting a cross-sectional comparison of teacher ICT competencies frameworks through the following topics:

- Framework structure;
- Definition of ICT competencies;
- Objectives and scope;
- Theoretical foundations;
- Framework content;
- Support resources;
- Implementation.

3. Results

3.1 Framework Structure

To facilitate understanding and readability, this study first provides an overview of the structure of the eight representative frameworks, and their original images are presented in Appendix.

3.1.1 ISTE standards for educators: a guide for teachers and other professionals (ISTE Standard)

The ISTE Standards recognize the need for educators to leverage technology and tools to achieve optimal practice and promote student-centered learning. Educators effectively serve as both empowered professional and learning transformation catalysts, the ISTE Standards identify seven standards that educators should possess:

- Learner;
- Leader;
- Citizen;
- Collaborator;
- Designer;
- Facilitator;
- Analyst.

The learner standard emphasizes educators' responsibility to learn from and collaborate with others to improve teaching and learning. The leader standard encourages educators to seek leadership opportunities to support student empowerment and success. The citizen standard highlights educators' role in inspiring students to contribute positively and engage responsibly in the digital world. The collaborator standard focuses on educators working with colleagues and students to enhance practice, share resources, and solve problems. The designer standard requires educators to create authentic, learner-driven activities and environments. The facilitator standard expects educators to use technology to support students in meeting ISTE student standards. The analyst standard involves using data to inform instruction and help students achieve their learning goals.

The first three standards are categorized as "empowered professional," and the latter four as "learning catalyst." Each standard is initially interpreted through its statement and indicators, detailing how technology is utilized. There is a total of 24 standard statements and 66 indicators, with three examples of successful implementation provided for each. The ISTE Standards also include reflective questions and tips sections for each indicator, with 71 questions and 128 tips in total.

3.1.2 Digital Competence Framework for Educators (DigCompEdu)

DigCompEdu proposes six areas of teacher ICT competencies:

- Area 1 Professional engagement;
- Area 2 Digital resources;
- Area 3 Teaching and learning;
- Area 4 Assessment;
- Area 5 Empowering learners;
- Area 6 Facilitating learners' digital competence.

Area 1: Professional engagement focuses on educators engaging professionally with stakeholders for personal and organizational development in the broader professional context. Area 2: Digital resources cover the effective and responsible use, creation, and sharing of digital learning resources. Area 3: Teaching and learning involve managing and coordinating digital technologies in teaching. Area 4: Assessment uses digital strategies to enhance assessment. Area 5: Empowering learners emphasizes learner-centered teaching using digital technology. Area 6: Facilitating learners' digital competence details teaching capabilities to promote students' digital competence. These areas are not parallel to each other. Area 1 is seen as educators' professional competencies, areas 2-5 as educators' pedagogical competencies, and area 6 as learner's competencies.

DigCompEdu features a three-block, six-level Progression Model, linked to the Common European Framework of Reference for Languages (CEFR) and Bloom's taxonomy. In Newcomer (A1) and Explorer (A2), educators absorb new information and develop basic digital practices. Integrator (B1) and Expert (B2) involve applying, expanding, and reflecting on digital practices. Leader (C1) and Pioneer (C2) focus on disseminating knowledge, critiquing, and developing new practices.

The six areas of DigCompEdu cover 22 competencies, each with a descriptor, progression and proficiency statements, and examples of typical activities for each level, totaling 156 activities. Notably, the progression model is intended as a reflective tool, not a prescriptive framework or performance assessment.

3.1.3 UNESCO ICT competency framework for teachers (ICT CTF) Version 3

The ICT CFT forms a two-dimensional structure with 18 teacher competency elements. It's organized vertically into the following six aspects:

- Understanding ICT in Education Policy;
- Curriculum and Assessment;
- Pedagogy;
- Application of Digital Skills;
- Organization and Administration;
- Teacher Professional Learning.

The six aspects of ICT application can be horizontally categorized into three progressive levels, which align with how teachers typically adopt technology, becoming progressively more complex with less emphasis on the technology itself. The levels are:

- knowledge acquisition;
- knowledge deepening;
- knowledge creation.

The first Knowledge Acquisition aims for teachers help diverse students use ICT and become effective learners and productive members of society. Then Knowledge Deepening require teachers assist students in applying knowledge to solve complex, real-world problems. The last Knowledge Creation ask teachers to engage in innovation and lifelong learning, designing activities and plans that support these goals inside and outside the classroom. This stage is transformative, promoting the highest levels of Bloom's taxonomy.

Each level is divided into six areas, and teachers generally possess competencies in all three levels, with varying strengths in different areas. ICT CFT provides detailed explanations in tabular form for each of the 18 teacher competencies, including curricular goals, teacher competencies, objectives, and total 83 example activities.

3.1.4 Professional Development Framework for Digital Learning (PDF-FDL)

PDF-FDL views teacher ICT competencies as essential for beginner teachers. It builds on this foundation within two contexts: the Integrated Strategic Planning Framework for Teacher Education and Development in South Africa 2011-2025, and the seven collective roles of the educator. The former expands the application scope of teacher ICT competencies into three key areas of curriculum integration:

- Professional Growth and Knowledge;
- Curriculum Focus;
- Leadership.

Professional Growth and Knowledge requires teachers to explore digital tools for their own development, enhancing learner engagement and learning value. Curriculum Focus demands continual and appropriate use of digital tools to achieve curriculum goals. Leadership expects teachers to demonstrate a vision for digital learning and take responsibility for its implementation and development. These three areas encompass 13 digital learning competencies, each with indicators, applicability for educators in different contexts, and requirements for knowledge, skills, and attitudes, totaling 52 indicators and 44 requirements.

PDF-FDL extends the application of teacher ICT competencies to the seven collective roles of the educator, they are Specialist; Learning Mediator; Interpreter and Designer; Leader, Administrator, and Manager; Scholar, Researcher, and Lifelong Learner; Assessor; Community, Citizenship, and Pastoral Role. These roles highlight various aspects of educators' responsibilities, emphasizing how ICT competencies enhance their effectiveness across these functions.

3.1.5 Digital literacy of teachers (DLoT)

DLoT specifies five dimensions of teacher ICT competencies requirements:

- Digital awareness;
- Digital technology knowledge and skills;
- Digital application;
- Digital social responsibility;
- Professional Development.

Digital awareness involves teachers' digital activities. Digital technology knowledge and skills encompass the knowledge and skills teachers need for daily educational activities. Digital application refers to the use of digital resources for educational activities, including instructional design, teaching implementation, academic assessment, and collaborative education. Digital social responsibility includes ethical behavior in digital activities, such as protecting personal information, maintaining data security, and ensuring network security. Professional development involves using digital resources for personal and community growth. DLoT details these areas through 13 secondary dimensions, refined into 33 tertiary dimensions.

3.1.6 Building digital capabilities framework (BDCF)

The BDCF framework centers on digital proficiency and productivity. Digital proficiency involves using digital devices, networks, applications, software, and services, while digital productivity refers to utilizing digital skills to accomplish tasks. Expanding further outward from them, ICT competencies divide into the following five areas:

- Digital creation, problem-solving and innovation;
- Digital learning and development;
- Information, data and media literacies;
- Digital communication, collaboration and participation;
- Digital identity and wellbeing.

Digital creation, problem-solving, and innovation involve the ability to digitally produce, make decisions, solve problems, and innovate with digital technologies. Digital learning and development is about gaining personal learning benefits from digital resources and supporting others in digital environments. Information, data, and media literacies including finding, evaluating, organizing, and sharing information, processing data, and responding to digital media. Digital communication, collaboration, and participation encompass all means of communicating and collaborating in digital media and networks to achieve a specific goal. Digital identity and wellbeing require to develop and manage digital identities and reputations, and control ICT's impact on oneself.

To aid understanding, BDCF breaks each area into several elements, with reflective questions and practical examples. The five areas comprise 13 elements and 50 examples in total.

3.1.7 Educators' Digital Competence Framework (EDC Framework)

The EDC framework divides teacher ICT competencies into four progressively advancing areas:

- Knowledge development;
- Knowledge application;
- Knowledge sharing;
- Knowledge communication.

The Knowledge Development area covers educators' digital competencies related to digital teaching and learning, focusing on their connection to national policies, digital teaching methods, learning, and assessment approaches. The Knowledge Application area involves promote effective learning, responsible ICT use, and problem-solving, aiming to develop, disseminate, and create new knowledge. The Knowledge Sharing area explores the use of communities of practice (CoP) to enhance competencies for constructive dialogues, fostering a collaborative professional culture. The Knowledge Communication area focuses on using digital technologies to support organizational communication, improving communication with learners and stakeholders, and ensuring the safe and responsible use of digital resources.

These four areas are subdivided into 12 subareas with 21 competencies, each containing several objectives, totaling 93 objectives. This framework provides detailed answers to "what" and "how" questions, outlining the competencies needed for innovative and inclusive digital education and explaining how to support digital education in areas such as environment, communication, and learning.

3.1.8 Digital Teaching Professional Framework (DTPF) Version 2

DTPF interprets teacher ICT competencies across 7 areas:

- Planning your teaching;
- Approaches to teaching;
- Supporting learners to develop employment skills;
- Subject and industry specific teaching;
- Assessment;
- Accessibility and inclusion;
- Self development.

Planning your teaching encourages the use of digital technology to enhance teaching and learning. Approaches to teaching involves using resources to promote learner engagement in various instructional scenarios, including face-to-face, blended, online, and hybrid learning. Supporting learners to develop employment skills uses digital technology to improve learners' employment prospects. Subject and industry-specific teaching organizes professional development activities to enhance subject knowledge and industry awareness. Assessment uses digital technology to improve assessment and feedback. Accessibility and inclusion ensure all learners can fully utilize digital technology. Self-development encourages reflection on professional practice, continuous professional development, and promoting safe digital identities.

These seven areas contain 21 competencies, with specific activity descriptions (170 total) and exemplary descriptions for three proficiency levels: Exploring, Adopting, and Leading, based on DigCompEdu. Each competency also includes a key indicating how components map across five reference models, highlighting connections and relationships between DTPF and these frameworks.

3.2 Definition of ICT Competencies

The frameworks use inconsistent terms, with "digital literacy," "digital capability," "digital competence," and "ICT literacy" all being synonyms for "ICT competencies." The ISTE standards and DTPF do not explicitly define ICT competencies. DigCompEdu, BDCF, and PDF-FDL regard ICT competencies as fundamental life skills, including attitudes towards ICT. ICT CFT focuses on using ICT to perform tasks, while DLoT restricts this to teachers' educational work, emphasizing awareness, ability, and responsibility. Despite the contrary, both frameworks emphasize understanding, processing, and presenting information using ICT. The EDC Framework uses the ICT CFT definition, since they both originate from UNESCO.

3.3 Objectives and Scope

Except for DLoT and PDF-FDL, which are published as standards, other frameworks serve as references to enhance teacher ICT competencies, supporting adaptation to local contexts. DigCompEdu, ICT CTF, EDC Framework and PDF-FDL are aimed at equity and inclusion in education, while the first three of these also promote lifelong learning. DLoT, DTPF, DigCompEdu, ICT CTF, and PDF-FDL foster ICT use in education and innovation, and the last two highlight updates due to ICT advancements. ISTE Standards aim to help educators recognize their roles as catalysts for transforming learning and fostering student independence.

Most frameworks support various educational stages and provide guidance in policy-making, training, reflection, practice, and assessment. BDCF extends its scope to employees and students in any role. However, EDC Framework targets primary and secondary education policy-making, DLoT focuses on teacher training and evaluation, and DTPF is for further and TVET education. Only ICT CTF recommends including ICT training in teachers' professional development cycles, covering pre-service and in-service training, both formal and informal.

3.4 Theoretical Foundations

Despite the different structural frameworks of the ICT CTF and the DigCompEdu, both coincidentally referred Bloom's taxonomy to categorize stages/levels of teachers' ICT competencies. This helps educators reflect on their proficiency levels and identify specific development needs. Both frameworks also provide a solid foundation for the construction of other frameworks; the EDC Framework and the DLoT align to some extent with the DigCompEdu and the ICT CTF (China Education Newspaper, 2023).

The PDF-FDL, the ISTE Standards, and the BDCF do not include any description of theoretical foundations, while the DTPF draws broader references from the ETF's Professional Standards for Teachers and Trainers; the ETF's Professional Standards for Aspiring Leaders; the ETF's Professional Standards for Middle Leaders; the BDCF and the DigCompEdu.

In addition, SAMR model and TPACK model have also been widely applied (Mishra & Koehler, 2006; Puentedura, 2003). For instance, PDF-FDL provides a TPACK-based lesson analysis tool and SAMR-based progress assessment standards. DTPF also demonstrates how to use the SAMR model within its framework.

3.5 Framework Content

NVivo software was adopted to perform a thematic analysis of the content from those 8 ICT competencies frameworks, categorizing it into 9 competencies and 28 sub-competencies, as shown in Table 2. It has been shown that, based on differences in national contexts and educational backgrounds, the areas covered by these frameworks overlap to some extent, but they emphasize different roles played by teachers.

DLoT emphasizes teachers as citizens and designers, focusing on digital society building, digital assessment, and digital teaching and learning. This makes it more suitable for foundational education stages but overlooks teachers' roles as leaders, collaborators, and facilitators (Liu & Yi, 2023). Despite emphasizing ICT skills and knowledge, DLoT lacks specific ICT types and application examples, which may challenge in-service teachers in becoming learners.

The development of ICT CFT is evidence-based, incorporating feedback from global experts, educators, policymakers, school administrators, and teachers. Thus, it emphasizes teachers as designers and collaborators, focusing on interdisciplinary collaboration, negotiation, and stakeholder interaction. It coordinates pre-service and in-service teacher ICT competencies training, providing a framework for digital teaching transformation (Dai & Huangfu, 2021; Lan et al., 2021). However, as a universal framework, it only briefly mentions specific technological innovations without detailed analysis.

The BDCF's rich descriptions of digital awareness, ICT knowledge and skills, digital society building, and digital career development reflect teachers as both citizens and learners. DigCompEdu, DTPF, ISTE standards, PDF-FDL, and the EDC Framework emphasize teachers as facilitators, serving student needs and supporting development. DigCompEdu offers a comprehensive overview of teacher digital competencies for people to fully perceive, understand, and evaluate (Lai et al., 2023; Yan & Liu, 2022). In contrast, BDCF fail to reflect the facilitator role, while PDF-FDL also emphasizes teachers as collaborators.

This study conducted a statistical analysis of the frequency of descriptions for each competency, as shown in Figure 1. "Development of Students' Digital Competencies" is the most emphasized teacher competency, aligning with the current "student-centered" educational philosophy (Shehata et al., 2024). The description frequency of "Digital Inclusive Education" is only 5%, partly because some frameworks, like DLoF, do not include "equity and inclusion" or covering only certain sub-competencies. Moreover, "inclusive education" is often presented as a philosophical concept within frameworks, lacking detailed elaboration.

The proportions of competencies such as Digital Society Building, Digital Career Development, Digital Communication and Collaboration, Digital Assessment, and Digital Teaching and Learning are relatively similar, indicating their importance as supported by various frameworks.

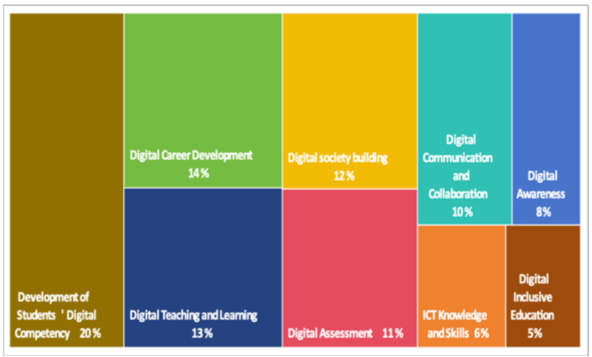

Figure 1 - The frequency of descriptions for each competency.

For the competencies of Digital Awareness and ICT Knowledge and Skills, different frameworks exhibit significant variation in interpretation. Digital Awareness can be viewed as an intermediate variable, suggesting that frameworks should assume teachers using them already possess adequate digital awareness. Alternatively, Digital Awareness can be seen as an aspect of teacher ICT competencies, which encompass a combination of knowledge, skills, and values.

The TPACK theory from Mishra & Koehler (2006) provides framework developers with the option to construct frameworks from different perspectives: either treating TK as standalone competencies (including the description of ICT Knowledge and Skills) or describing it through TCK, TPK, and TPCK (excluding the specific description of ICT Knowledge and Skills).

3.6 Support Resources

To support the explanation and understanding of frameworks, most manuals provide explanations of related terms or vocabulary. For example, the EDC Framework, ICT CTF, and PDF-FDL manuals include glossaries. The ICT CTF manual also discusses emerging technologies and international principles extensively. Manuals are tailored for readability and meet educators' diverse needs, with options like the "In Brief" and detailed "In Detail" versions in the EDC Framework and DTPF. DigCompEdu offers three versions: Nutshell, Explained, and Detail. Frameworks often include modules to aid implementation; for instance, ICT CTF showcases numerous case studies, and DTPF integrates the SAMR model. The ISTE standards detail alignment with other frameworks and standards, featuring adoption and implementation profiles, tips, and essential conditions modules. PDF-FDL includes self-assessment tools and progress, professional development activities, a TPACK model-based lesson analysis checklist, learning activities, and a digital learning progress rubric with the SAMR model context.

Frameworks are also supported by a wealth of digital resources. ICT CTF, BDCF, DigCompEdu, and ISTE Standards offer online courses and multilingual translations. DTPF, DigCompEdu, BDCF, ISTE Standards, and EDC Framework provide self-reflection tools, posters, research, reports, and other digital resources. Both ETF and ISTE offer professional certification services. JISC not only offers personalized frameworks for practitioners in different roles, but also organizational-level frameworks for digital leaders.

3.7 Implementation

The ICT CFT has had a global impact, influencing education policies, national teacher standards, ICT competencies assessments, curriculum design, and professional development across Latin America and the Caribbean, Asia and the Pacific, Europe, and North America (UNESCO, 2018). In the EU, more than 20 major studies on teacher ICT competencies have been conducted, resulting in over 120 publications aimed at helping member states tailor teacher training to national contexts (European Commission, n.d.). DigCompEdu has gained widespread recognition among scholars, framework developers, and educational departments globally, establishing itself as a fundamental framework for teacher ICT competencies worldwide.

Since 2018, supported by the South African Department of Basic Education, PDF-FDL initiatives have included roadshows, conferences, workshops, online courses, self-reflection portals, electronic portfolios, and Professional Learning Communities (PLCs) on online platforms (Department of Basic Education, n.d., 2018). The ISTE Standards are continuously researched and updated, adopted in all 50 U.S. states and numerous countries globally (International Society for Technology in Education, n.d.). In 2021, the ETF supported 3,226 teachers, trainers, and assessors, with 91% of ICT teachers recommending DTPF courses (Education and Training Foundation, n.d.). In 2022, ETF introduced a new learning management system, implementing BDCF-based training courses and strategies in UK schools (Joint Information Systems Committee, n.d.).

Competency	Sub-Competency	Description	ISTE Standard	DigCompEdu	ICT CTF	PDF-FDL	DLoT	BD CF	EDC Framework	DTPF
Digital Awareness	Digital Cognition	Understanding the value of ICT in economic, social, and educational development.			√		√	√	√	√
		Understanding the opportunities and challenges brought by the development of ICT to education and teaching.			√	√	√	√		
	Digital Attitude	The willingness to actively learn and use ICT resources.					√			
		The initiative to engage in educational digital practices, exploration, and innovation.	√			√	√	√		
	Digital Willpower	The confidence and determination to overcome difficulties and challenges encountered in educational digitization.					√			
ICT Knowledge and Skills	ICT Knowledge	Understanding common concepts and basic principles of ICT.			√	√	√	√		
	ICT Skill	Acquiring, evaluating, organizing, using, and disseminating information on digital platforms.	√		√	√		√		√
		Mastering the principles and methods of using and selecting digital devices, software, and platforms for teaching.	√		√	√	√	√		
Digital society building	Law and Ethics	Compliance with Internet laws and regulations, regulating various online behaviors conscientiously.	√		√		√	√		
		Respecting intellectual property rights, maintaining a balance between the digital environment and personal health, safety, interpersonal relationships, as well as work and life (digital wellbeing).	√	√	√		√	√	√	√
		Adhering to online communication norms, engaging in civilized communication, and safeguarding the privacy of personal communication.	√		√		√	√		
	Digital Security Protection	Managing and protecting personal information, privacy data, and digital identity, and maintaining one's digital reputation.	√		√		√	√		√
		Prioritizing the security maintenance of student, parent, business, and research data.	√	√			√	√	√	√
		Identifying, preventing, and dealing with online risks such as rumors, cyberbullying, telecommunications fraud, and information theft.	√	√	√		√			√
Digital Career Development	Digital Learning	Keeping updated on developments in relevant industry fields.						√		√
		Using ICT resources for continuous learning according to personal development needs.	√	√	√	√		√	√	√
		Using ICT resources to analyze personal teaching practices, supporting reflection and improvement in teaching, scientific research, industry-academia-research collaboration, social services, etc.	√	√		√	√	√	√	√
	Digital Research and Innovation	Using ICT resources to support research activities such as teaching, scientific research, industry-academia-research collaboration, and social services, etc.				√				
		Using ICT resources to Continuously innovative teaching models, improve teaching activities, and transform student learning methods.	√	√		√	√	√	√	√
	Digital Leadership	Participating in, promoting, and assisting colleagues in digital education practices.	√	√	√				√	√
		Promoting further development of organizational practices, policies, and visions related to ICT usage actively.	√	√	√	√		√	√	√
Digital Communication and Collaboration	Peer Communication and Collaboration	Using ICT to support dialogue, collaboration, cooperative learning, and innovation among peers.	√	√	√	√	√	√	√	√
	Teacher-Student Communication and Collaboration	Using ICT to support dialogue, collaboration, cooperative learning, and innovation between students and teachers.	√	√	√	√	√	√	√	√
	School-Enterprise Communication and Collaboration	Using ICT to support dialogue, collaboration, cooperative learning, and innovation between teachers and stakeholders such as industry.		√	√			√	√	
	Home-School Communication and Collaboration	Using ICT to support dialogue and collaboration between teachers and parents.	√	√	√		√	√	√	

Table 2 - Thematic analysis of the content of the eight representative frameworks.

(continued)

Competency	Sub-Competency	Description	ISTE Standard	DigCompEdu	ICT CTF	PDF-FDL	DLoT	BD CF	EDC Framework	DTPF
Digital Assessment	Strategy Selection and Optimization	Making rational choices and using ICT to enhance the diversity of assessment formats and methods.	√	√	√	√	√		√	√
		Designing and optimizing digital academic assessment strategies reasonably and flexibly.		√	√	√			√	√
	Tool Selection and Data Monitoring	Selecting and applying digital tools to monitor students' progress reasonably and collect multimodal academic assessment data.	√	√	√	√	√		√	√
	Data Analysis and Feedback	Selecting and applying appropriate models for data analysis and providing reasonable interpretations.	√	√		√	√	√		√
		Maximizing the use of digital tools for feedback and providing substantive feedback to stakeholders such as students and parents as soon as possible.	√	√						√
Digital Teaching and Learning	Digital Teaching and Learning Design	Collecting digital educational resources through multiple channels, and selecting, managing, and creating them based on teaching needs.	√	√	√		√	√	√	√
		Designing teaching activities that integrate ICT resources based on teaching objectives and student characteristics.	√	√	√	√	√	√	√	√
		Using ICT resources to overcome temporal and spatial constraints, integrating various learning environments such as online education, mobile learning, and blended learning.	√	√	√	√	√	√	√	√
	Digital Teaching and Learning Implementation	Using ICT resources to Organize teaching activities in an orderly manner, and to enhance student engagement and promoting proactive communication.	√	√	√	√	√			√
		Using ICT resources to identify students' learning differences and provide targeted guidance.	√	√			√		√	√
Digital Inclusive Education	Digital Moral and Psychological Education	Using ICT to conduct various forms of moral education and mental health education activities.					√			
	Inclusivity	Ensuring equitable access to appropriate ICT and resources, so that all students, including those with special needs, can access learning resources and activities.	√	√	√	√			√	√
	Personalization and Diversity	Using ICT to meet the diverse learning needs of students, enabling them to progress at different levels and speeds, and following their individual learning paths and goals.	√	√	√			√	√	√
Development of Students' Digital Competency	Digital Learning and Reflection	Cultivating students' ability to autonomously plan and support their learning using ICT.	√	√	√	√	√	√	√	√
		Cultivating students' ability to engage in self-reflection and self-assessment using ICT.	√	√	√				√	√
	Digital Skills and Creation	Developing students' fluency in using ICT.	√			√	√		√	
		Encouraging students to express themselves digitally, edit, and create digital content in various formats.	√	√					√	√
	Digital Communication and Collaboration	Cultivating students' ability to communicate, share, and collaborate with others using ICT.	√	√	√	√			√	√
	Digital Responsibility and Security	Enhancing students' literacy in organizing, storing, and retrieving data, information, and content in a digital environment (media literacy and information literacy).	√	√	√	√			√	√
		Instilling in students an awareness of using ICT responsibly to avoid risks and threats and to protect their physical and mental well-being (digital wellbeing).		√					√	√
		Instilling in students an awareness of copyright, privacy protection, and maintaining digital reputation.	√	√		√	√		√	√
	Digital Problem-Solving Thinking	Fostering students' critical thinking, computational thinking, problem-solving skills, and higher-order thinking using ICT.	√	√	√		√		√	√
	Digital Organization and Entrepreneurship	Encouraging students to use ICT to develop project plans, assign tasks to group members, set progress standards, and allocate responsibilities.			√					
		Developing students' financial digital skills to support future self-employment or freelance careers.								√

Table 2 - Thematic analysis of the content of the eight representative frameworks.

The EDC Framework, under the LearnIn initiative, is being systematically implemented in several Western Balkan countries with comprehensive support from ECARO, including platforms, content, national tasks, internet access, and devices (UNICEF ECARO, 2021). In China, provincial education bureaus have launched teacher digital enhancement projects based on DLoT, such as the ongoing Teacher Digital Enhancement Project 2.0 in Guangdong Province (Guangdong Education Department, 2020).

4. Discussion and Conclusions

4.1 Commonalities

From a global perspective, teacher ICT competencies represent a fusion of knowledge, skills, and values, focusing on how teachers acquire, process, and convey information. The objectives of the eight representative frameworks for teacher ICT competencies are inherently aligned with Sustainable Development Goal 4 (SDG 4), which aims to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (United Nations, 2022).

These frameworks articulate their core areas through structured divisions, supported by detailed lists that expand on statements, indicators, and examples of activities. In today's digital era, it is crucial for educators to enhance the usage ICT to foster their own professional growth, foster a digital social environment, engage in digital communication and collaboration, drive digital teaching transformations, and importantly, nurture students' ICT competencies. These areas have transcended geographical boundaries, achieving global consensus.

To facilitate the effective implementation of these frameworks, developers have provided extensive resources, particularly digital ones. These efforts have proven impactful, benefiting teachers worldwide to varying extents through comprehensive support and resources.

4.2 Diversity

The diversity in educational environments globally necessitates nuanced approaches to developing teacher ICT competencies, leading to variations in requirements, terminology, definitions, goals, and scopes across the eight representative frameworks. Each framework places unique emphasis based on regional and educational needs. For instance, while some prioritize "equity and inclusion," others focus on fostering "educational innovation" as core objectives.

Secondly, frameworks delineate distinct core areas and competencies. The ISTE standards outline seven roles for teachers, emphasizing transformational learning. Frameworks like EDC, DigCompEdu, PDF-FDL, and ISTE underscore the role of "Facilitator," whereas ICT CTF focuses more on "Collaborator." Others like DTPF highlight dual roles such as "Facilitator" and "Collaborator"; DBCF focus on "Citizen" and "Learner," and DLoT emphasizes "Designer" and "Citizen".

Finally, practical implementation support varies among frameworks. DigCompEdu and ICT CTF facilitate self-assessment based on Bloom's taxonomy, whereas DTPF and PDF-FDL utilize the SAMR model to aid implementation. The availability and richness of digital resources accompanying these frameworks depend on factors like developer influence, funding levels, and expert involvement.

4.3 Conclusions and Recommendations

In conclusion, this study comprehensively analyzes eight representative frameworks from around the world, elucidating the commonalities and differences in the global landscape of teacher ICT competencies. This study aims to contribute to the ongoing dialogue about shaping the future of teacher education, helping educators, policymakers, and digital leaders understand global standards for teacher ICT competencies, develop effective and inclusive frameworks, and explore best practices for the development of teacher ICT competencies.

We recommend that future researchers delve deeply into the educational needs of different regions, ensuring that the teacher ICT competencies framework for is closely aligned with local policies and cultural contexts. On this basis, further develop a teacher ICT competencies framework that meets the needs of various educational stages. Additionally, we advocate for empirical research to assess the effectiveness of these frameworks in practical application, to ensure they can truly enhance the professionalism of teachers.

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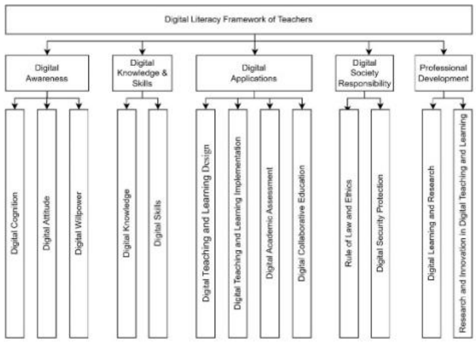
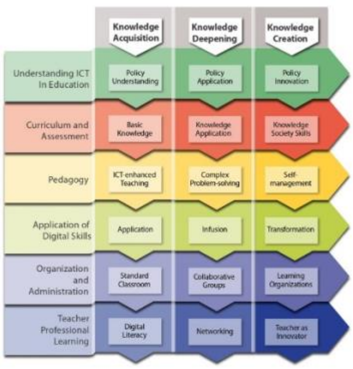
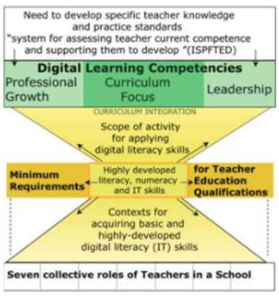
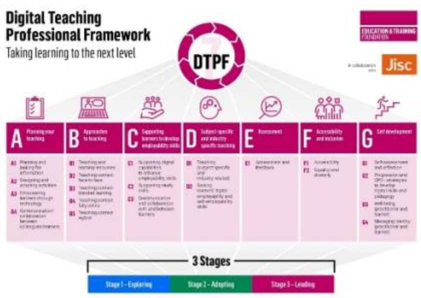
Appendix - Original Images of Eight Representative Frameworks

No.	Name	No.	Original Image
1	 ISTE standards for educators: a guide for teachers and other professionals (ISTE Standard, 2017)	5	 Digital literacy of teachers (DLoT, 2022)
2	 Digital Competence Framework for Educators (DigCompEdu, 2017)	6	 Building digital capabilities framework (BDCF, 2022)
3	 UNESCO ICT competency framework for teachers (ICT CTF, 2018) Version 3	7	 Educators' Digital Competence Framework (EDC Framework, 2022)
4	 Professional Development Framework for Digital Learning (PDF-FDL, 2018)	8	 Digital Teaching Professional Framework (DTPF, 2023) Version 2

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Influence of Internet of Things Cybersecurity (IoTCS) on Educational Assessment Practices in University Learning Spaces in Nigeria

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Abstract

The Internet of Things (IoT) presents a unique flexibility that facilitates higher productivity and rapid advancement in the educational sector, and more specifically in educational assessment. However, the huge cybersecurity issues associated with cyberspace pose a challenge for the IOT. The present study investigated the influence of the Internet of Things Cybersecurity (IoTCS) on educational assessment practices in university learning spaces. The researchers adopted a correlation research design involving a multistage sampling procedure with 297 lecturers as participants drawn from six universities in South-East Nigeria, who shared their opinions on the influence of IoTCS on assessment practices. The Internet of Things Cybersecurity Questionnaire (IoTCSQ) and Assessment Practices Scale (APS) were two instruments used for data collection and they were validated in line with the purpose of the study by three experts. The Cronbach Alpha reliability indices of the two instruments were 0.82, and 0.89 respectively. The result showed a significantly moderate positive relationship between the adoption of IoTCS and the effectiveness of assessment practices in university learning spaces, among others. The study concluded that the incorporation of IoTCS significantly influences assessment practices in university learning spaces, and recommended among others that school administrators should consider investing in IoT cybersecurity for the safety, fairness and reliability of assessment data.

KEYWORDS: Internet of Things Cybersecurity (IoTCS), Assessment Practices, Formative Assessment, Summative Assessment, Authentic Assessment.

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1. Introduction

Educational assessments have emphatically sustained as a critical component of the educational system, due to their role in the fulcrum of purifying, certifying and providing evidence for critical decisions that have to do with the credibility of the processes and products of the educational system. Over the years, educational assessment practices have developed from the orthodox paper-and-pencil tests (PPT) form to the real-time gathering of data through the use of smart devices in the league of Internet of Things (IoT), following the rapid advancement in communication technology which is significantly changing the natural way of life. However, this has highlighted the worries of researchers on the security of assessment cyberspaces especially in the recent global spike in the introduction of IoT in educational assessment practices, particularly in Nigeria as most examination bodies are adopting large-scale digital assessments. The Joint Admission and Matriculation Board (JAMB) has long adopted digital assessment, and recently the West African Examination Council (WAEC) has expressed commitment to the

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same and likewise in most university learning spaces among others. These digital assessments are possible through the amazing role of IoT over the cloud.

The Internet of Things (IoT) has transformed the way we communicate with our environment, and its growing impact is being felt in the educational system. Ramlowat and Pattanayak (2019) opine that the advent of IoT has transformed all human interactions and the way we do things in education. Sheng et al. (2018) pointed out that, these transformations have given rise to new educational opportunities, especially for enhancing assessment practices in university learning spaces. Although the new opportunities, the American Council on Education (2017) highlighted that the prevalence of IoT devices in educational settings has been followed by a significant impact on the integrity and security of assessment processes due to the potential vulnerabilities occasioned by the unique characteristics of IoT, such as the diversity of interconnected devices, large attack surface and often limited security features, resulting in critical cybersecurity concerns. Literature notes that the emergence of IoT has not been without associated challenges which confound the digital approach for measuring focal constructs. Howbeit, these concerns have also highlighted the need for robust cybersecurity measures to protect sensitive educational data.

Cybersecurity issues are not exclusively the concerns of tech experts, but a general issue for users of tech devices. The growing influx of IoT in educational assessment practices have likewise been visited with such cybersecurity challenges, due to the activities of cybercriminals who continue to adapt their strategies to the new environment. According to Robles et al. (2017); Domeij (2019), such activities result in the theft and destruction of many forms of educational assessment data, ranging from delicate information, personally identifiable information (PII), protected health and personal data, intellectual property data, data about assessment questions task sand outcome scores, and information systems used for the assessment purposes. Therefore, this increasingly calls on teachers and educational assessment experts to take decisive measures to effectively tackle cybersecurity concerns, create a safer cyberspace for fair assessments, and maintain the role of educational assessments.

The role of assessment is to support and guide teaching and learning, as well as to inform educational stakeholders about student performance and program effectiveness (Nworgu, 2016). Assessment is concerned with the process of gathering data from a variety of sources on the activities of teaching and learning for understanding, describing and improving learning (Oguguo et al., 2023). Mertler (2019) emphasized that the core mandate of assessment should focus on improving student learning and understanding. In addition, Hattie and Timperley (2007); Wiliam and Leahy (2015) emphasized the need for timely feedback to support learning progressions based on information gathered from assessments. Nworgu and Ellah (2015); Wiliam (2017) agree that assessment practices should be embedded in instructional activities to enhance student learning and understanding. Klenowski (2020) strongly emphasized the importance of assessment and promulgated a variety of assessment practices which could find relevance in the university learning spaces. Assessment helps to validate the effectiveness of the teaching and learning process and it points out students' strengths and areas requiring more attention (Oguguo et al., 2023).

1.1. Formative Assessment

Various scholars and educators view assessment practices from a mired of perspectives based on the purpose for which the assessment is necessary, but generally to measure student learning and understanding. Popham (2018); Herman et al. (2020) provides an overview of various approaches to assessment as well as practical guide on implementing effective assessment practices. Assessment practices may be formative, summative or authentic (Monteiro et al., 2021). Formative assessments are assessments for learning, which stem from the pedagogical pole and seek to improve learning (Brown & Remesal, 2017). Adikwu et al. (2014) described formative assessment as assessments performed during the course of instruction. Formative assessments are not only for students; however, they also provide teachers with actionable feedback to improve the instruction (Nworgu & Ellah, 2015). Assessment for learning is a useful tool in tracking the trend in students' learning while instruction is ongoing (Stiggins & Chappuis, 2020). Formative assessments are ongoing assessments which often take the form of quizzes or classroom discussions, and are used to diagnose student difficulties, identify areas where students may need additional support, guide instruction, monitor student progress and provide feedback to both the student and the teacher to modify teaching and learning strategies. Although, it requires investment of time, it can be gainful in enhancing the effectiveness of instruction.

1.2 Summative Assessment

Summative assessments are assessments of learning, and often take the form of final exams, standardized tests and end-of-unit projects. Assessments of learning proceed from the societal pole by providing an overall measure of student achievement, and are used to evaluate student learning at the end of a unit, course or school year (Brown & Remesal, 2017). Summative assessment is the form of assessment carried out after teaching is concluded (Adikwu et al., 2014). Summative assessments for learning are judgmental, often used for high-stakes accountability, ranking, grading, and/or certification purposes (Emaikwu, 2011). Assessment of learning is the cumulative evaluation of students' achievement after complete exposure to a sequence of instruction. The goal of assessment of learning is to communicate student level of achievement rather than to specifically provide detail feedback about the learning process or suggesting problem areas, although students can receive the latter during the examination.

1.3 Authentic Assessment

Authentic assessments are assessments as learning, which often take the form of performance assessments, portfolios and project-based assessments. Authentic assessments measure students' abilities to apply their learning (knowledge and skills) in meaningful and relevant ways to real-world tasks and problems (Fuchs & Fuchs, 2017; Brookhart, 2019). Authentic assessment is an approach to evaluating student learning through real-world, relevant tasks and activities. Authentic assessment focuses on evaluating students' ability to apply their knowledge and skills in meaningful contexts to real practical experiences, rather than just regurgitating memorized facts (Yip, 2021). Sewagegn and Diale (2020) view authentic assessment as that assessment which enhances students' learning and makes them competent in their study area. Authentic assessments are assessments which connect theoretical knowledge with real life application with the view of evaluating students' ability to solve real world problems using the knowledge of their learning.

Assessment practice according to American Educational Research Association, American Psychological Association, & National Council on Measurement in Education (AER, APA & NCME, 2014); Pellegrino and Chudowsky (2018); Gamito et al. (2022); Darling-Hammond and Adamson (2020) emphasized that educators must enthrone the principles of assessment when designing and implementing assessment practices by ensuring that assessments are valid, reliable, fair, and equitable for all students. Given the caution, it behoves squarely on educators to employ means that administer assessments that accommodate the principles of validity, reliability, fairness and equality in testing, which digital technologies offer through the Internet of Things (IoT). The drift to IoT summarizes a wide range of physical objects embedded with sensors, software and other technologies, and networked over the internet to enable them to communicate, share and exchange data with one another, as well as other devices and systems. According to Bosche et al. (2018) noted that the adoption of IoT devices has continued to increase, nearly doubling yearly; and Darina (2023), 127 new IoT devices are connecting to the web every second, from the status of billions of active IoT devices since 2019. This may imply favorable satisfaction due to IoT, leading to its global expansion. The composition of IoT fuses the first principles from the fields of electronics, communication and computer science engineering in a spectrum of programmable devices that function efficiently enough to address the target essence for their built by creating a smart and connected environment.

1.4 Application of Internet of Things (IoT)

The Internet of Things (IoT) is a network of uniquely identifiable objects, ranging from everyday devices to sophisticated industrial tools, each equipped with sensors to gather and transmit data for various purposes, so that they communicate without human interaction through the use of embedded systems, either through the internet or other means of connectivity (Atzori et al., 2010). Kortuem et al. (2010) described the Internet of Things (IoT) as encompassing the integration of sensors and actuators into a wide range of devices connected by the use of networks to allow diverse objects to communicate and exchange information for the purpose of automation, monitoring, and control via data exchange and provision of various services to individuals and organizations. The major insight about IoT is simply the improvement of everyday objects with some identification, sensor, network and processing capabilities that will enable them to communicate with each other, as well as with other devices and services through the internet, according to Rakić (2023). Immediately after the upgrade, the regular objects become smart objects and become capable of generating, exchanging, collecting, analyzing and managing data with minimal or even no human intervention. The IoT encompasses the extension of Internet connectivity into physical devices and everyday objects; a collective network of interrelated devices and smart objects, and the technology that facilitates communication between them and other objects over the cloud. IoT encapsulates technology that allows us to add a device to an inert object to aid the measurement of environmental parameters, generate associated data and transmit the data through a communication network for others to access.

IoT can be effectively used in almost every facet of human life, including education. IoT has long been applied in the health sector as microchips and wearable devices such as fitness trackers and remote monitoring tools for collecting and analyzing data from patients for personalized healthcare to better manage chronic conditions (Iqbal & Qadir, 2021). IoT in healthcare integrates wearable devices, medical equipment and remote patient monitoring systems to gather health data, support telemedicine, and improve patient outcomes through continuous monitoring and personalized care (Rezaee et al., 2016; Catarinucci et al., 2015). This also covers consumer IoTs such as home appliances (including thermostats, lighting systems, and door locks), wearable devices (including fitness trackers, and smartwatches) and connected car technologies designed for personal use for improved convenience. Tao et al. (2018) pointed out that industrial IoT such as smart manufacturing systems, remote equipment monitoring, and asset tracking solutions focuses on the deployment of connected devices and sensors in industrial settings to optimize processes, monitor equipment performance and enable predictive maintenance. IoT is also applied in Agriculture through connected sensors, drones and automated machinery to monitor crop conditions, optimize irrigation, monitor livestock and birds, and general farm management to improve farm productivity (Liu et al., 2018). Zanella et al. (2014) accounted that smart cities can also implement IoT by deploying of interconnected sensors, smart infrastructure and data analytics to enhance urban services, optimize traffic management, improve energy efficiency, and support environmental monitoring. Environmental IoT involves the use of connected sensors and monitoring devices to gather real-time data on air quality, water pollution, and weather conditions, enabling environmental monitoring and management systems (Perera et al., 2014).

1.5 Benefits of Internet of Things (IoT) in Assessment Practices in Education

Scholars have pointed out the beneficial impasse of IoT across the educational system, especially in university learning spaces for collecting and analyzing relevant data such as student learning behaviors, engagement levels and performance in real-time, thereby providing valuable insights to educators and administrators. IoT devices can track students' progress and customize learning materials according to individual needs, leading to improved learning outcomes and student engagement (Haque, 2019). Chen and Zhu (2019) pointed out that IoT devices can help teachers manage the classroom more effectively and teachers focus more on teaching and student interaction, by automating routine tasks such as attendance, grading and classroom organization. Rifkin (2019) argues that IoT devices can also be used to ensure and monitor the safety of staff and students on campus by identifying potential threats, tracking movement and alerting authorities in case of emergencies. IoT devices in the form of extended realities can be used to connect students to a pseudo-real-world experience through virtual realities to access risky locations remotely, expel experimental or real-world hazards and make learning more relevant and engaging (Agah et al., 2023). In addition, since IoT devices are automated by programming, they can be used to streamline administrative processes such as resource management, scheduling and facility maintenance, leading to improved efficiency and cost savings in educational institutions. The growing penetration of IoT in the educational sector cuts across its length and breadth, and is finding more relevance in educational assessment practices in university learning spaces due to the strategic role of higher education in nation-building. The IoT provides an opportunity for smart campuses across university learning spaces (Gikas & Grant, 2013; Le et al., 2020; Chen et al., 2021).

Literature affirms the significant role of IoT in educational assessment practices in university learning spaces by providing valuable data and insights into student performance, behavior, and learning environments (Blikstein, 2020; Al-Zou'bi, 2021; Mishra et al., 2021; Jiménez Sabino & Cabero Almenara, 2021; Valverde et al., 2021). For example, IoT sensors placed on desks and strategic places in the smart classroom can track students' attendance, movements, interactions and engagements with learning materials, and detect when students are participating actively in discussions or group activities by measuring movement and noise levels (Premalatha & Krishnan, 2020). This data can help provide teachers with valuable data to identify students who may need extra support or encouragement and inform teaching strategies. IoT-enabled smart pens and notebooks used in smart schools can record students' notes, sketches, and annotations during assessments (Wadowsky, 2023). These devices can analyze handwriting, note-taking patterns, and time spent on different sections to provide feedback on students' comprehension, study habits and suggest ways for students to improve their note-taking techniques or highlight key concepts they may have missed during a lecture. Also, IoT devices are used to monitor online exams and remote assessments to ensure academic integrity based on facial recognition technology in which students' identities are verified and eye-tracking or keystroke analysis can detect any irregularities during the assessment (Oncul, 2021). IoT devices can track and monitor students' progress by collecting real-time data on student engagement, behavior, and performance to identify areas for improvement (Nguyen Gia & Tam, 2020), since Reeve (2019) already highlights the interconnections of assessment practices with student engagement and psychological factors. Likewise, Kadam and Kadam (2017) opine that the data collected through IoT devices can become helpful to tailor instruction and assessment to meet each student's specific needs through personalized learning experiences that suit individual student preferences, learning styles, and performance. Data collected through IoT sensors can also help in creating more conducive learning spaces which optimizes assessment conditions by monitoring environmental factors, such as temperature, noise levels and air quality, which may be capable of impacting students' learning and performance (Spikol, 2018). Chappuis and Stiggins (2019) emphasis the importance of student involvement in assessment for which evidence shows that the practice enhances learning and understanding; and impacts on raising classroom standards (Black et al., 2019). Islam (2019) also pointed out that IoT data can be analyzed using machine learning and predictive analytics to identify patterns and trends in student performance. This information can help educators make informed decisions about assessment strategies and interventions for support. Brookhart (2018) believes that incorporating classroom assessment practices into instruction can improve higher-order thinking in students; and provide teachers with valuable information to inform their instruction (Chappuis, 2015). IoT devices are capable of sending and receiving data and can provide real-time feedback to both students and teachers, giving room for immediate identification of students' learning needs, adjustments and interventions for support (Datta, 2019). This real-time engagement is made possible over cyberspace.

1.6 IoT Cybersecurity in Educational Assessment

The impasse of the cyberspace over which the IoT operates presents us with unique challenges, some of which can be intentionally damaging with grave consequences. Projected to hit 75 billion IoT devices by 2025 (Fernandez-Carames & Fraga-Lames, 2020), an IoT global data collection of 73.1 zettabytes by 2025 (Bojan, 2022) and approximately 125 billion devices by 2030 (Jenalea, 2017), the worry has now drifted to cybersecurity, the securing of IoT in cyberspace. Cybersecurity is the state of being safe from, and the measures taken to forestall criminal or unauthorized use of electronic data and devices (Rahman et al., 2020). The Department of Homeland Security (DHS, 2014) defined cybersecurity as the activity, process, ability or state whereby information and communications systems and the information contained therein are protected from and/or defended against damage, unauthorized modification, exploitation or use. Oguguo and Ocheni (2023) defined cybersecurity in educational assessment as security breaches in assessment over cyberspace. From the foregoing, it may be deduced that the essentials of cybersecurity are the securing and protection of data, devices and people connected in cyberspace. Therefore, IoT cybersecurity (IoTCS) can be seen as measures that ensure the safety of data, systems and people connected over the internet network through various IoT devices. The credibility of the security level of IoT devices is crucial in securing the IoT devices, however, it is difficult to ratify an acceptable IoT standard due to the heterogeneous and dynamic nature of the IoT devices (Matheu et al., 2019), which poses a significant challenge to the adoption of IoT in educational assessment issues. Educational assessments are serious businesses that cannot afford to entertain activities that mar the validity or reliability of its outcomes. Todorov and Vela (2023) identify cybersecurity issues as an important challenge in the integration of IoT in education, and assessment.

Scholars have identified several cybercriminal activities involving IoT in assessment practices. Oguguo and Ocheni (2023) revealed that hacking into assessment systems and websites to alter assessment scores, colluding via social media, phishing of login credentials or other assessment-sensitive materials to gain access or cheat on assessments via phishing links, using man-in-the-middle (MITM) attack are some of the cyberattacks on educational assessments. Other assessment cybersecurity issues include impersonating with the use of fake identities to take exams on behalf of other students, the deployment of ransomware to encrypt or disrupt the assessment system until demands are met, peer collaboration to cheat or plagiarize the assessment by accessing unauthorized information during assessment via using IoT devices, sharing or selling assessment questions with other students prior or during assessment through using IoT devices, bullying, harassing or intimidating teachers and students through IoT cyberspace to affect performance in the assessment, distributing malware and lunching of IoT denial of service attacks to flaw the assessment processes, distributing fake academic credentials, among others. These criminal activities in IoT cyberspace compromise the integrity of the assessment processes and require strict vigilance and implementation of strong cybersecurity measures by the lecturers and administrators in university learning spaces to curb the menace.

Several IoTCS tools have been tested and implemented in various sectors of society, some of which have proved effective for the purposes they were adopted. Among so many of them are Fore scout, Armis, Claroty, Check Point IoT Security, Trustwave IoT Security, Bastille, McAfee MVISION Endpoint, CyberX, NXM S.T.A.T, Zingbox, Amazon Web Service (AWS) IoT device defender, Broadcom, IoT Secure, Palo AltoNetworks, Entrust Authority, ForgeRock, DigiCert IoT Trust, Ordr, Asimily, Audra Homeshild Dotlines, Axonius Cybersecurity Asset Management, Sepio, Caarwall, Intel Enhanced Infrastructure Protection, Intel IoT Gateway Security, Pwine Express Pulse IoT Security, Karamba Security, Fortrust Cyber MDX, Tempered, Securithings, Sectrio, Overwatch, NanoLock, ForitNAC, FirstPoint, Cisco IoT Security, Azure IoT, Atonomi, Bastile, Trustwave, SensorHound, Google CloudIoT, Shodan (Fernandez-Carames & Fraga-Lames, 2020; Zakariyya, Kalutarage & Al-Kadri, 2023) among others. Eleje,et al. (2022) found that cybersecurity problems negatively influenced digital assessment. According to Oluga et al. (2014); AlSalem, et al. (2023); and Triplett, et al. (2023), cybersecurity issues are a serious challenge to the effectiveness of IoT for the purposes designed, and may influence assessment practices. However, Kandasamy, et al. (2020); and Lee (2020) have pointed out the paucity of research on the bearing of IoT cybersecurity for assessment practices, although IoT plays amazing roles in educational assessment. Owing to the numerous possibilities, convenience and efficiency IoT provides for assessment practices, the cybersecurity issues associated with the IoT cannot be overlooked. Therefore, the study investigated the impact of IoTCS on educational assessment practices in university learning spaces. The following specific issues were addressed:

1. What is the influence of IoT cybersecurity on the effectiveness of formative assessment practices in university learning spaces?
2. What is the influence of IoT cybersecurity on the effectiveness of summative assessment practices in university learning spaces?
3. What is the influence of IoT cybersecurity on the effectiveness of authentic assessment practices in university learning spaces?
4. What is the influence of IoT cybersecurity on the effectiveness of assessment practices in university learning spaces?

2. Materials and Methods

Correlation research design was adopted for this study which determined the impact of Internet of Things (IoT) Cybersecurity on educational assessment practices in university learning spaces. The research design explores the relationship between two or more variables in a study (Nworgu, 2015). The study was conducted in six universities in South-East, Nigeria, which comprised of Alex Ekwueme Federal University, Ndufu-Alike, Ikwo (AE-FUNAI); Alvan Ikoku Federal University of Education, Owerri (AIFUEO); Federal University of Technology, Owerri (FUTO); Michael Okpara University of Agriculture, Umudike (MOUAU); Nnamdi Azikiwe University, Awka (NAUA); and University of Nigeria, Nsukka (UNN). The study sampled 297 lecturers from the universities in the South-East, Nigeria. Multistage sampling procedure was adopted to recruit 297 (male = 202 and female = 95) respondents who participated in the study. The lecturers that participated in the study had between five and 30years of teaching experience. First, disproportionate stratified sampling technique was adopted to determine the proportion of university lecturers to be drawn from each university in the South-East. Simple random sampling technique was further applied in each stratum to select 40, 45, 58, 48, 40 and 68 lecturers from each of the six universities. Then, the researchers randomly sampled six Faculties in each university using simple random sampling procedure by balloting without replacement.

The instruments for data collection were two researchers developed four-point Likert scale questionnaire titled Internet of Things Cybersecurity Questionnaire (IoTCSQ) and Assessment Practices Scale (APS). The IoTCSQ consist of two sections (Section A elicited demographic data of the respondents while Section B holds the 12-item statements which sought to elicit information on IoT Cybersecurity tools and devices available at the disposal of the lecturers in university learning spaces). The APS consists of two sections (Section A elicited demographic information of the respondents, while Section B contains three clusters, A, B and C hold 8-item statements each on Formative, Summative and Authentic assessments, respectively, 24 items in all which sought to elicit information on respective assessment practices adopted by the lecturers in the university learning spaces). Both instruments were designed to elicit participants responses towards addressing the research issues raised for the study. The items of the instruments (IoTCSQ and APS) were validated in line with the purpose of the study by three experts in the area. Their suggestions and recommendations were incorporated into the final version of the instrument. Data collected from trial testing of the two instruments (IoTCSQ and APS) showed evidence of normality by Shapiro-Wilk test p-values of 0.34 and 0.95 respectively and then were subjected to Cronbach Alpha reliability test, IoTCSQ has a reliability index of 0.82 while the overall reliability index of APS was 0.85, and clusters A, B and C had reliability indices of 0.81, 0.92 and 0.84 respectively.

The instruments, IoTCSQ and APS were distributed by the faculty Deans to the sampled lecturers in the sampled faculties who served as research assistants after briefing on the purpose of the study. The instruments were retrieved from the Deans after the subjects had attended to them for analysis. Data was analyzed using SPSS v.25, and the research questions were addressed using Pearson Product Moment Correlation and Coefficient of Determination. The criterion adopted for interpreting the result was according to Schober and Boer (2018) which considered absolute values of correlation coefficient below 0.1 as negligible, 0.1-0.39 as weak, 0.40-0.69 as moderate, 0.70-0.89 as strong while 0.90-1.00 as high relationships.

3. Results

3.1 Participants Statistics

Figure 1 shows the population distribution of male and female lecturers in the South-East universities. The chart shows that males are more in number than females among lecturers in all the federal universities in South-East, Nigeria. This implies that the responses of the male lecturers could largely infer the influence of IoT Cybersecurity on the effectiveness of formative, summative and authentic assessment practices in university learning spaces since they have a larger population. The chart also shows that UNN has more lecturers among the six federal universities in South-East, Nigeria.

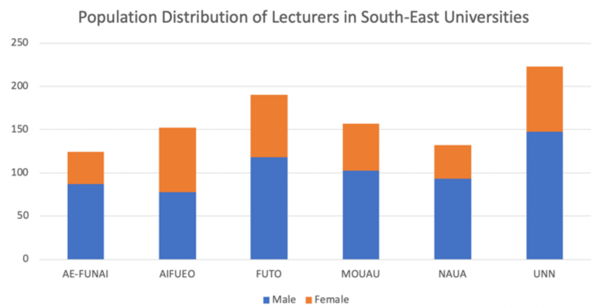

Figure 1 - Population Distribution of Lecturers in South-East Universities.

3.2 IoT Cybersecurity on the Effectiveness of Formative Assessment Practices

Table 1 shows a moderate positive relationship between the incorporation of IoTCS and the effectiveness of formative assessment practice (r = 0.52). The result also shows a coefficient of determination of 0.2704, implying that the opinion of lecturers on the adoption of IoTCS explains 27.04% of the variation in formative assessment in university learning spaces.

3.3 Integration of IoT Cybersecurity in Summative Assessment Practices

The result in Table 2 shows a strong positive relationship between the incorporation of IoTCS and the effectiveness of summative assessment practices in university learning spaces (r = 0.70). With a coefficient of determination of 0.49, it implies that the adoption of IoTCS in the opinion of the lectures explains 49% of the variation in summative assessment in university learning spaces.

3.4 IoT Cybersecurity and Authentic Assessment Practices

The result in Table 3 shows a moderate positive relationship between the incorporation of IoTCS and the effectiveness of authentic assessment practices in university learning spaces (r = 0.41). The result also shows a coefficient of determination of 0.1681, implying that lecturers' adoption of IoTCS explains about 16.81% of authentic assessment in university learning spaces.

Table 1 - Integration of IoT in formative assessment practices in university learning spaces.

	r	r^2
IoT*FA	0.52	0.2704
r = Pearson's Correlation coefficient r^2 = Coefficient of Determination		

Table 2 - Integration of IoT in summative assessment practices in university learning spaces.

	r	r^2
IoT*SA	0.70	0.4900
r = Pearson's Correlation coefficient r^2 = Coefficient of Determination		

Table 3 - Integration of IoT in authentic assessment practices in university learning spaces.

	r	r^2
IoT*AA	0.41	0.1681
r = Pearson's Correlation coefficient r^2 = Coefficient of Determination		

3.5 IoT Cybersecurity on the Effectiveness of Assessment Practices

The result in Table 4 shows a moderate positive relationship between the incorporation of IoTCS and the joint effectiveness of assessment practices in university learning spaces (r = 0.62). The coefficient of determination of 0.3844, implies that the adoption of IoTCS by lecturers explains about 38.44% of assessment practices (the joint of formative, summative and authentic assessments) in university learning spaces.

Table 4 - Integration of IoT in assessment practices in university learning spaces.

	r	r^2
IoT*JAP	0.62	0.3844
r = Pearson's Correlation coefficient r^2 = Coefficient of Determination		

From Table 5, the F-ratio of 185.487 with an associated probability value of 0.000 was obtained for the incorporation of IoTCS and the effectiveness of assessment practices in university learning spaces. The associated probability value was found to be significant because 0.00 is less than 0.05 (the level of significance) when compared for testing the hypothesis. Therefore, the null hypothesis which stated that the influence of IoT cybersecurity on the effectiveness of assessment practices in university learning spaces is not significant was rejected. Hence, it is inferred that IoT cybersecurity adoption significantly influences the effectiveness of assessment practices in university learning spaces.

4. Discussion

The result of this study shows that the opinion of lecturers depicts a moderate positive relationship between the incorporation of IoTCS and the effectiveness of formative assessment practice. This finding suggests that IoTCS influences the effectiveness of formative assessments by preventing the threats on IoT devices for students to receive instant feedback that strengthens continuous and personalized learning.

This may be plausible because IoTCS technology can detect and intercept activities of malware, ransomware and other tools that endanger the data and effectiveness of IoT devices on the network during the assessment, so the assessment practice intended to provide the opportunity for the collection of real-time data and personalized feedback to students based on student progress is not distorted. However, this moderate relationship may have sufficed because most lecturers pay less attention to formative assessment practices in most Nigerian university learning spaces which may have graced their opinions about the influence of

Table 5 - ANOVA of the integration of IoT in assessment practices in university learning spaces.

		Sum of squares	Df	Mean square	F	Sig.
1	Regression	18942.380	1	18942.380	185.487	.000[b]
	Residual	30126.051	295	102.122		
	Total	49068.431	296			
a. Dependent Variable: Joint Assessment Practices b. Predictors: (Constant), Internet of Things Cybersecurity						

cybersecurity on the effectiveness of formative assessments. This finding is in line with the findings of Chelliah et al. (2017); Pollock and Satterthwaite (2018); Misra and Pal (2019); Lee (2020); Eleje et al. (2022); and Oguguo and Ocheni (2023).

We discovered a strong positive relationship in the opinion of lecturers between the incorporation of IoTCS and the effectiveness of summative assessment practice. This finding suggests that IoTCS provides confidence in the automated real-time data collection and analysis of students' achievement, leading to improved efficiency and objectivity in trust in the outcome of end-of-course assessments, although most hackers target this final assessment. This implies that IoTCS can enable the effective collection of diverse data that can be relied upon for comprehensive and holistic assessment of students' achievement. The strong positive relationship between the adoption of IoT and the effectiveness of summative assessment practices in university learning spaces may have turned out so because the emphasis has always been on the final examinations which often hold the largest chunk of scores, for which society attaches more relevance (Sewagegn & Diale, 2020) therefore, the tendency of protecting it from malicious activities is high. This finding agrees with the findings of Chalmers et al. (2017); Papapanagiotou et al. (2017); Sharma and Jain (2019); Kandasamy, et al. (2020); Eleje et al. (2022); and Oguguo and Ocheni (2023).

The result further revealed that the opinion of lecturers shows a moderate positive relationship between the incorporation of IoTCS and the effectiveness of authentic assessment practices in university learning spaces. This finding indicated that IoTCS contextual data collection can be defended in real time, leading to trustworthy data from real-world implications of meaningful learning. This result may also have turned out so because the assessment practices in most developing countries like Nigeria seldom focus on meaningful contexts that solve real-world problems, therefore the rate of defending the same by adopting IoTCS is expectedly relative. This finding supports the reports of Borges and Sthel (2018); Tom Dieck, and Jung (2018); and Alivernini et al. (2020); Kandasamy, et al. (2020); Eleje et al. (2022); and Oguguo and Ocheni (2023).

There was a moderate positive relationship between the adoption of IoTCS and the joint of formative, summative and authentic assessment practices in university learning spaces based on the opinion of lecturers. This moderate positive relationship was found to significantly influence assessment practices in university learning spaces. This result may have been plausible since more studies advocate the extension of cybersecurity in assessment practices to mitigate the challenges posed by cybercriminals which cannot be patronized over the many conveniences and possibilities of IoT assessment practices in university learning spaces as accounted by (Al-Zou'bi, 2021; Valverde et al., 2021). The findings of this study are consistent with the views of Oluga, et al. (2014); Chen and Zhu (2019); Le et al. (2020); Chen et al. (2021); Monteiro et al. (2021); Eleje, et al. (2022); Triplett (2023); and Oguguo and Ocheni (2023), to the extent that the integration of IoT influences assessment practices in university learning spaces.

5. Conclusions

Assessment has over time been an integral component of the educational system, with practices varying from the traditional summative form to the learning-informed assessment perspective. The influx of technology has been accompanied by advances in internet access enabling almost any object to share resources online in real time. The Internet of Things (IoT) presents a unique flexibility that injects more productivity and powers the previously impossible with less effort, even in facets of the educational sectors. However, the wave of cyberattacks experienced over the internet has not spared the IoTs wherever they are adopted, even in educational assessment practices. Evidence from this study shows that the opinion of the lecturers on the adoption of IoT Cybersecurity (IoTCS) can significantly influence the effectiveness of assessment practices in university learning spaces. Given the foregoing, it has become necessary for the university learning spaces to incorporate IoTCS tools into their assessment systems to improve the fairness and reliability of the data collected and the feedback generated by the IoT devices used in such assessment practices. Also, the fact suffices that if lecturers feel safe with the assessment tools used from a cybersecurity perspective, they could use a variety of teaching and assessment solutions, including online or at a distance. However, the novelty of IoT and the huge cybersecurity implications associated with Nigeria's educational system if not intercepted has prompted this study which the researchers hope would engender further exploration of the IoTCS issues for educational assessment practices in university learning spaces. Based on the findings of the study, the following recommendations were made.

1. School administrators should consider investing in IoT cybersecurity for the safety, fairness and reliability of assessment data.
2. The government should partner with tech agencies to provide special training and services for university lecturers for the detection of IoT vulnerabilities.
3. University lecturers should encourage the adoption of IoT cybersecurity measures in assessment practices in university learning spaces.
4. Due to the cost implications involved in opting for IoTcybersecurity tools, the government should fund universities to afford the same in their learning spaces.
5. Educational policies should strengthen the incorporation of IoTCS in assessment practices in university learning spaces.

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Transforming Learning Spaces in the digitalization era: a bibliometric exploration of emerging trends

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Abstract

Learning Space is the physical and psychological place of acquiring knowledge, which has evolved significantly, influenced by technological advancements, pedagogical shifts, and changing student needs. The transformation of learning spaces is crucial for fulfilling the needs of the 21st generation learners and improving the learner's overall outcome. This study aims to explore the available literature on learning spaces to analyse the past, current and future trends of study themes, in learning spaces, through a bibliometric analysis approach. Vos viewer software is used to determine the author, countries, and publications, which have made the greatest contribution to learning spaces research, as well as the key themes and emerging trends of study. The findings of the study show that most of the learning space research is focused on the user experience in traditional and digitally equipped learning spaces, the impact of learning spaces on users' cognition, attitude, engagement, performance and well-being, and the design of innovative learning spaces. Still, there is a lack of research on the design and utilization of spaces to satisfy the needs of the 21st-century digital generation, for the well-being of the learner, and improvement of learning outcomes. The emerging theme of research is focused on the learner's mental, physical and social well-being. This study will help the researchers to understand the research gap in the field of learning space research.

KEYWORDS: Learning Spaces, Digitalization, Pedagogical Shifts, Well-Being, Bibliometric Analysis.

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1. Introduction

Research in learning spaces dates back to the 1990s, as retrieved from the Scopus database. There is a strong relationship between learning spaces, pedagogy, and technology (Sardinha et al., 2020). Still, compared to research on pedagogical approaches, the studies on learning spaces are very limited in educational research (Edgerton & Mckechnie, 2023; Zaid et al., 2021). There is an evident need to improve the learning spaces for adaptation to emerging educational needs (Almansour & Almoayad, 2024) and meet the global trend of learning skills for the 21st century (Grannäs & Stavem, 2021). Educators are beginning to consider learning spaces as an additional resource to acquire desired learning outcomes in educational institutions (Attai et al., 2021), or 'learning organizations' focussed towards digital transformation (McGregor, 2004). It's a challenge to develop experiential learning, engagement and teamwork in the learning spaces to attain the goal of Education 4.0 (Munoz Cantero et al., 2016). If a country aspires to progress, it must achieve SDG-4 of quality education (OECD, 2017) and focus on Education 4.0. In the 21st century, the digital transformation of 'learning spaces' or 'built pedagogy' is leading towards smart learning (Wang et al., 2024) and innovation. The use of technologies supports an interactive and engaging learning experience, better learning outcomes and shifts in the learner's expectations of learning spaces (Aburas et al., 2014). These can contribute to the teaching-learning process (Zaid et al., 2021), student academic success (Choi et al., 2014), and the fulfilment of students' psychological needs (Ismail & Abdullah, 2018; Dhasmana et al., 2022).

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The first step towards effective learning is to understand the role of learning spaces. Various researchers have put forward different aspects of learning spaces to foster student learning (Young & Cleveland, 2022). Learning Spaces influence human behaviour and attitudes (Higgins et al., 2005), enhance learning outcomes (Owoseni et al., 2020), and increase satisfaction levels (Costa & Steffgen, 2020). Appropriately designed school spaces can play a significant role in the teaching-learning process (Szpytma & Szpytma, 2019) and the well-being of children (Chourasia et al., 2023). The Joint Information Systems Committee (JISC, 2006) has suggested that "Spaces themselves are agents for change and changing spaces will change practices".

Bibliometric analysis is a method of evaluating development trends, to put forward the future direction of research in a particular field using statistical approaches (Xu & Yu, 2019). Diverse fields of study commonly use this method to map current and future study trends and identify research gaps. This research aims to determine the studies conducted on learning spaces and to analyse the current and future trends in studies of learning spaces through bibliometric research analysis and using the Scopus database. This study contributes to the knowledge of learning spaces, their impact on various aspects of learning and the learner, and the innovation in learning spaces. The study helps researchers throughout the world to know less explored themes. The study aims to determine the answers to four research questions:

RQ1: How much the research in learning spaces has gained importance in education and architecture research?

RQ2: Which authors, countries, and publications have made the maximum contribution to the learning spaces research?

RQ3: What are the main research themes and how they have evolved with time?

RQ4: What future research areas are prevalent in the educational and architecture research about learning spaces?

2. Research Methodology

2.1 Data Collection

The researcher has explored the Scopus database to collect data for this study. The Scopus database is quite popular for its peer-reviewed publications (Arora et al., 2022), and provides relevant data required to explore the existing literature on 'Learning Spaces'. The required data for study had been acquired on July 4, 2024. Publications were collected through keywords search, either in the title, abstract or the author keywords. The keywords used for search engine are "Conducive learning spaces" OR "Physical learning environment" OR "School built environment" OR "School spaces design". The researcher has retrieved whole of the data published from 1996 to 2024, available on the study topic in the Scopus database. This data had helped the researcher to understand the growth of new fields of study towards achieving effective learning spaces, in the educational research.

The PRISMA or Preferred Reporting Items for Systematic Reviews and Meta-Analysis approach (Arora et al., 2022) had been utilized for data collection. This approach involves identification of the articles through keywords search, screening of the collected data (by limiting to 'Final' publication and 'English' language), checking the eligibility after proofreading of the articles, and including the remaining articles in the study. Table 1 represents published articles retrieved from the Scopus database. The PRISMA approach used in the study has been explained in Figure 1.

Table 1 - Publications retrieved for study.

Description	Results
Total documents	228
Article	157
Conference Paper	45
Book chapter	15
Review	9
Note	1
Erratum	1
Sources of documents	
Journals	156
Proceedings	38
Books	14
Others	8
Publication period	1996-2024
Authors	470
Author's Keywords	590

2.2 Data Analysis

A large number of software are available to conduct bibliometric analysis. However, the researcher had chosen VOS viewer software to analyse the data, for its remarkable results. It is adopted mainly for network analysis and descriptive data analysis. The total publication count is 176, with 147 sources, 470 authors, 370 organisations, and 52 countries involved in the research on this theme. There was a total of 6900 cited references. The total number of keywords is 1201, the author keywords are 590 and the index keywords are 773. Data analysis is done by determining the publication count, citation count, co-citation analysis, and keyword co-occurrence.

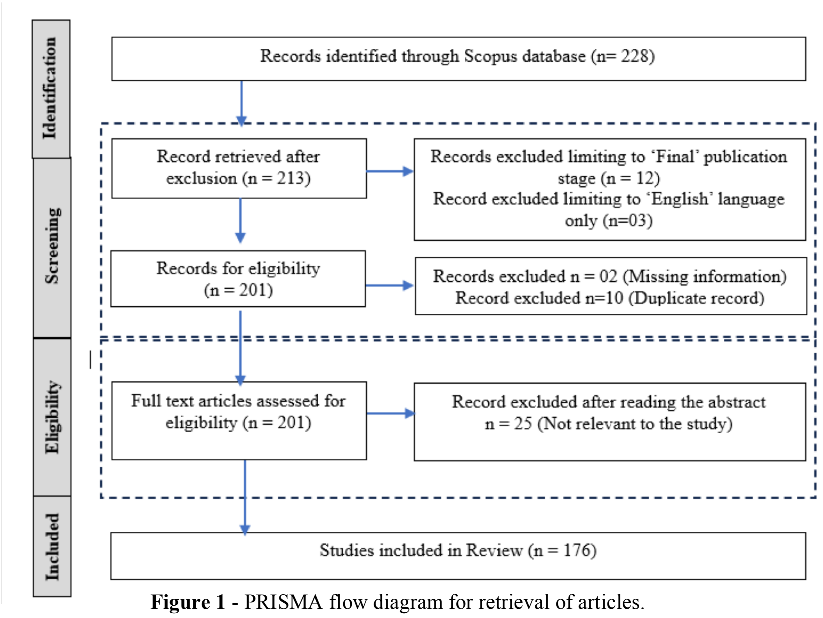

Figure 1 - PRISMA flow diagram for retrieval of articles.

3. Results of Analysis

3.1 Descriptive Data Analysis

Descriptive data analysis contains analyses of articles to determine the level of growth in publications, the productivity of authors, the most productive source, cited publication and the productive country.

Publication trends

The number of publications regarding learning spaces, in 1996 was as low as one publication. As the awareness grew the publication rose to 12 number of publications in the years 2018 and 2019. The COVID-19 pandemic made a remarkable increase in the studies from 16 publications in 2020 to 27 publications in 2021 (Figure 2). Later the publication score gets reduced to a certain extent to 17 articles in 2022 to 20 articles in 2023. The number of publications in 2024 is only 8, as the data analysed is till June 2024.

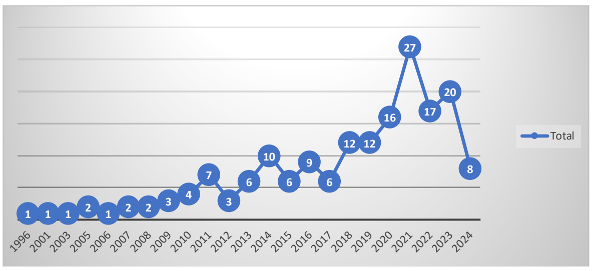

Figure 2 - Trend in publication.

3.2 Citation Analysis

Top Publications

Research on learning spaces has grown considerably since the past decade, evidenced by the increase in related publications. (Figure 2). Citations refer to the value and acceptability of any article. The higher citations of a research article depict its credibility (Arora et al., 2022). Table 2 shows the most cited publications on the impact of learning spaces relate to cognition, social aspects, and student engagement. The publication with the maximum number of citations is by Choi H.H et al. (2014) with 225 citations. The second position is held by McCarthy's (2010) publication with 187 citations and the third position by Mathews et al. (2011) with 125 citations.

Leading Universities

This section reviews the top five institutions contributing significantly to the field and has maximum citations worldwide. Table 3, signifies that although Tallinn University from Estonia has a maximum number of 11 citations, institutions from the Netherlands emphasise more on research in the field of learning spaces. Three universities from the Netherlands with 10 citations each, are among the five Universities with highly cited publications.

Most productive Authors

Table 4 represents the top ten productive authors based on the number of publications and their citations. The most productive author can be analysed by dividing the number of citations of an author by the number of publications. McCarthy J. emerged as the most productive author, with 187 citations and two publications. The second position is held by the Buliung R., Howard A., Macarthur C. and Rothman L., with 91 citations and two published documents. Cleveland B. with 141 citations and four publications grabbed the third position. Woolner P. hold the fourth position with 70 citations and two publications. Zandvliet D. B. stood in the fifth position.

Table 2 - Top ten Publications with maximum citations.

Rank	Author	Title	Year	Source	Citations
1	Choi H.-H., Van Merriënboer J.J.G., Paas F.	Effects of the Physical Environment on Cognitive Load and Learning: Towards a New Model of Cognitive Load	2014	Educational Psychology Review	225
2	McCarthy J.	Blended learning environments: Using social networking sites to enhance the first-year experience	2010	Australasian Journal of Educational Technology	187
3	Matthews K.E., Andrews V., Adams P.	Social learning spaces and student engagement	2011	Higher Education Research and Development	125
4	Young F., Cleveland B.	Affordances, Architecture and the Action Possibilities of Learning Environments: A Critical Review of the Literature and Future Directions	2014	Buildings	121
5	Steen-Utheim A.T., Foldnes N.	A qualitative investigation of student engagement in a flipped classroom	2018	Teaching in Higher Education	103
6	Cukurova M., Luckin R., Millán E., Mavrikis M.	The NISPI framework: Analysing collaborative problem-solving from students' physical interactions	2018	Computers and Education	75
7	Woolner P., Hall E.	Noise in schools: A holistic approach to the issue	2010	International Journal of Environmental Research and Public Health	68
8	Rothman L., Howard A., Buliung R., Macarthur C., Richmond S.A., Macpherson A.	School environments and social risk factors for child pedestrian-motor vehicle collisions: A case-control study	2017	Accident Analysis and Prevention	67
9	Getie A.S.	Factors affecting the attitudes of students towards learning English as a foreign language	2020	Cogent Education	65
10	Zandvliet D.B., Fraser B.J.	Physical and psychosocial environments associated with networked classrooms	2005	Learning Environments Research	63

Leading Sources of Publication

This research includes articles from 156 Journals, 38 conference proceedings, 14 books and 8 other publications. The top 3 publication sources with maximum citations and more than 3 publications are the Learning Environment Research, International Journal of Environmental Research and Public Health, and ACM International conference proceeding series (Table 5). Out of these three 'Learning Environments Research' tops the list with 12 publications and 312 citations.

Most productive country

Figure 3 represents the maximum number of publications by the top ten countries in the field of learning spaces. The United States tops the list with 30 articles, followed by Australia and the United Kingdom with 19 and 16 articles respectively. India lies in the 6th position with 8 articles. Figure 4 represents the top 10 most productive countries according to citations. Australia is in the top position with 889 citations, the Netherlands has 305 citations and the United Kingdom has 284 citations. Canada with 264 citations is in the fourth position and the United States with 228 citations is in the fifth. India secures the 8th position with only 28 citations. The most productive countries are determined by dividing the citations by the number of publications. Australia is the most productive country in learning spaces research, followed by the Netherlands and the United Kingdom.

Table 3 - Top five Leading Universities.

Rank	Universities	Country	Documents	Citations
1	Tallinn University	Estonia	2	11
2	Delft University of Technology	Netherlands	2	10
3	Eindhoven University of Technology	Netherlands	2	10
4	NHL Stenden University	Netherlands	2	10
5	University of Otago	New Zealand	2	9

Table 4 - Author ranked based on Documents and Citations.

Authors ranked based on documents				Authors ranked based on citations			
Rank	Author	Documents	Citations	Rank	Author	Documents	Citations
1	Cleveland B.	4	141	1	Mccarthy J.	2	187
2	Helfenstein S.	3	52	2	Cleveland B.	4	141
3	Mäkelä T.	3	52	3	Buliung R.	2	91
4	Zandvliet D.B.	3	88	4	Howard A.	2	91
5	Almawaldi M.K.	2	1	5	Macarthur C.	2	91
6	Baars S.	2	10	6	Rothman L.	2	91
7	Barnes B.	2	37	7	Zandvliet D.B.	3	88
8	Brachtl S.	2	18	8	Woolner P.	2	70
9	Buliung R.	2	91	9	Helfenstein S.	3	52
10	Ciordas-Hertel G.-P.	2	8	10	Mäkelä T.	3	52
11	Cross D.	2	5	11	Barnes B.	2	37
12	Drachsler H.	2	8	12	Hao Q.	2	37
13	Francis J.	2	5	13	Jing M.	2	37
14	Gomes A.S.	2	2	14	Sigurdardóttir A.K.	2	31
15	Hao Q.	2	37	15	Brachtl S.	2	18

Table 5 - Leading Publication Source.

Rank	Source	Number of Articles Published	Citations
1	Learning Environments Research	12	312
2	International Journal of Environmental Research and Public Health	4	85
3	ACM International Conference Proceeding Series	3	33

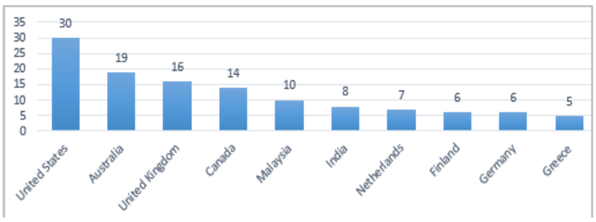

Figure 3 - Top ten productive countries according to publications.

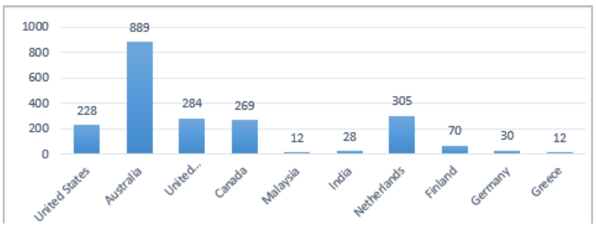

Figure 4 - Top ten productive countries according to citations.

3.3 Co-Citation Analysis

Cited references

Co-citation analysis of 6900 cited references has a total of 48 references, meeting a minimum of 3 citations of a cited reference. 48 items have been classified into four clusters with a minimum of 8 items in each cluster. Cluster 1 (red) has 19 items, Cluster 2 (green) has a total of 11 items, and Cluster 3 (blue) and 4 (yellow) have 9 items each (Figure 5). The research theme of Cluster 1(red) addressed the innovative design of learning spaces, cluster 2 is based on the psychosocial environment, Cluster 3 studies the impact of learning spaces on learning and Cluster 4 relates to the evaluation of the school buildings.

Keyword Analysis

There are 553 author keywords out of which 25 meet the threshold of 3 occurrences minimum. Keywords with high occurrence are “learning spaces”, “learning environment”, “pedagogy”, “school buildings”, “higher education” and “built environment” (Table 6).

Figure 6 illustrates the emergence of various topics in educational learning spaces from 2013 to 2024. The network visualisation of all 1109 keywords has found 43 keywords with a minimum of three occurrences. 43 keywords have been classified into four clusters- red, blue, green and yellow. Cluster-1 (red) has 12 keywords related to school-built environment, Cluster-2 (green) has 11 keywords on technology integration, Cluster-3 (blue) has 10 keywords on well-being, and Cluster-4 (yellow) comprise 10 keywords on active learning spaces. The key themes identified from these clusters are school-built environment, technology integration, design for well-being, and active learning spaces.

4. Discussion and Findings

4.1 Importance

The publications depict that learning spaces have gained importance in education and architecture research. The research on learning spaces has shown tremendous growth, with the changing needs of the users, industry and the education system. The publication trend of learning spaces research shows an increase in articles, in 2011 and reached the heights in 2021. The increase in publications since 2020 is remarkable. The publications rose to a peak in the year 2021, after the Covid-19 pandemic, due to the raised attention of researchers towards online, and blended learning spaces. After 2021, the research is focused towards various other fields for the development of learning spaces to meet the needs of the 21st century.

4.2 Contribution

The most productive author if ranked based on documents is Cleveland, and the citations are Mccarthy. The leading source of publication is ‘Learning Environment Research’ and the leading University is ‘Tallinn University’. Australia leads in the publication on learning spaces. Most of the research is limited to developed countries. There is a gap in research in underdeveloped countries. The most cited publication is by Choi H.H et al. (2014), followed by McCarthy (2010) and Mathews et al. (2011). Highly cited publications are related to the impact of learning spaces on cognition, social aspects, and student engagement.

4.3 Key Themes

Innovative school building design

In the design process of school building design, all three factors the teacher, the designer and the school management were involved but the learners were uninvolved (Bojer, 2020). So, buildings work against learner-centred pedagogies (Szpytma & Szpytma, 2019). Schools designed for educational purposes (Grannäs & Stavem, 2021), embeds flexibility, adaptability (Lefdal, 2023), and continuous learning (Maturana et al., 2021). Flexibility (Hubber & Ramseger, 2016) and functionality (Ismail & Abdullah, 2018) are the most important factors required for quality twenty-first-century learning spaces (Makela & Halfenstein, 2016), fulfilling the psychological, physiological and bio-physical needs, of the user (De Vrieze & Moll, 2018). New school building design identifies students’ preferences, transfers them to planning processes (Lefdal, 2023) and develops learner-centred spaces.

Integration of Technology

Digital transformation in the educational field has brought out a change in user behaviour (Noreiga et al., 2013); learners’ relationship to their learning (De Jong, 2021); and even the learning-teaching process (Kusmin & Laanpere, 2023). A large number of studies analysed the users’ experiences (Wang, 2023; Sardinha et al., 2020), and the effectiveness of online learning (Attalla et al., 2021). The development of online mobile classrooms (Pattanasith, 2016), simulated learning environments (Alfred et al., 2018), and gamification strategies (Raphael, 2016) indicates a high level of satisfaction among the users. Research on new technologies like metaverse-based learning (Dreamson & Park, 2023), Virtual reality (Riemann et al., 2020), virtual robotics (Chichekian et al., 2024) and the Internet of Things (Hwang et al., 2023) have been grown worldwide, to improve the overall quality of instruction (Wang et al., 2024). In smart learning spaces (Cao & Baki, 2024) students’ individuality, social

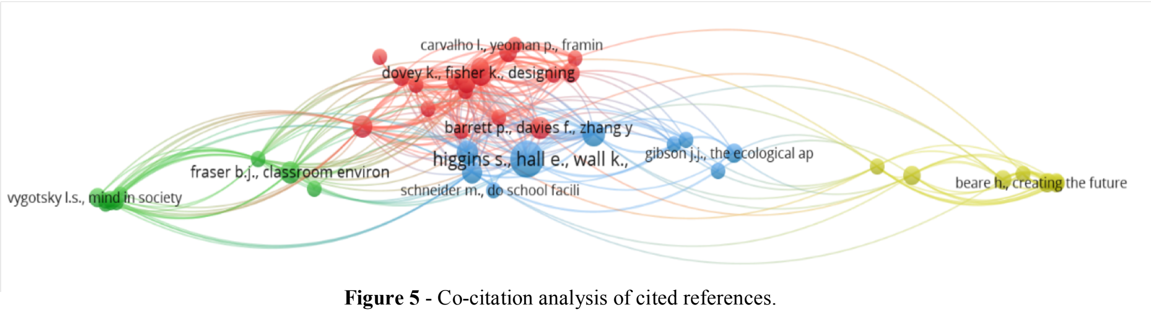

Figure 5 - Co-citation analysis of cited references.

Table 6 - Keyword occurrence analysis.

Rank	Keyword	Occurrences	Rank	Keyword	Occurrences
1	Learning Spaces	42	14	Participatory Design	5
2	Learning Environment	24	15	Architecture	4
3	Pedagogy	15	16	Psychosocial Learning Environment	4
4	School Buildings	13	17	Student Engagement	4
5	Higher Education	11	18	Active Transportation	3
6	Built Environment	10	19	Childhood Obesity	3
7	Classroom design	9	20	Collaborative learning	3
8	Children	8	21	E-learning	3
9	Covid-19	7	22	Environment Aspects	3
10	Physical Activity	7	23	Home Learning Environment	3
11	Distance Learning	6	24	Motivation	3
12	Online Education	6	25	Well-being	3
13	Active Learning	5			

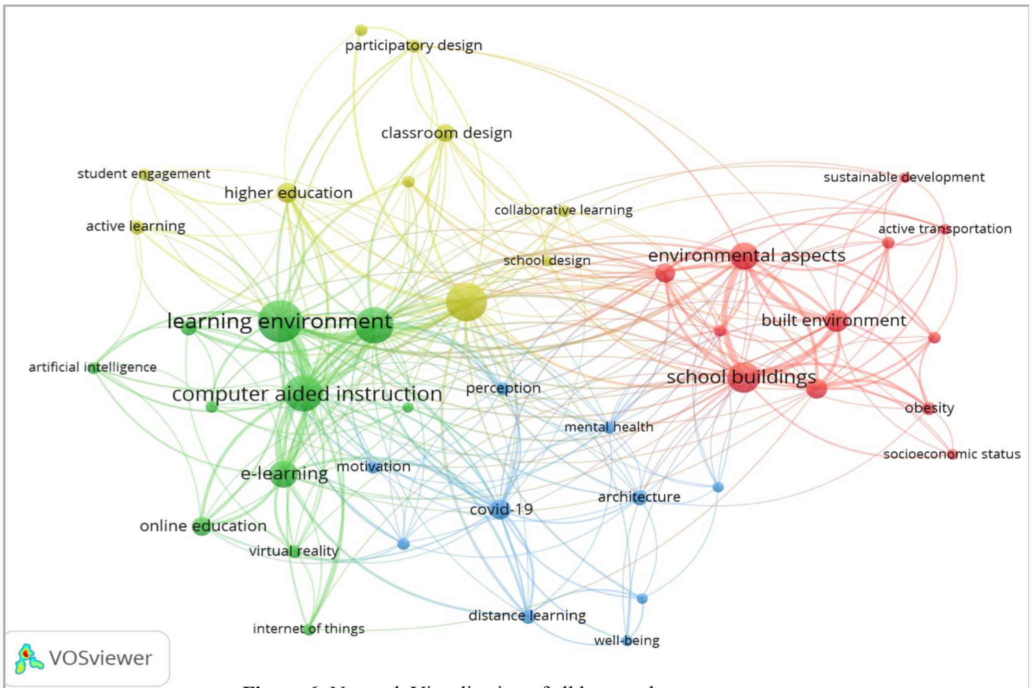

Figure 6: Network Visualization of all keyword occurrence.

interaction ability, thinking ability, creativity and cognition are increased to a remarkable extent.

Well-being

The well-being involves the individual's physical, mental and social wellness (Makela et al., 2014). Sustainable development goals include concern for the well-being of the learners (Kerr & Averill, 2024), and learning spaces to foster well-being (Maturana et al., 2021). COVID-19 led to inadequate physical activity (Triemstra et al., 2021) and a negative psychological impact (Panagiotis & Nikolina, 2024) on the students, diverting the researchers' focus towards the well-being of the students. The sense of well-being is significantly affected by classroom design and furniture (Perry et al., 2023), noise within and outside the classroom ((Naude & Meier, 2019), large classroom sizes (Owoseni, 2020), sound pressure levels (Soares & Trombetta, 2016), and low luminance (Lekan-Kehinde & Asojo, 2021). The negative impact on students' well-being can be reduced through change in design (Brachtl et al., 2023).

Impact of Learning Spaces

The learning space, a secondary element of education (Szpytma & Szpytma, 2019) supports innovative pedagogies (Baars et al., 2023). Learning spaces impact students' cognition, behaviour and engagement in learning (Bojer, 2020; Munoz Cantero et al., 2016); attitudes and motivation (Getie, 2020); active learning (Riemann et al., 2020); satisfaction (Costa & Steffgen, 2020); and achievement (Choi et al., 2014). Most researches are based on user participation (Rönnlund et al., 2021), and has used a qualitative approach (Naude & Meier, 2019). Students perceive learning spaces to be meaningful, easily accessible, active, socially engaging and physically-emotionally comfortable (Nyabando & Evanshen, 2022).

4.4 Emerging Trends

The overlay visualization of author keyword occurrence shows the emerging trend in learning spaces. The growing emphasis on the achievement of sustainable development goals has transferred the focus of the researchers towards the well-being of the users, to enhance student outcomes and holistic growth. Peer learning plays an important role in the psychological and social well-being of the students. Another emerging research field is the use of Internet of Things (IoT) technology in learning spaces, with a growing emphasis on virtual reality and artificial intelligence as tools for creating immersive simulated learning experiences for students.

5. Conclusion

This bibliometric analysis highlights the tremendous growth, with the changing needs of the users, industry and the education system. But still, the research in the field of learning spaces is too low and there is a need to give more importance to the learning spaces in both the educational and architecture research. Researchers have conceptualized the connections between the spaces and the activities involved in the learning spaces, taking care of the technological developments in the educational field. The emerging need for various teaching methods and learning styles for students raises the importance of innovative learning spaces linked to pedagogy and student outcomes. The closure of schools due to COVID-19 led to the development of online learning, but online learning cannot bring the same learning experience as face-to-face learning. Learning spaces can motivate and engage students, to have better learning experiences. Learning space studies are mainly qualitative, with a questionnaire as a tool for assessment. School spaces have a deep impact on the mental-physical health of the students, which affects the well-being of the students and has a gap for future research. There is a need for studies in developing nations, as most of the studies are concentrated in developed nations.

The most cited publications relate to the impact of learning spaces on cognition, social aspects, and student engagement. The initial learning spaces studies were focused on pedagogy, and themes like active learning, collaborative learning and the teaching-learning process. Later, the researchers took an interest in the various aspects of the built environment like classroom design focussing on the participation of the users, and physical activities in the schools, for the better well-being of the students. Before the outbreak of the Covid 19, research was focused on the evaluation of learning spaces and the relationship between pedagogy and learning spaces. Later, after Covid 19, the research was more aligned towards online learning environments, distance learning, virtual learning environments, the effectiveness of digitalised blended learning and the integration of new technologies like virtual reality, artificial intelligence and mobile sensing. The latest themes that have evolved in the research are the innovative school building design, integration of technology, user mental, physical and social well-being and impact of learning spaces on user behaviour, attitude, outcome and satisfaction. These key themes provide a base for future research. New emerging themes include overall well-being and technological advancement in learning spaces. Changes in educational pedagogies, user needs and integration of technologies, require ongoing bibliometric analyses for tracking new emerging themes of research and developments.

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