# JOURNAL OF e-LEARNING AND KNOWLEDGE SOCIETY

www.je-lks.org

VOLUME 21 | ISSUE NO. 2 | AUGUST 2025

## REGULAR ISSUE

PEER REVIEWED RESEARCH PAPERS

AN INTERNATIONAL AND OPEN ACCESS JOURNAL BY THE ITALIAN E-LEARNING ASSOCIATION

ISSN (online) 1971 - 8829 | ISSN (paper) 1826 - 6223

Photo cover by Iris,Helen,silvy da Pixabay

# JOURNAL OF e-LEARNING AND KNOWLEDGE SOCIETY

www.je-lks.org

VOLUME 21 | ISSUE NO. 2 | AUGUST 2025

REGULAR ISSUE

PEER REVIEWED
RESEARCH PAPERS

AN INTERNATIONAL AND OPEN ACCESS JOURNAL
BY THE ITALIAN E-LEARNING ASSOCIATION

ISSN (online) 1971 - 8829 | ISSN (paper) 1826 - 6223

# JOURNAL OF e-LEARNING AND KNOWLEDGE SOCIETY

*www.je-lks.org - www.sie-l.it*

ISSN (online) 1971 - 8829 |ISSN (paper) 1826 - 6223


Je-LKS is an Open Access Online publication. This means that everybody can free access online to abstracts and full t articles.

The Journal is issued online three times per year.

**ANVUR Ranking: A-Class for Sector 10, 11-D1 and 11-D2**

**Libraries or researchers, can subscribe a Printed Copies Service or an Issue Reprint Service.**

The Printed Copies Service is on a yearly basis and you can receive the three printed year issues.

The Issue Reprint Service provide five printed copies of a specific issue.

Both the Services have the same cost of 150€ (including taxes).

Shipping costs are not included and will be charged.

In order to subscribe Printed Copies or Issue Reprint Services contact:

email: segreteria@sie-l.it

email: staff@je-lks.org

Tel. +39 0522 522521

website: www.sie-l.it


## PUBLISHER AND COPYRIGHT

Italian e-Learning Association (SIe-L)


## CONTACTS

editor@je-lks.org

managing.editor@je-lks.org

assistant.editors@je-lks.org


Registration at the Rome Court in the pipeline

ISSN (online) 1971 - 8829

ISSN (paper) 1826 - 6223

JOURNAL OF e-LEARNING
AND KNOWLEDGE SOCIETY
*www.je-lks.org*
ISSN (online) 1971 - 8829
ISSN (paper) 1826 - 6223

**VOLUME 21 | ISSUE NO. 2 | AUGUST 2025**

**PEER REVIEWED PAPERS**
**PERMANENT CALL**

JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 21, No. 2 (2025), pp. 1-17

# Assessing Digital Competence in Indonesian students: demographic and Internet usage factors through the Rasch Model

Wibowo Heru Prasetiyo[a,1], Beti Indah Sari[b], Rizky Novia Saputri[a], Noor Banu Mahadir Naidu[c], Triyanto[d], Jagad Aditya Dewantara[e]

[a]*Universitas Muhammadiyah Surakarta, Dept. of Civic Education – Surakarta (Indonesia)*

[b]*Universitas Negeri Surabaya, Dept. of Pancasila and Civic Education – Surabaya (Indonesia)*

[c]*University Pendidikan Sultan Idris, Dept. of Moral, Civics, and Character Building Studies – Tanjong Malim (Malaysia)*

[d]*Universitas Sebelas Maret, Dept. of Civic Education – Surakarta (Indonesia)*

[e]*Universitas Tanjungpura, Dept. of Civic Education – Surakarta (Indonesia)*

*(submitted: 27/7/2024; accepted: 19/8/2025; published: 31/8/2025)*

**Abstract**

In today's rapidly evolving digital landscape, technological advancements continue to reshape human lifestyles, making robust digital competence (DC) essential in an interconnected world. This study addresses existing gaps in the literature by evaluating the digital competence of Indonesian students and examining the influence of parental educational backgrounds and daily internet usage frequency. Utilizing convenience sampling and online questionnaires, data were collected from 251 students and analyzed using the Rasch Model with Winsteps software version 5.7.3.0. The findings reveal gender-based differences in digital skills, indicating the need for tailored educational strategies. Additionally, students with less educated parents tend to prioritize personal data protection, while those with highly educated parents display broader digital competencies. Although high internet usage is associated with enhanced digital competence, it also carries risks to mental health, such as increased internalizing symptoms and cognitive distortions. This study contributes to ongoing discussions on improving student digital competence and underscores the importance of balanced internet usage strategies.

**KEYWORDS:** Demographic, Internet Usage, Rasch, Students' Digital Competence.

**DOI**
https://doi.org/10.20368/1971-8829/1135991

**CITE AS**
Prasetiyo, W.H., Sari, B.I., Saputri, R.N., Naidu, N.B.M., Triyanto, & Dewantara, J.A. (2025). Assessing Digital Competence in Indonesian students: demographic and Internet usage factors through the Rasch Model. Journal of e-Learning and Knowledge Society, 21(2), 1-18.
https://doi.org/10.20368/1971-8829/1135991

## 1. Introduction

In the 21st century, human lives have been increasingly shaped by technological advancements that facilitate communication, productivity, and access to information. Innovations in areas such as telemedicine, digital payments, autonomous transportation, and e-commerce highlight the pervasive role of digital technology in everyday life. The integration of digital tools is not a temporary response to a global crisis but a continuous evolution that transforms how individuals live, learn, and interact. Modern people no longer live with technology; they live within it. While the COVID-19 pandemic may have accelerated this trend, the

[1] corresponding author - email: whp823@ums.ac.id

broader digital transformation remains an enduring and significant force in shaping modern society. As everyday activities intertwine with technology, mastering digital competence becomes essential due to its comprehensive focus on ethical, safety, and social dimensions, alongside the incorporation of diverse knowledge, abilities, and aspirations of individuals (Falloon, 2020). Consequently, acquiring digital competence encompasses not only proficiency in operating ICT devices but also a comprehensive set of abilities that contribute to overall well-being and quality of life (UNESCO, 2018).

Furthermore, digital competence (DC) is becoming a prerequisite in an internet-connected world, opening new job opportunities for the future. A study by Murphy and Feeney (2023) indicates that the impact of AI on future employment has led to the creation of professions requiring digital skills and data analysis mastery. For example, the legal and accounting professions are undergoing significant transformation due to AI and data analytics, signaling a shift toward knowledge-orientated activities (Mendoza-Chan & Pee, 2024). This development supports the prediction that jobs that rely solely on basic human skills will be disrupted in the next decade. According to Guitert et al. (2021) and Zhao et al. (2021a), the key components of DC are crucial for fostering continuous learning and enhancing employability. Digital competence is increasingly vital for career prospects and advancement. Juárez Arall and Marqués Molías (2019) note that the rapid development of ICT has led to progressive digitalization, reshaping the labor market and making digital competence essential for successful job searches and greater autonomy. Moreover, women's professional development requires digital proficiency to minimize digital disparities in the job market (Sánchez-Canut et al., 2023).

Unfortunately, as challenges to adopting advanced technology rise, the problem of digital gaps remains a significant issue in third world countries. Indonesia, with a vast digital community of more than 220 million individuals, faces numerous challenges and issues. The primary challenge for the government is to ensure equitable access to technology for all citizens (Prasetiyo et al., 2022). Two studies indicate persistent inequality in digital access between urban and rural communities (Gayatri et al., 2014; Puspitasari & Ishii, 2016). A survey conducted by the Association of Indonesian Internet Providers (APJII, 2018) reveals a striking digital divide between the West and East regions of Indonesia. Western regions such as Java, Sumatra, and Borneo dominate internet use with 83.6%, while the Eastern region accounts for only 16.4%.

In 2008, the government issued Law Number 11/2008 on Information and Electronic Transactions (UU ITE) to supervise online activities and combat cybercrime, such as hacking, malware, and fraudulent transactions. The Ministry of Communication and Informatics (MoCI) has established a digital literacy initiative called "Siberkreasi" or Indonesian National Digital Literacy Movement aimed at educating people to mitigate the spread of harmful content, including cyberbullying, fake news, hate speech, pornography, and digital piracy (Rudiantara, 2019). To support this program, MoCI distributed 21 digital literacy books to the public, covering topics such as cybersecurity, legal protections for internet users, appropriate online behavior, and digital skills like infographics, e-commerce, and internet governance.

Additionally, several countries have successfully integrated technology into educational settings to enhance students' digital competence. Luo et al. (2021) highlight that China, the United States and Australia have established national policies and curricula to guide the incorporation of technology in early childhood education. According to Kuka et al. (2022)., AI technologies, such as machine learning, data mining, and learning analytics, are gradually reshaping higher education by enhancing instructional practices, learning experiences, and educational decision-making. Integration of AI integration in education provides insights into automating administrative processes and tasks, as well as creating curriculum and educational materials (Vrcelj et al., 2023). Research indicates that factors such as providing adequate ICT infrastructure, offering training programmes for teachers and students, implementing clear policies, fostering collaboration among stakeholders, and promoting didactic ICT innovation projects are common strategies in countries like Spain, Norway, Ireland and others (Esteve□Mon et al., 2023; McGarr et al., 2021; Valverde-Berrocoso et al., 2021). The UK's Digital Capabilities Framework promotes six components to help students self-direct their learning for advancement (Biggins et al., 2017). According to Castaño Muñoz et al. (2023), most European educational systems view digital competence as a cross-cutting topic in the curriculum.

Various studies have tested digital competence among students. Jeong et al. (2024) found that student digital readiness significantly enhances academic performance. Patwardhan et al. (2023) note that higher digital competencies in students significantly impact learning outcomes. Additionally, Scholes et al. (2024) revealed that high socioeconomic levels, such as the occupation of parents and educational background, correlate with improved digital skills in students. However, studies to date do not provide complete knowledge about the digital competencies of students from developing countries compared to their counterparts in developed nations. Without additional references, it is challenging to make a balanced comparison regarding whether students from third world countries have sufficient opportunities to face similar future challenges. While some studies have described the level of digital competence among students (Hidayat et al., 2025; Nguyen et al., 2024; Syahrin et al., 2023), few focus on demographic conditions and internet usage habits.

Therefore, new research directions are needed to capture these challenges and guide efforts to improve student digital competence. This study aims to fill gaps in the literature by assessing the digital competence of Indonesian students and the influential factors, such as parents' work and education backgrounds, as well as the frequency of daily internet usage. We hope that this study contributes to ongoing discussions about factors affecting student digital competence and introduces ideas for the development of student competence related to mastery and technology skills.

## 2. Literature Review

### 2.1 Student's Digital Competence

Digital technology is playing an increasingly important role in modern life, making digital competence essential. The Council of the European Union (2018) identified digital competence as one of the key competencies for lifelong learning, while Kjällander et al. (2021) highlighted its significance in education. Digital competence involves using digital tools and media effectively while practising good digital citizenship (Martzoukou et al., 2022). High digital competence allows students to grasp learning material more easily and excel in online education (Palomares-Ruiz et al., 2020). Conversely, students with low digital abilities face greater challenges, particularly in online learning environments (Kjällander et al., 2021).

The definition of digital competence has broadened to encompass a multidisciplinary approach, focusing on the skills necessary for citizens to be literate and engaged. (Ferrari, 2012) defines digital competence as the ability to comprehend media, effectively search for and analyze information, and communicate using various methods. It incorporates technical skills, critical thinking about digital technology, and an inclination to participate in digital culture (Ilomäki et al., 2016). The Digital Competence Framework for Citizens outlines digital competence in terms of information and data literacy, communication and collaboration, creation of digital content (including programming and intellectual property issues), safety (including digital well-being and cybersecurity), and problem solving with digital tools tools (Carretero et al., 2017; Vuorikari et al., 2016).

Students' digital competence is thus a multifaceted skill set requiring continuous attention and support from educational institutions to ensure that they are prepared for the digital age. A digitally competent student can effectively search for and evaluate information online, collaborate using digital tools like Google Docs or Slack, and create engaging digital content such as videos or blog posts. They are also aware of online safety measures, such as using strong passwords and being cautious about sharing personal information, and possess problem-solving skills to troubleshoot technical issues. It is crucial for educational institutions to identify specific areas where students need improvement and provide appropriate support and training to enhance their digital competence (Verdú-Pina et al., 2024).

### 2.2 Factors Affecting Digital Competence

Sociodemographic differences among individuals can significantly impact their digital competence. The digital gap, influenced by access and competence, is often correlated with gender (Grande-de-Prado et al., 2021; Rodríguez Muñoz & Ruiz-Domínguez, 2021). Previous studies indicate that men, who frequently use various websites, tend to have greater digital knowledge, leading to more frequent technology use compared to women (Grande-de-Prado et al., 2021). Flores-Lueg and Roig-Vila (2019) and Padilla-Carmona et al. (2016) generally found that women are less competent in digital mastery compared to men. However, Hatlevik et al. (2015) demonstrated that girls scored higher on digital competency tests than boys. Not all research identifies gender differences in digital competence; for example, Bejarano et al. (2021) found no significant differences between men and women in mastering digital competencies, with gender not being a significant predictor of digital competency levels.

Research has also examined the influence of socio-familial variables. Shala & Grajcevci (2018) found that parents' education levels did not significantly affect students' IT skills. Chea and Chea (2022) showed that parental education negatively impacts children's technology readiness, keeping the wealth effect constant. Conversely, Casillas-Martín et al. (2022) discovered that students' digital competency is closely related to their families' economic and cultural status and access to digital gadgets at home. Higher economic and cultural status and more devices at home enhance digital knowledge and communication and collaboration skills. Fernández-Mellizo and Manzano (2018) found a positive correlation between students' digital competence and their access to new technology outside school, partly attributable to families' financial status. Thus, students living in different environments develop different levels of digital competency.

## 3. Method

### 3.1 Instrumentation

This study employed a digital competence measurement instrument adapted from the framework developed by Tzafilkou et al. (2022), originally comprising 28 items measured on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Prior to the adaptation process, all items were translated into Indonesian. The translated version was subsequently reviewed by both a language expert and an educational technology specialist to ensure clarity, accuracy, and contextual appropriateness.

Based on the experts' evaluations, several adjustments were made to tailor the instrument to the context of Indonesian senior high school students. These adjustments included not only the removal of certain items but also the addition of new ones that better reflect the digital practices and realities of the target population. The response scale was also modified to a four-point Likert scale (ranging from 1 = Strongly Disagree to 4 = Strongly Agree) to eliminate the neutral midpoint and encourage more definitive responses.

In terms of content adjustments, the entire domain of "Develop, Apply, Modify" was excluded from the final instrument. This decision was made due to the nature of the items, which assess proficiency in statistical analysis software such as SPSS or R—tools that are typically not introduced at the high school level in Indonesia. Similarly, items within the "Communicate, Collaborate, Share" domain that referred to teaching through e-seminars or e-courses were also removed, as such activities are not part of the instructional experience of Indonesian high school students. To enhance the instrument's contextual relevance, four additional items were developed and incorporated to capture students' digital communication behaviors and interactions across various social media platforms.

Despite these modifications, the adapted instrument preserves the core structure of the original framework, encompassing key domains of digital competence including information search and access, content development and modification, communication and collaboration, data management, critical evaluation, and digital safety and protection. The complete version of the final instrument is provided in the Appendix.

To ensure the psychometric robustness of the instrument, item analysis and reliability testing were conducted. The corrected item-total correlations ranged from 0.57 to 0.78, indicating strong alignment of each item with the overall construct. Internal consistency was confirmed by a Cronbach's alpha of 0.966 and a standardized alpha of 0.967, both of which demonstrate excellent reliability. These results suggest that the instrument is both psychometrically sound and contextually appropriate for assessing digital competence among Indonesian high school students.

### 3.2 Respondents

The study sampled students from six Higher Secondary and Higher Teaching Schools in Surakarta, Central Java, Indonesia, using convenience sampling techniques. An online questionnaire, prioritizing confidentiality and informed consent, was administered to gather responses. Respondents consented to provide their biodata and responses, and the initial presentation of the study includes the identity of respondents. The researchers then distributed the questionnaire personally among the participants. A total of 251 participants provided their feedback on digital competence, with researchers ensuring accurate completion of the questionnaires.

### 3.3 Data Collection and Analysis

The collected data were entered into a Microsoft Excel file and analyzed using the Rasch Model via Winsteps software version 5.7.3.0. This phase involved instrument validation and reliability analysis, as well as simultaneous testing of person and item compatibility. Instrument validation was assessed based on the Outfit Mean Square (MNSQ) value (acceptable range: 0.5 < MNSQ < 1.5), Outfit Z-Standard (ZSTD) value (acceptable range: -2.0 < ZSTD < +2.0) and Point Measure Correlation (Pt Mean Corr) (acceptable range: 0.4 < Pt Mean Corr < 0.85) (Sumintono & Widhiarso, 2014). Consistent with Widhiarso and Sumintono (2016), items and persons that fit the model indicate no respondents deviated significantly from the response patterns of others. The analysis included all student responses, with no missing data. The demographic profile of the students is shown in Table 1.

Table 1 - Respondent's demographic profile.

| *Characteristics Demographic* | *Students % (n = 251)* |
|---|---|
| Sex | |
| Male | 44.2% (111) |
| Female | 55.8% (140) |
| School | |
| SMA Batik 1 Surakarta | 40.6% (102) |
| SMA Batik 2 Surakarta | 18.3% (46) |
| SMK Batik 2 Surakarta | 14.7% (37) |
| SMA Muhammadiyah 1 Surakarta | 18.3% (46) |
| SMA Muhammadiyah PK Surakarta | 8.0% (20) |
| SMA Batik 1 Surakarta | 40.6% (102) |
| Class | |
| XII IPA (Natural Science Class) | 52.6% (132) |
| XII IPS (Social Science Class) | 30.7% (77) |
| XII MM (Multimedia) | 2.0% (5) |
| XII OTKP (Office and Management) | 7.2% (18) |
| XII TKKR (Beauty and Body Care) | 7.6% (19) |

| *Characteristics Demographic* | *Students % (n = 251)* |
|---|---|
| Parent Educational Level | |
| Elementary School | 5.2% (13) |
| Junior High School | 9.2% (23) |
| Senior High School | 53% (133) |
| Bachelor | 25.5% (64) |
| Master | 6% (15) |
| Doctorate | 1.2% (3) |
| Parents' Occupation | |
| Teacher | 6.8% (17) |
| Entrepreneur | 33.9% (85) |
| Military/Policeman | 2.8% (7) |
| Civil Servant | 3.2% (8) |
| Fishery/Farmer | 1.2% (3) |
| Labor | 12.7% (32) |
| Other(s) | 39.4% (99) |
| Length of Internet Usage in a Day (in Hours) | |
| 1-3 (Low) | 8% (20) |
| 4-6 (Medium) | 26,7% (67) |
| 7-9 (Medium High) | 28,3% (71) |
| > 9 (High) | 37,1% (93) |
| Gadgets Used | |
| Smartphone | 66,5% (167) |
| Tablet | 0,4% (1) |
| Laptop | 0,4% (1) |
| Desktop/PC | 0,4% (1) |
| Smartphone, Tablet | 2% (5) |
| Smartphone, Laptop | 23,1% (58) |
| Smartphone, Dekstop/PC | 1,6% (4) |
| Laptop, Dekstop/PC | 0,4% (1) |
| Smartphone, Laptop, Dekstop | 3,2% (8) |
| Smartphone, Tablet, Laptop | 2% (5) |
| Internet Budged per Month | |
| IDR10.000-25.000 | 9,2% (23) |
| IDR26.000-50.000 | 25,1% (63) |
| IDR51.000-75.000 | 31,1% (78) |
| > IDR75.000 | 34,7% (87) |

3.4 Validity and Reliability

In this study, validity and reliability were assessed using Rasch Model analysis via Winsteps software version 5.7.3.0. The Rasch model was selected due to its capability to calibrate the difficulty level of items and the abilities of respondents, as well as to identify matching items and measure respondents' knowledge creation levels. This model enables researchers to more accurately predict respondents' answers to items that conform to the measurement model, based on the person's ability and the item's difficulty level. These benefits are crucial in the application of the Rasch model (Bond & Fox, 2007a; Boone et al., 2014b; Engelhard, 2013; Linarce, 2012; Sumintono & Widhiarso, 2014a; Wirth et al., 2016). Furthermore, the Rasch model analysis produces more precise results, aiding in maintaining respondents' consistency with the questionnaire (person fit statistic). The measurements are derived using a logarithmic function, resulting in either an interval scale or a unit scale (logit), which allows for a calibration measurement model that establishes the relationship between item difficulty and respondent ability. Consequently, this study employed Wright maps to evaluate individuals and items, assessing the quality of the 30 items measuring students' digital proficiency and the responses of 251 participants. The measurement of items was centralized at zero, enabling students to "float" and calibrate their levels of digital competence. The internal quality of the instrument, including digital competence and psychometric properties, was determined by referencing the statistical fit score or reliability index in logit size, as shown in Table 2.

**Table 2** - Summary Statistics of Person and Items.

| *Psychometric Properties* | *Person* | *Item* |
|---|---|---|
| *N* | 251 | 30 |
| *Outfit mean square* | 1.07 | 1.05 |
| Mean | 0.88 | 0.00 |
| SD | 1.40 | 0.53 |
| Separation | 3.55 | 5.26 |
| Reliability | 0.97 | 0.97 |
| Alpha Cronbach | 0.95 | |
| Chi-square ($\chi^2$) | 14449.3303 | |
| Raw Variance Explain by Measure<br>$p < 0.0001$ | 44.7% | |

According to Table 2, the person reliability index of 0.96 indicates that the consistency of student responses is classified as 'very good' (Sumintono & Widhiarso, 2014). Similarly, the item reliability index of 0.96 falls into the "exceptionally good" category (Sumintono & Widhiarso, 2014), demonstrating that both the items and responses exhibit 'very good' reliability. Additionally, the Alpha Cronbach coefficient of 0.97 (see Table 2) signifies a high level of interaction between the 251 students and the 30 items, categorizing the coefficient as 'very good'. Bond and Fox (2007) assert that a reliable instrument should have high psychometric internal consistency, reflecting "very good" reliability. Consequently, the Digital Competence (DigComp) tool is deemed reliable across various respondent groups. Furthermore, Fisher (2007) highlighted that instrument reliability can also be assessed through one-dimensional scores of raw variance explained by the Measure, which should exceed the 40% standard. The Raw Variation Explained by Measures score of 46.1% indicates that the Digital Competence (DigComp) instrument effectively measures students' digital competence levels. Boone et al. (2014) and Engelhard (2013) noted that the effectiveness of an instrument can be evaluated by examining the outfit mean square values for both person scores and items, with values close to 1.0 being ideal. They also emphasized that a significant chi-square score, as a standard for evaluation, demonstrates that the data align well with the model.

The subsequent analysis involved evaluating the separation index to estimate the effectiveness and quality of the Digital Competence Instrument (DigComp). This phase aimed to differentiate between "personal abilities" and latent variables using the separation index score. A higher separation index indicates a greater ability to distinguish between respondents based on their correct responses, reflecting the range of item difficulty from accessible to complex. In addition to categorizing items, the spread analysis also determines the fit of items, where a broader item spread suggests better item matching. A separation score equal to or greater than three indicates a well-fitting model (Boone et al., 2014; Fisher, 2007). The separation index scores presented in Table 2 show that both the person separation index (4.93) and the item separation index (5.01) are reliable and effectively distributed across respondents and items, meeting the fit model criteria and accurately identifying students' levels of digital competence.

Given these findings, the Rasch measurement model was deemed appropriate for data analysis, as it effectively measures latent traits in assessing human perceptions and attitudes. Winsteps version 5.7.3.0 was utilized to evaluate students' digital competence levels based on demographic characteristics, including gender, class type, parental education level, and daily internet usage, using descriptive statistics (mean and standard deviation), item logit values, and person logit values. A positive logit value for a person indicates that the student's digital competence perception is higher than the average item difficulty. Thus, a higher logit score reflects a greater level of digital competence among students.

## 4. Results

### 4.1 Introduction Respondent demographics affect student digital competence

According to Table 3, the mean person measure (logit) is +0.88 with a standard deviation (SD) of +1.40. This indicates that, on average, students possess a strong knowledge and understanding of technology and the Internet, as the average logit measure of +0.88 (SD = +1.40) is above zero. The data reveal variations in the levels of digital competence among students, as illustrated in the subsequent display.

Figure 1 illustrates the variations in digital competence levels among students based on gender. The analysis revealed significant differences in digital competence across 24 of the 30 identified items, including S1, S2, S3, S4, S5, M1, M3, M4, M5, B3, B4, B5, Ev1, Ev2, Ev3, Ev4, Ev5, D1, D2, D5, P1, P2, P3, and P4. Specifically, items S5, Ev3, D2, M3, B3, P1, and P4 indicated that male students generally exhibited higher levels of digital competence compared to female students, particularly in aspects related to data protection. Conversely, female students demonstrated greater proficiency in managing, operating, and evaluating technology. For other items, such as B1, B2, and D3, there were no significant differences in digital competence between genders.

**Table 3** - Results of Student's Digital Competence.

| *Descriptive Statistics* | *Person* | *Item* |
|---|---|---|
| *N* | 251 | 30 |
| *Measure* | | |
| Mean | 0.88 | 0.00 |
| SD | 1.40 | 0.53 |
| Standard Error | 0.09 | 0.10 |

Furthermore, Figure 2 presents the distribution of person scores based on digital competence levels categorized into "strong," "moderate," and "weak" as visualized on the Wright map. The map shows that individuals, both female and male, are distributed across the categories, with those in the 'weak' category having logit scores < +0.88, and those in the 'strong' category having logit scores > +1.40. Both gender groups are evenly represented across the three clusters.

Overall, significant differences among student majors do not indicate a dominant pattern in digital competence. For instance, students majoring in Automation of Office Management (AOM) exhibit higher levels of digital competence in data protection, as evidenced by items P1, P3, P4, B2, and S2. Conversely, Social Science majors demonstrate superior proficiency in technology use and internet communication, particularly in evaluating websites, as indicated by items B3, D2, and Ev3. Students majoring in Natural Sciences show an advantage in searching for visible data, as reflected in items S4 and S5. Additionally, the Multi-Media (MM) major achieved the highest scores across items B1, B4, B5, B6, Ev1, Ev2, Ev4, Ev5, D3, D4, D5, S1, S3, M1, and M5, indicating they possess balanced capabilities across all dimensions. Figure 4 reveals that the distribution of students in Natural Science and Social Science majors spans across the strong, moderate, and weak clusters, with only a few students in the Skin and Hair Beautification major classified in the strong cluster. Notably, no students from the Multi-Media and Automation of Office Management majors fall into the strong level category; these majors only reach the medium category.

Figure 5 presents that most items exhibit significant differences across educational levels, with twenty items showing notable variation. Specifically, significant differences were observed for items B1, B2, B5, B6, D1, D2, D3, D4, D5, Ev1, Ev3, Ev4, M3, M5, P1, P3, S2, S4, and S5. Among these, students whose parents have only completed elementary school demonstrate the highest levels of digital competence across sixteen items. In contrast, students whose parents hold doctoral degrees scored highest on eleven items. Students with parents who have completed master's, junior high school, bachelor's, and senior high school education followed in subsequent rankings.

The data also reveal that students with parents having primary or junior high school education tend to exhibit greater proficiency in personal data protection, as indicated by items P1, P2, P3, and P4. Conversely, students with parents holding advanced degrees, such as doctoral or master's, show a more balanced distribution of competence across various aspects. The results of the DIF analysis align with the distribution of student responses across items, as depicted in Figure 5. The Wright map further illustrates the levels of digital competence among students based on parental education, showing that students with parents who have only completed high school or bachelor's degrees are in the most vulnerable category of digital competence (see Figure 6).

Figure 7 shows variations in digital competence levels based on students' daily Internet usage. Students with low Internet usage (1-3 hours per day) primarily engage in online tasks and hobbies, as indicated by items D1, D2, M1, M4, B3, B6, and S3. Those in the Medium category (4-6 hours per day) use the Internet mainly for simple productivity activities, such as searching for information and using office applications. Students in the Medium-High category (7-9 hours per day) exhibit significant self-protection behaviors, as demonstrated by differences in items P2, P3, P4, and Ev3. The digital competence of students in the High category (more than 9 hours per day) is evenly distributed across various aspects, with this group showing proficiency in most activities across all subcategories of digital competence, including items B1, Ev2, Ev4, M2, M5, S5, and D3, D4. This suggests that extensive Internet use in this group is associated with communication, productivity, copyright management, and personal data management.

Furthermore, the distribution of digital competence levels among students, based on Internet usage frequency, is depicted in the Wright map (Figure 8). This map categorizes students into “strong”, “moderate”, and “weak” groups based on their logit scores. The “weak” category is represented at the bottom right of the map with logit scores < +0.88, while the “strong” category is shown at the top right with logit scores > +1.40.

## 4. Discussion

In our research, we discovered notable differences in digital competence between male and female students. Specifically, male students rated themselves higher in areas like data protection, aligning with findings by Grande-de-Prado et al. (2020) that men often perceive themselves as more competent with ICTs. On the other hand, female students excelled in management, operational, and evaluation aspects of technology use. This observation is consistent with Huatay et al. (2023), who found that females in Peru had higher competence in online safety and technical problem-solving. The ICILS study (Gebhardt et al., 2019) also supports our findings, revealing that female students performed better in tasks related to communication, design, and creativity, whereas male students excelled in technical and security-related tasks. Cabezas González and Casillas Martín (2018) further reinforces this pattern, noting that male students scored higher in ICT familiarity, while females assessed themselves more positively in their attitudes towards ICT. These consistent results across various studies highlight the complex nature of gender differences in digital competence (Bachmann & Hertweck, 2023; Khoo et al., 2023; Zhao et al., 2021).

Parents play a crucial role in shaping their children’s digital competence, serving as significant learning agents alongside family and friends (Antolín et al., 2018; Martínez-Piñeiro et al., 2018). They influence how children use and access technologies within the home, mediating their learning and development of digital skills (Antolín et al., 2018). The educational background and perceptions of parents determine the technologies available to their children, impacting how they guide them in using digital tools (Dias et al., 2016). Additionally, family economics and cultural backgrounds influence the level of digital knowledge and skills students possess Casillas-Martín et al. (2022). Our research found that students with parents who have primary or junior high school education levels tend to have a stronger awareness of personal data protection. On the other hand, students whose parents hold advanced degrees, such as doctorates and masters, display a more balanced and significant digital competence across various areas. This aligns with Pons-Salvador et al. (2022)**,** who noted that more educated parents often have better digital skills, which positively influences their children’s internet use.

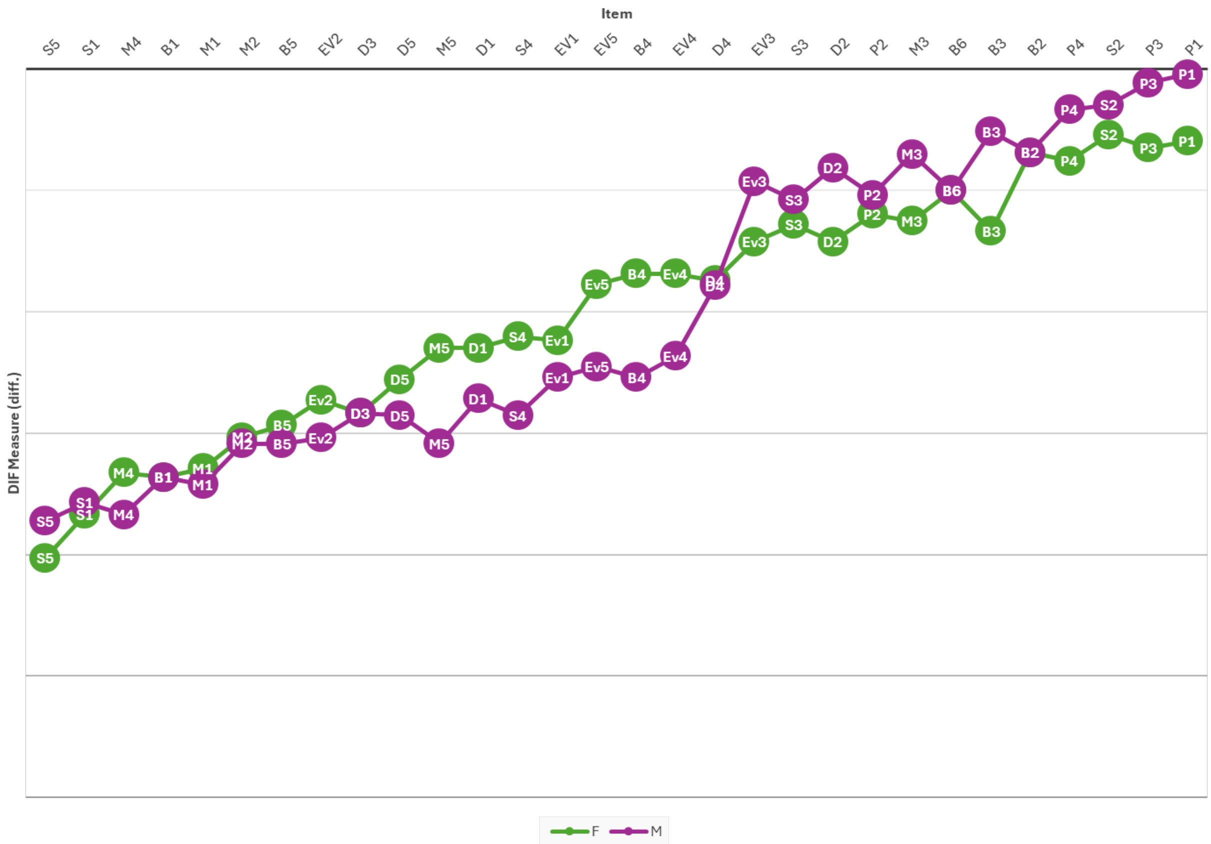

**Figure 1** - Person DIF plot based on Gender. Noted: M: Male; F: Female.

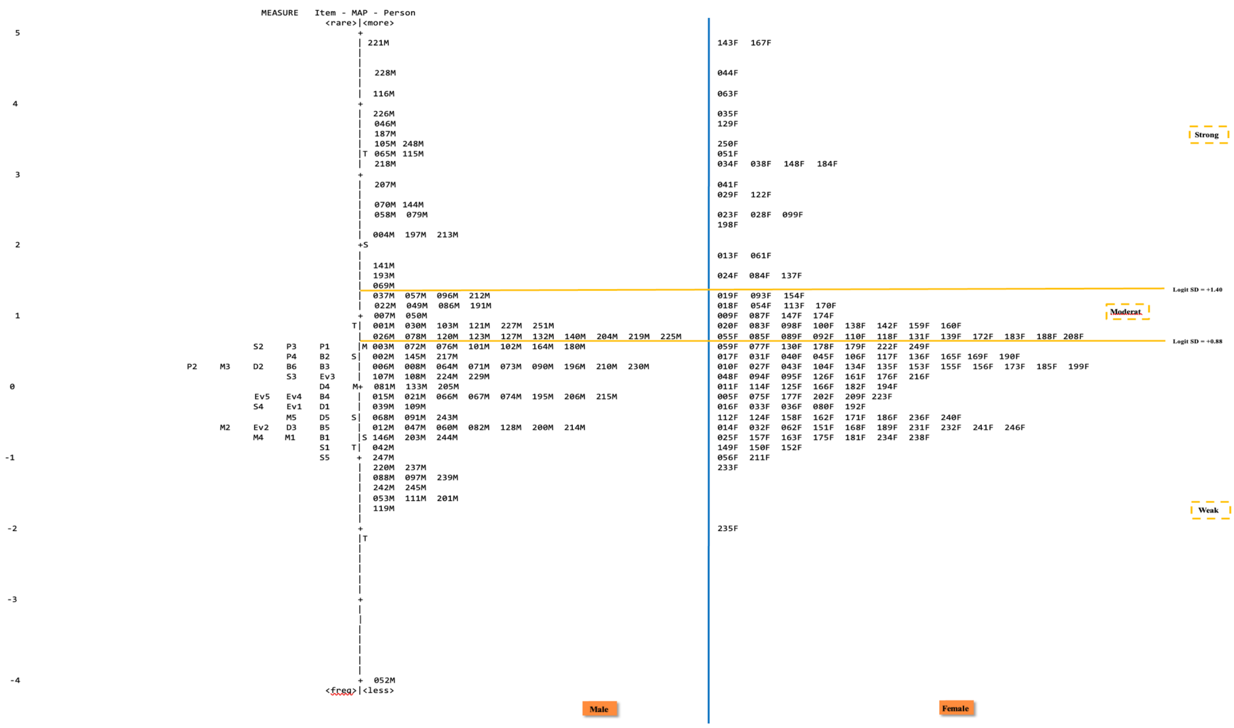

**Figure 2** - Rasch Wright Person Logit Map of Digital Competence based on Gender.

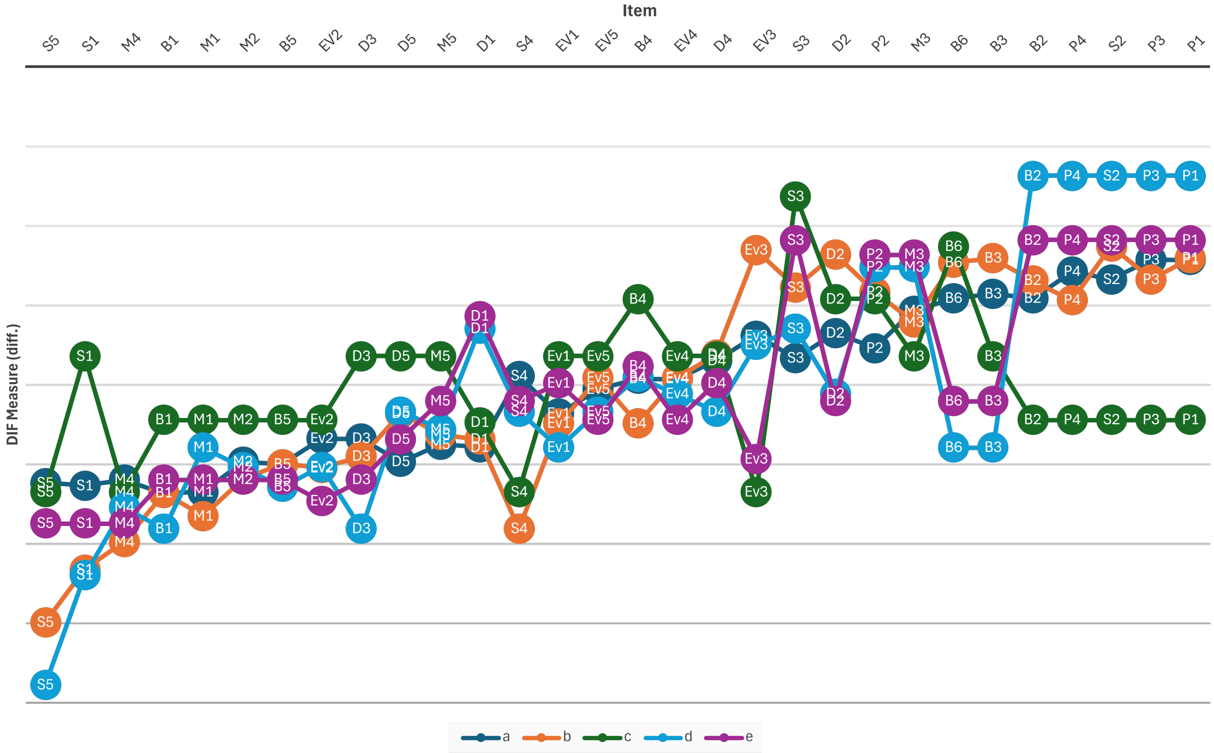


**Figure 3** - Person DIF based on Class/Students Major. Noted: a: XII Natural Science (NS), b: XII Social Science (SS), c: XII Multi-Media (MM), d: XII Automation of Office Management (AOM).

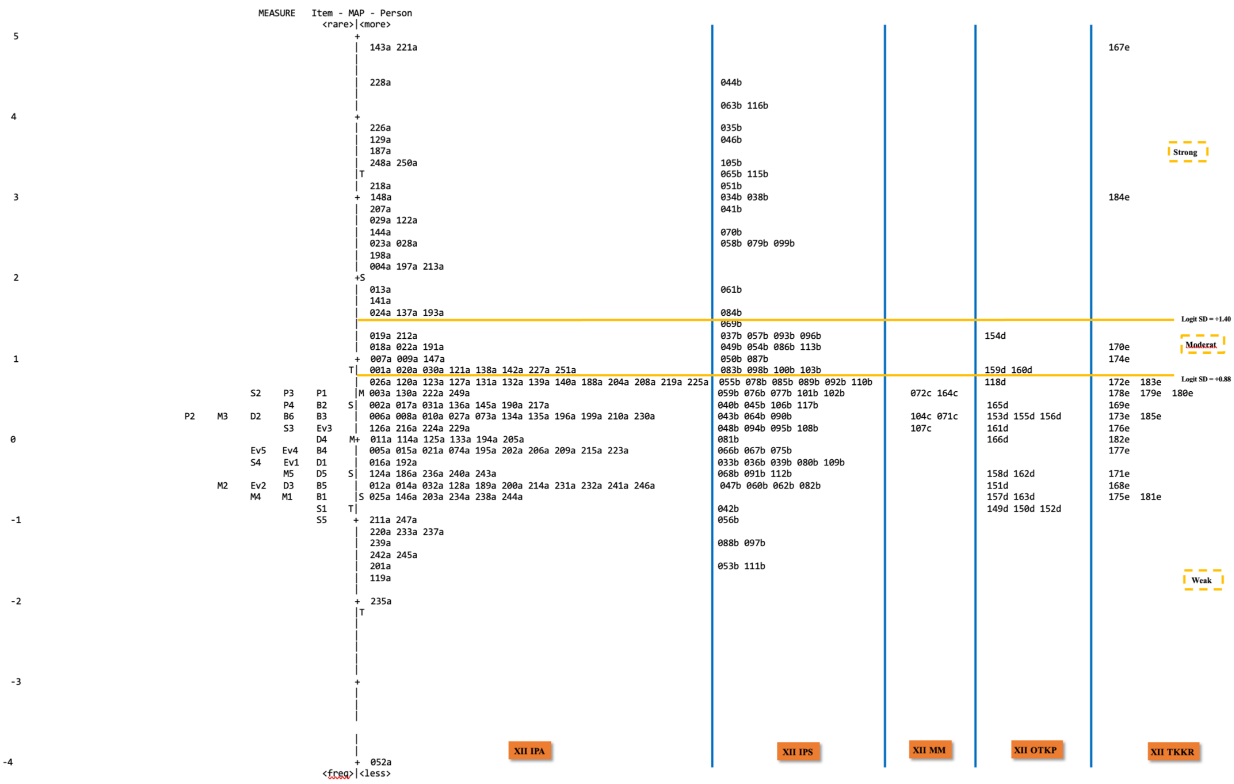


**Figure 4** - Rasch Wright Person Logit Map of Digital Competence based on Class/Students Major.

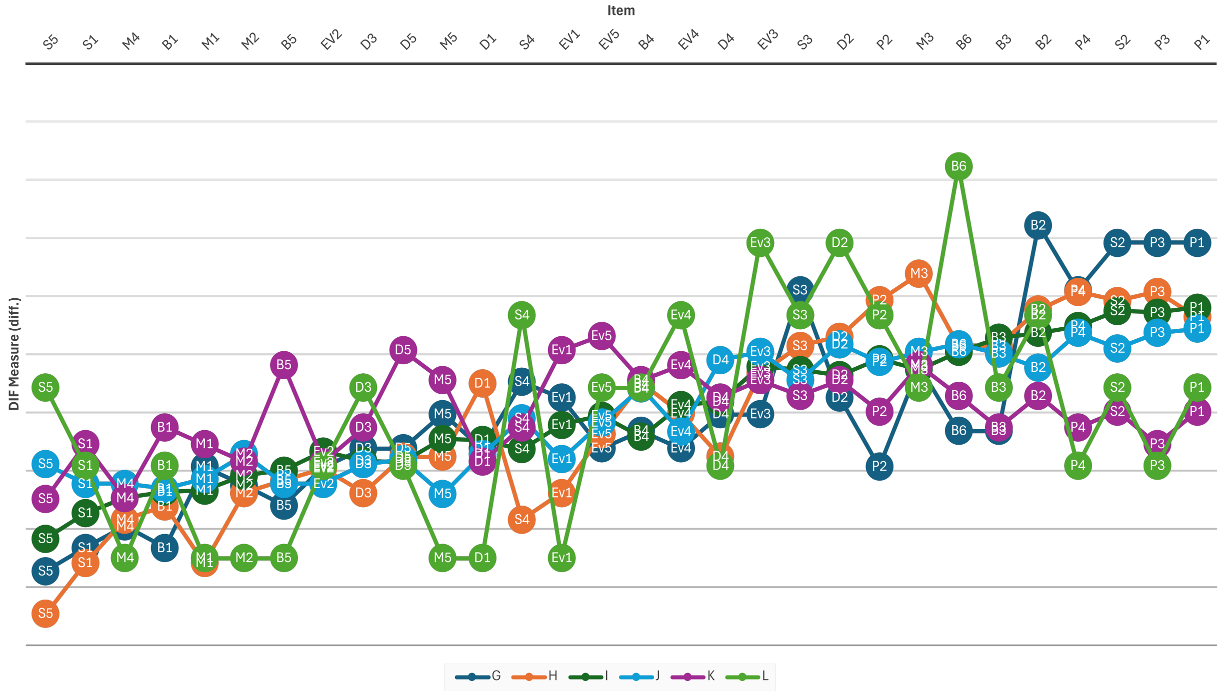


**Figure 5** - Person DIF based on Parents Education Level. Noted: G: Elementary School, H: Junior High School, I: Senior High School, J: Bachelor, K: Master, L: Doctorate.

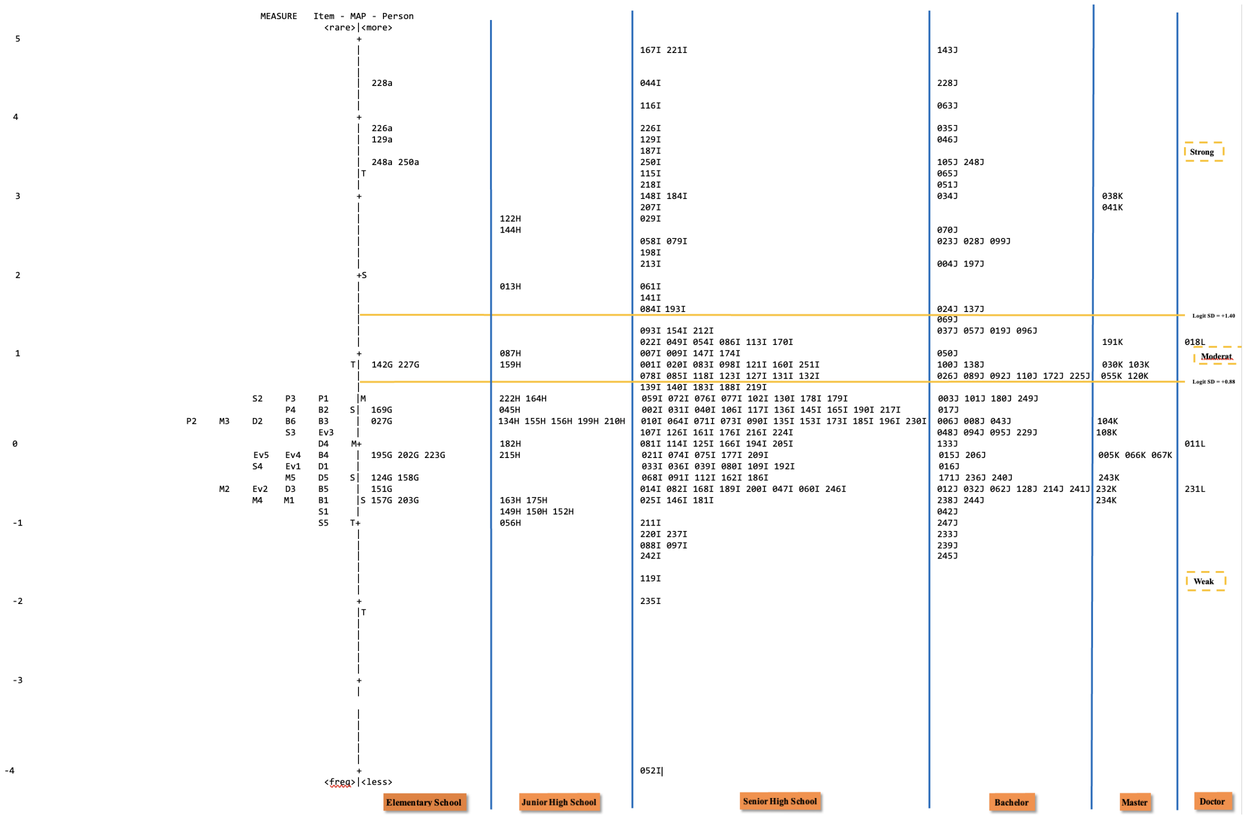


**Figure 6** - Rasch Wright Person Logit Map of Digital Competence based on Parents Education Level.

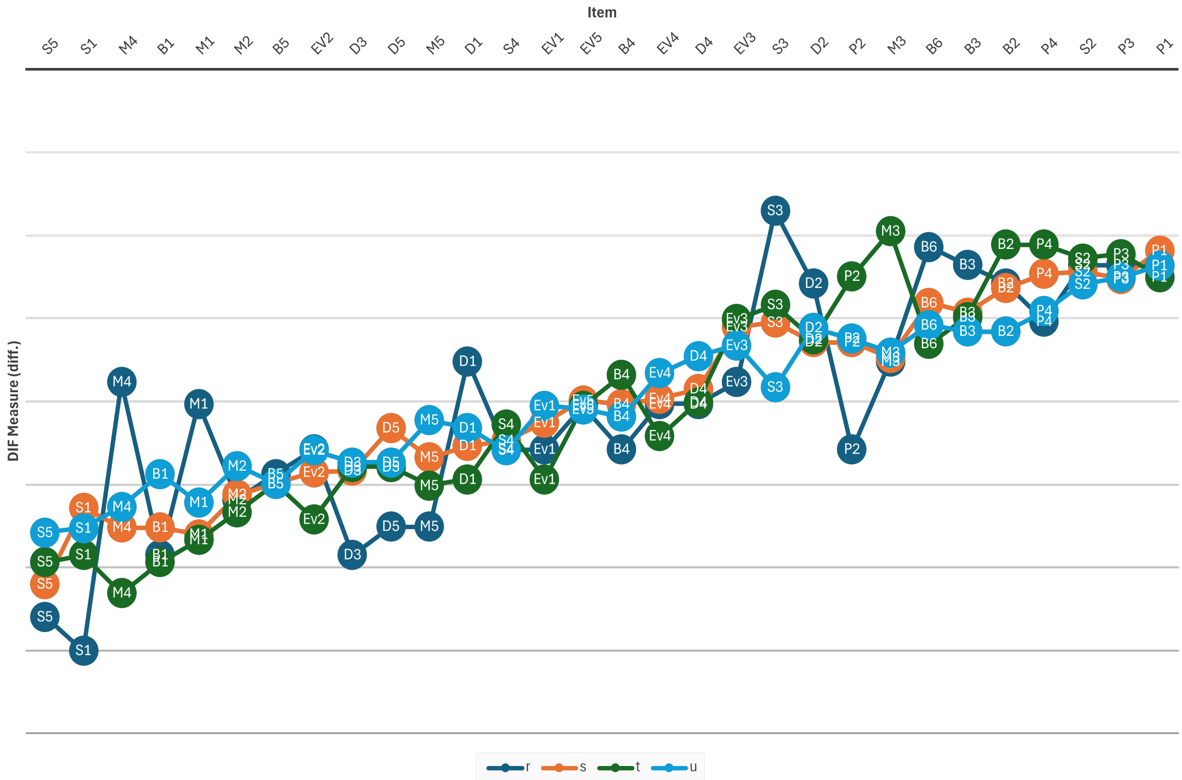


**Figure 7** - Person DIF based on Frequency Using Internet. Noted: r: Low, s: Medium, T: Medium High, u: High.

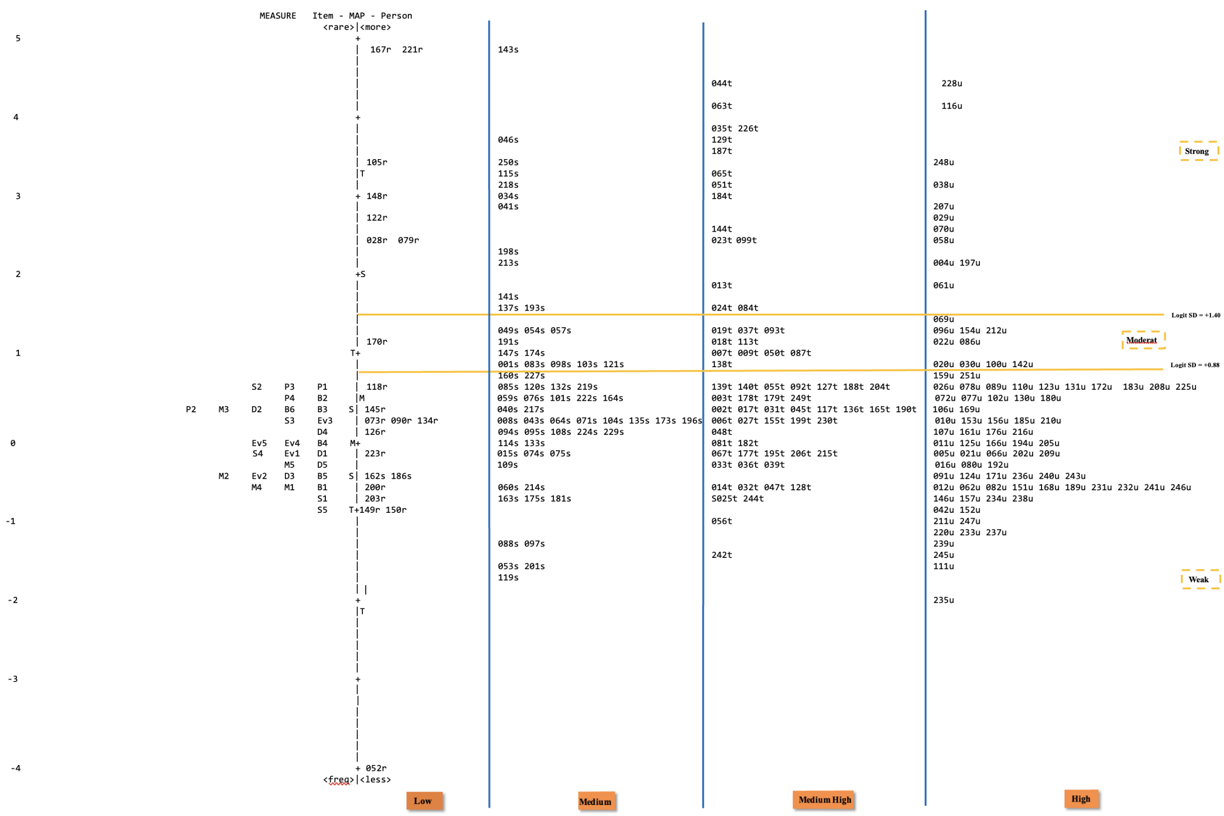


**Figure 8** - Rasch Wright Person Logit Map of Digital Competence based on Frekuensi Using Internet.

Similarly, Guillén-Gámez et al. (2024) found that parents with higher academic backgrounds enhance their children's digital skills and self-confidence, mirroring our findings of a more evenly distributed digital competence among these students.

Our research reveals that students with low internet usage tend to limit their online activities to assignments and hobbies. In contrast, those in the medium category use the internet for simple productivity tasks like googling and office applications. When looking at students who use the internet for 7-9 hours a day (Medium High category), there is a noticeable trend towards taking steps to protect personal data. Furthermore, students with very high internet usage (more than 9 hours per day) show a balanced distribution of digital competence across various activities, including communication, productivity, copyright management, and personal data protection. These findings align with Sutormina (2024)'s research, which found that increased internet use is linked to better digital competence, especially when the internet is used for educational purposes like modeling experiments and participating in online competitions. Additionally, Perifanou et al. (2021)'s study supports our findings by demonstrating a strong positive association between frequent YouTube use and improved digital skills, particularly in content evaluation and data protection.

However, it's important to consider the potential downsides of high internet usage. Müller and Scherer (2022) found that excessive internet use is associated with higher rates of internalizing symptoms, cognitive distortions, and internet use disorders among adolescents. This suggests that while high internet usage can enhance digital competence, it also poses risks to mental health. Our findings highlight the need for a balanced approach to internet use. Educational programs should aim to maximize the benefits of internet use for developing digital competence while also teaching students about the potential risks and promoting healthy online habits. By doing so, we can help students develop comprehensive digital skills and protect their well-being.

## 5. Conclusion

Our research provides valuable insights into the nuanced nature of digital competence among students, particularly in relation to gender differences, parental education, and internet usage. We found that male and female students exhibit different strengths in digital skills, suggesting that educational strategies should be tailored to address these disparities. Specifically, enhancing technical training in data protection for female students and improving management and evaluation skills for male students could help bridge the competency gap. Additionally, the educational background of parents contributes to differences in digital competence preferences. Students with parents who have lower educational levels tend to focus more on personal data protection, while those with highly educated parents demonstrate broader digital skills. This emphasizes the need for educational programs to consider these dynamics and provide tailored support to ensure all students develop strong digital skills, regardless of their family background. Moreover, while high internet usage is associated with enhanced digital competence, our findings also indicate potential risks to mental health, such as increased internalizing symptoms and cognitive distortions. Therefore, a balanced approach to internet use is essential. Educational programs should not only promote the benefits of internet use for developing digital skills but also address the potential mental health risks by teaching healthy online habits. By doing so, educators can help students harness the advantages of digital technologies while safeguarding their well-being, ensuring they are well-prepared to navigate the technological demands of the modern world.

## 6. Limitations

The limited number of samples in categories presents challenges in fully understanding the diverse preferences and competencies in internet use and digital tools. This limitation restricts our ability to generalize findings and appreciate the broader spectrum of digital skills. Future research should aim to include larger sample sizes to ensure that the data collected is more varied and representative of the wider student population. Additionally, employing a combination of methodologies—such as experiments, interviews, observations, and comprehension assessments—would provide a richer, more nuanced understanding of the factors influencing digital competence. This multi-faceted approach will not only yield more reliable insights but also enable the development of targeted interventions to enhance digital literacy. By addressing these gaps, future studies can contribute significantly to creating a digitally inclusive educational environment where every student is equipped with the necessary skills to thrive in an increasingly digital world.

## References

Antolín, P. S., Viloria, C. A., & Labra, J. P. (2018). The role of the family in the development of digital competence. Analysis of four cases. Digital Education Review, 34, 44–58.

Association of Indonesia Internet Provider. (2018). *Laporan survei penetrasi & profil perilaku pengguna internet Indonesia 2018 (Penetration survey report & behavior profile of Indonesian internet users 2018)*. https://apjii.or.id/survei2018s

Bachmann, R., & Hertweck, F. (2023). The gender gap in digital literacy: a cohort analysis for Germany. *Applied Economics Letters*, 1–6. https://doi.org/10.1080/13504851.2023.2277685

Bejarano, D. A. A., Garay, J. P. P., Flores-Sotelo, W. S., Francisco, R. L. T., Sáenz, R. A. C., & Ancaya-Martínez, M. D. C. (2021). Self-efficacy and digital competence in university students. *Revista Geintec-Gestao Inovacao e Technologias*, *11*(3), 710–718.

Biggins, D., Holley, D., Evangelinos, G., & Zezulkova, M. (2017). *Digital Competence and Capability Frameworks in the Context of Learning, Self-Development and HE Pedagogy* (pp. 46–53). https://doi.org/10.1007/978-3-319-49625-2_6

Bond, T. G., & Fox, C. M. (2007). *Applying the Rasch Model: Fundamental Measurement in the Human Sciences*. Psychology Press.

Boone, W. J., Staver, J. R., & Yale, M. S. (2014). *Rasch Analysis in the Human Sciences*. Springer Science & Business Media. https://doi.org/10.1007/978-94-007-6857-4

Cabezas González, M., & Casillas Martín, S. (2018). Social Educators: A Study of Digital Competence from a Gender Differences Perspective / Socijalni pedagozi: istraživanje digitalne kompetencije iz perspektive spolnih razlika. *Croatian Journal of Education - Hrvatski Časopis Za Odgoj i Obrazovanje*, *20*(1). https://doi.org/10.15516/cje.v20i1.2632

Carretero, S., Vuorikari, R., & Punie, Y. (2017). *DigComp 2.1 - the Digital Competence Framework for Citizens with Eight Proficiency Levels and Examples of Use*. Publications Office of the European Union. http://svwo.be/sites/default/files/DigComp%202.1.pdf

Casillas-Martín, S., Cabezas-González, M., & Muñoz-Repiso, A. G.-V. (2022). Influence of socio-familial variables on digital competence in communication and collaboration. *Pixel-Bit, Revista de Medios y Educacion*, *63*, 7–33. https://doi.org/https://10.12795/PIXELBIT.84595

Castaño Muñoz, J., Vuorikari, R., Costa, P., Hippe, R., & Kampylis, P. (2023). Teacher collaboration and students' digital competence - evidence from the SELFIE tool. *European Journal of Teacher Education*, *46*(3), 476–497. https://doi.org/10.1080/02619768.2021.1938535

Chea, V., & Chea, P. (2022). Family Background as the Determinant of University Student's Technological Readiness: Evidence from Cambodia. *2022 14th International Conference on Software, Knowledge, Information Management and Applications (SKIMA)*, 322–328. https://doi.org/10.1109/SKIMA57145.2022.10029566

Council of European Union. (2018). *Declaration on Promoting Citizenship and the Common Values of Freedom, Tolerance and Non-Discrimination through Education*. Eurydice. https://ec.europa.eu/assets/eac/education/news/2015/documents/citizenship-education-declaration_en.pdf

Dias, P., Brito, R., Ribbens, W., Daniela, L., Rubene, Z., Dreier, M., Gemo, M., Di Gioia, R., & Chaudron, S. (2016). The role of parents in the engagement of young children with digital technologies: Exploring tensions between rights of access and protection, from 'Gatekeepers' to 'Scaffolders.' *Global Studies of Childhood*, *6*(4), 414–427. https://doi.org/10.1177/2043610616676024

Engelhard, G. (2013). Invariant measurement: Using rasch models in the social, behavioral, and health sciences. *Invariant Measurement: Using Rasch Models in the Social, Behavioral, and Health Sciences*, 1–288. https://doi.org/10.4324/9780203073636/INVARIANT-MEASUREMENT-GEORGE-ENGELHARD-JR

Esteve-Mon, F. M., Postigo-Fuentes, A. Y., & Castañeda, L. (2023). A strategic approach of the crucial elements for the implementation of digital tools and processes in higher education. *Higher Education Quarterly*, *77*(3), 558–573. https://doi.org/10.1111/hequ.12411

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and*

*Development*, *68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Fernández-Mellizo, M., & Manzano, D. (2018). Analyzing differences in digital competence of Spanish students. *Papers. Revista de Sociologia*, *103*(2), 175. https://doi.org/10.5565/rev/papers.2369

Ferrari, A. (2012). *Digital competence in practice: An analysis of frameworks* (Vol. 10). http://www.ifap.ru/library/book522.pdf

Fisher, W. P. (2007). Rating Scale Instrument Quality Criteria. *Rasch Measurement Transactions*, *21*(1), 1095.

Flores-Lueg, C., & Roig-Vila, R. (2019). Personal factors influencing future teachers' self-assessment about the pedagogical dimension of ICT use. *Revista Iberoamericana de Educación Superior*, 151–171. https://doi.org/10.22201/iisue.20072872e.2019.27.345

Gayatri, G., Rusadi, U., Meininhsih, S., Mahmudah, D., Sari, D., Kautsarina, Karman, & Nugroho, A. C. (2014). Digital citizenship safety among children and adolescents in Indonesia. *Jurnal Penelitian Dan Pengembangan Komunikasi Dan Informatika*, *6*(1), 1–16.

Gebhardt, E., Thomson, S., Ainley, J., & Hillman, K. (2019). *Student Achievement and Beliefs Related to Computer and Information Literacy* (pp. 21–31). https://doi.org/10.1007/978-3-030-26203-7_3

Grande-de-Prado, M., Cañón, R., García-Martín, S., & Cantón, I. (2020). Digital Competence and Gender: Teachers in Training. A Case Study. *Future Internet*, *12*(11), 204. https://doi.org/10.3390/fi12110204

Grande-de-Prado, M., Cañón-Rodríguez, R., García-Martin, S., & Cantón-Mayo, I. (2021). Digital competence: Teachers in training and troubleshooting. *Educar*, *57*(2), 381–396. https://doi.org/10.5565/rev/educar.1159

Guillén-Gámez, F. D., Colomo-Magaña, E., Cívico-Ariza, A., & Linde-Valenzuela, T. (2024). Which is the Digital Competence of Each Member of Educational Community to Use the Computer? Which Predictors Have a Greater Influence? *Technology, Knowledge and Learning*, *29*(1), 1–20. https://doi.org/10.1007/s10758-023-09646-w

Guitert, M., Romeu, T., & Baztán, P. (2021). The digital competence framework for primary and secondary schools in Europe. *European Journal of Education*, *56*(1), 133–149. https://doi.org/10.1111/ejed.12430

Hatlevik, O. E., Gudmundsdóttir, G. B., & Loi, M. (2015). Examining factors predicting students' digital competence. *Journal of Information Technology Education*, *14*(1), 123–137. https://doi.org/10.28945/2126

Hidayat, M. L., Abdurahman, S. G., Astuti, D. S., Prabawati, R., Anif, S., Hariyatmi, H., & Zannah, F. (2025). Pilot Study of Digital Competency Mapping of Indonesian Preservice Teachers: Rasch Model Analysis. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, 100–116. https://doi.org/10.23917/ijolae.v7i1.23935

Huatay, K. C. V., Mendoza, A. P. M., Rodriguez, J. C. F., & Ninaquispe, J. C. M. (2023). Digital Literacy in Basic Secondary School Students: A Gender Comparative Study. *2023 IEEE 3rd International Conference on Advanced Learning Technologies on Education & Research (ICALTER)*, 1–4. https://doi.org/10.1109/ICALTER61411.2023.10372931

Ilomäki, L., Paavola, S., Lakkala, M., & Kantosalo, A. (2016). Digital competence – an emergent boundary concept for policy and educational research. *Education and Information Technologies*, *21*(3), 655–679. https://doi.org/10.1007/s10639-014-9346-4

Jeong, D. W., Moon, H., Jeong, S. M., & Moon, C. J. (2024). Digital capital accumulation in schools, teachers, and students and academic achievement: Cross-country evidence from the PISA 2018. *International Journal of Educational Development*, *107*, 103024. https://doi.org/10.1016/j.ijedudev.2024.103024

Juárez Arall, J., & Marqués Molías, L. (2019). Digital competence aspects for employability. *REOP - Revista Española de Orientación y Psicopedagogía*, *30*(2), 67. https://doi.org/10.5944/reop.vol.30.num.2.2019.25339

Khoo, C., Yang, E. C. L., Tan, R. Y. Y., Alonso-Vazquez, M., Ricaurte-Quijano, C., Pécot, M., & Barahona-Canales, D. (2023). Opportunities and challenges of digital competencies for women tourism entrepreneurs in Latin America: a gendered perspective. *Journal of Sustainable*

*Tourism*, 1–21. https://doi.org/10.1080/09669582.2023.2189622

Kjällander, S., Mannila, L., Åkerfeldt, A., & Heintz, F. (2021). Elementary Students' First Approach to Computational Thinking and Programming. *Education Sciences*, *11*(2), 80. https://doi.org/10.3390/educsci11020080

Kuka, L., Hörmann, C., & Sabitzer, B. (2022). *Teaching and Learning with AI in Higher Education: A Scoping Review* (pp. 551–571). https://doi.org/10.1007/978-3-031-04286-7_26

Linarce, J. M. (2012). A user's guide to Winsteps Ministeps Rasch Model (Version 3.74.0. *Chicago IL: Winstep. Com*.

Luo, W., Berson, I. R., & Berson, M. J. (2021). Integration of Digital Technology into an Early Childhood Teacher Preparation Program in China. *Early Childhood Education Journal*, *49*(6), 1165–1175. https://doi.org/10.1007/s10643-020-01115-8

Martínez-Piñeiro, E., Couñago, E. V., & Barujel, A. G. (2018). The role of the family in building digital competence. *RISTI - Revista Ibérica de Sistemas e Tecnologias de Informação*, *28*, 1–13. https://doi.org/10.17013/risti.28.1-13

Martzoukou, K., Kostagiolas, P., Lavranos, C., Lauterbach, T., & Fulton, C. (2022). A study of university law students' self-perceived digital competences. *Journal of Librarianship and Information Science*, *54*(4), 751–769. https://doi.org/10.1177/09610006211048004

McGarr, O., Mifsud, L., & Colomer Rubio, J. C. (2021). Digital competence in teacher education: comparing national policies in Norway, Ireland and Spain. *Learning, Media and Technology*, *46*(4), 483–497. https://doi.org/10.1080/17439884.2021.1913182

Mendoza-Chan, J., & Pee, L. G. (2024). Digital skilling of working adults: A systematic review. *Computers & Education*, *218*, 105076. https://doi.org/10.1016/j.compedu.2024.105076

Müller, K. W., & Scherer, L. (2022). Excessive Use Patterns and Internet Use Disorders: Effects on Psychosocial and Cognitive Development in Adolescence. *Praxis Der Kinderpsychologie Und Kinderpsychiatrie*, *71*(4), 345–361. https://doi.org/10.13109/prkk.2022.71.4.345

Murphy, B., & Feeney, O. (2023). *AI, Data Analytics and the Professions* (pp. 35–51). https://doi.org/10.1007/978-3-031-31494-0_3

Nguyen, T. Q., Ngoc, P. T. A., Phuong, H. A., Duy, D. P. T., Hiep, P. C., McClelland, R., & Noroozi, O. (2024). Digital competence of Vietnamese citizens: An application of digcomp framework and the role of individual factors. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-12585-3

Padilla-Carmona, M. T., Suárez-Ortega, M., & Sánchez-García, M. F. (2016). Digital inclusion of mature students: Analysis of their attitudes and ICT competences. *Revista Complutense de Educación*, *27*(3), 1229–1246. https://doi.org/10.5209/rev_RCED.2016.v27.n3.47669

Palomares-Ruiz, A., Cebrián, A., López-Parra, E., & García-Toledano, E. (2020). ICT Integration into Science Education and Its Relationship to the Digital Gender Gap. *Sustainability*, *12*(13), 5286. https://doi.org/10.3390/su12135286

Patwardhan, V., Mallya, J., Shedbalkar, R., Srivastava, S., & Bolar, K. (2023). Students' Digital Competence and Perceived Learning: The mediating role of Learner Agility. *F1000Research*, *11*, 1038. https://doi.org/10.12688/f1000research.124884.2

Perifanou, M., Tzafilkou, K., & Economides, A. A. (2021). The Role of Instagram, Facebook, and YouTube Frequency of Use in University Students' Digital Skills Components. *Education Sciences*, *11*(12), 766. https://doi.org/10.3390/educsci11120766

Pons-Salvador, G., Zubieta-Méndez, X., & Frias-Navarro, D. (2022). Parents' digital competence in guiding and supervising young children's use of the Internet. *European Journal of Communication*, *37*(4), 443–459. https://doi.org/10.1177/02673231211072669

Prasetiyo, W. H., Sari, B. I., Rahmawati, N., & Pambudi, G. (2022). Peningkatan Kompetensi Digital bagi Guru Muhammadiyah dalam Menghadapi Society 5.0. *Warta LPM*, 91–100. https://doi.org/10.23917/warta.v25i1.601

Puspitasari, L., & Ishii, K. (2016). Telematics and Informatics Digital divides and mobile Internet in Indonesia : Impact of smartphones. *Telematics and*

*Informatics*, *33*(2), 472–483. https://doi.org/10.1016/j.tele.2015.11.001

Rodríguez Muñoz, F. J., & Ruiz-Domínguez, M. del M. (2021). The digital competence of secondary school literature teachers in Spain. *Texto Livre: Linguagem e Tecnologia*, *14*(3), e31351. https://doi.org/10.35699/1983-3652.2021.31351

Rudiantara. (2019). *DAMO: Discovery, Adventure, Momentum, dan Outlook di Kominfo Memori Pertanggungjawaban Menteri Komunikasi dan Informatika Republik Indonesia 2014-2019*. Kementerian Komunikasi dan Informatika Republik Indonesia. https://k-cloud.kominfo.go.id/s/DAMOChiefRA#pdfviewer

Sánchez-Canut, S., Usart-Rodríguez, M., Grimalt-Álvaro, C., Martínez-Requejo, S., & Lores-Gómez, B. (2023). Professional Digital Competence: Definition, Frameworks, Measurement, and Gender Differences: A Systematic Literature Review. *Human Behavior and Emerging Technologies*, *2023*, 1–22. https://doi.org/10.1155/2023/8897227

Scholes, L., Rowe, L., Mills, K. A., Gutierrez, A., & Pink, E. (2024). Video gaming and digital competence among elementary school students. *Learning, Media and Technology*, *49*(2), 200–215. https://doi.org/10.1080/17439884.2022.2156537

Shala, A., & Grajcevci, A. (2018). Digital competencies among student populations in Kosovo: the impact of inclusion, socioeconomic status, ethnicity and type of residence. *Education and Information Technologies*, *23*(3), 1203–1218. https://doi.org/10.1007/s10639-017-9657-3

Sumintono, B., & Widhiarso, W. (2014). *Aplikasi Model Rasch : Untuk Penelitian Ilmu-Ilmu Sosial* (B. Trim, Ed.; Revisi). Trim Komunikata Publishing House.

Sutormina, N. V. (2024). Features of digital competence of schoolchildren and students and the specifics of their use of the Internet for educational purposes. *Perspectives of Science and Education*, *67*(1), 640–658. https://doi.org/10.32744/pse.2024.1.36

Syahrin, S., Almashiki, K., & Alzaanin, E. (2023). The Impact of COVID-19 on Digital Competence. *International Journal of Advanced Computer Science and Applications*, *14*(1). https://doi.org/10.14569/IJACSA.2023.0140156

Tzafilkou, K., Perifanou, M., & Economides, A. A. (2022). Development and validation of students' digital competence scale (SDiCoS). *International Journal of Educational Technology in Higher Education*, *19*(1). https://doi.org/10.1186/s41239-022-00330-0

UNESCO. (2018). *A Global Framework of Reference on Digital Literacy and Skills for Indicator 4.4.2*. A Global Framework of Reference on Digital Literacy and Skills for Indicator 4.4.2

Valverde-Berrocoso, J., Fernández-Sánchez, M. R., Revuelta Dominguez, F. I., & Sosa-Díaz, M. J. (2021). The educational integration of digital technologies preCovid-19: Lessons for teacher education. *PLOS ONE*, *16*(8), e0256283. https://doi.org/10.1371/journal.pone.0256283

Verdú-Pina, M., Grimalt-Álvaro, C., Usart, M., & Gisbert-Cervera, M. (2024). The digital competence of teachers and students in secondary education schools. *Edutec. Revista Electrónica de Tecnología Educativa*, *87*, 134–150. https://doi.org/10.21556/edutec.2024.87.3061

Vrcelj, S., Kušić, S., & Mrnjaus, K. (2023). Artificial Intelligence and Education: Rivals or Allies? *JAHR*, *14*(2), 429–445. https://doi.org/10.21860/j.14.2.9

Vuorikari, R., Punie, Y., Carretero Gomez, S., & van Den Brande, G. (2016). *DigComp 2.0: The Digital Competence Framework for Citizens. Update Phase 1: the Conceptual Reference Model*. Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC101254

Widhiarso, W., & Sumintono, B. (2016). Examining response aberrance as a cause of outliers in statistical analysis. *Personality and Individual Differences*, *98*, 11–15. https://doi.org/10.1016/j.paid.2016.03.099

Wirth, R., Houts, C., & Deal, L. (2016). Rasch Modeling With Small Samples: A Review Of The Literature. *Value in Health*, *19*(3), A109. https://doi.org/10.1016/j.jval.2016.03.1841

Zhao, Y., Sánchez Gómez, M. C., Pinto Llorente, A. M., & Zhao, L. (2021). Digital Competence in Higher Education: Students' Perception and Personal Factors. *Sustainability*, *13*(21), 12184. https://doi.org/10.3390/su132112184

# Appendix: Items

| Component | Acronym | Items |
|---|---|---|
| Search, Find, Access | S1 | I can search and find specific or similar things using various search engines (e.g., Google, Yahoo, Bing) |
| | S2 | I can search and find specific people in various digital media using various techniques and filters (e.g., various formats of names, photos, email addresses, schools, companies, etc.) |
| | S3 | I can search and find groups on specific topics (e.g., hobbies, professions, artists, science, historical events, travel destinations) in various social media |
| | S4 | I can navigate in the real-world using navigator features (e.g., Google Maps) |
| | S5 | I can read, listen, and view content in various digital media |
| Develop, Apply, Modify | D1 | I can set event notifications on a specific day using a digital calendar (e.g., Google Calendar, Apple Calendar, Microsoft Outlook Calendar, etc.) |
| | D2 | I can design creatively using various digital media (e.g., Canva, PowerPoint, etc.) |
| | D3 | I can create documents with text, diagrams, tables, and reports using various digital media (e.g., Microsoft Word, Microsoft Excel, etc.) |
| | D4 | I can apply copyright to content or software that I create (e.g., naming a self-made image design) |
| | D5 | I can convert content from one format to another format |
| Communicate, Collaborate, Share | B1 | I can communicate using different digital media |
| | B2 | I can edit documents with each other (collaboratively) using digital media |
| | B3 | I can actively participate in society using digital media |
| | B4 | I can upload and share my applications |
| | B5 | I can collaborate with people using various digital media |
| | B6 | I can share my experiences in digital media in interactions with others (e.g., social media, YouTube, etc.) |
| Store, Manage, Delete | M1 | I can take photos or videos and save them in various formats (mp4, gif, jpg, etc.) |
| | M2 | I can download content and save it directly to the appropriate folder |
| | M3 | I can copy and save screenshots from my phone or laptop |
| | M4 | I can delete some of my connections/friends on various social media |
| | M5 | I can organize files on my computer into an organized folder structure |
| Evaluate | Ev1 | I can evaluate an object and/or smart device using appropriate quality criteria (e.g., authenticity, usefulness, ease of use, appearance, functionality, enjoyment) |
| | Ev2 | I can evaluate whether some information is a hoax, fake, fraudulent, or a scam |
| | Ev3 | I can evaluate whether a website is safe and trustworthy |
| | Ev4 | I can identify copyright and intellectual property rights (IPR) from content I find on the Internet |
| | Ev5 | I can evaluate whether an email is spam, adware, phishing, or a scam |
| Protect | PR1 | I can regularly change my passwords and settings for my social media and Internet accounts |
| | PR2 | I can protect my various Internet accounts with different passwords and change them frequently |
| | PR3 | I can protect my personal data from identity theft, harassment, bullying, or defamation |
| | PR4 | I can use digital technology in a healthy and responsible way |

JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 21, No. 2 (2025), pp. 18-30

# Academic performance in AI Era: salient factors in higher education

Robi Hendra[a], Rasyono Rasyono[b], Akhmad Habibi[a,c,1], Lalu Nurul Yaqin[d], Sarah A Alahmari[e], Turki Mesfer Alharmali[f], Hansein Arif Wijaya[a]

[a]*Fakultas Keguruan dan Ilmu Pendidikan, Universitas Jambi (Indonesia)*

[b]*Fakultas Keguruan dan Ilmu Pendidikan, Universitas Sriwijaya (Indonesia)*

[c] *Graduate School of Education, Korea University, Seongbuk-gu, Seoul (South Korea)*

[d]*Language and Linguistics Programme, Faculty of Arts and Social Sciences, Universiti Brunei Darussalam, Gadong (Brunei Darussalam)*

[e]*Department of Early Childhood, Faculty of Education, King Khalid University (Saudi Arabia)*

[f]*e-Learning Centre and Department of Educational Sciences, College of Arts and Humanities, Jazan University, Jaza (Saudi Arabia)*

*(submitted: 24/8/2025; accepted: 19/8/2025; published: 31/8/2025)*

**Abstract**

This research integrates teacher AI competence (TAC), student learning agility (SLA), and student engagement (SE), as factors affecting student academic performance (SAP). We employed a survey methodology in which the instrument's validation was conducted through content and face validity, as well as a content validity index and measurement model in SmartPLS. A total of 380 lecturers from three universities participated as respondents in this survey study. Partial least squares structural equation modeling (PLS-SEM) procedures were employed for the primary data analysis of the study. The findings informed the validity and reliability of the model, highlighting the important roles of SLA and SA in relation to SAP. In addition, TAC was also correlated with SAP and SLA, while it has no relationship with SA.

**KEYWORDS:** AI Competence; Higher Education; Learning Agility; Engagement; Academic Performance.

**DOI**
https://doi.org/10.20368/1971-8829/1136015

**CITE AS**
Hendra, R., Rasyono, R., Habibi, A., Yaqin, L.N., Alahmari, S.A., Alharmali, T.M., Wijaya, H.A. (2025. Academic performance in AI Era: salient factors in higher education. *Journal of e-Learning and Knowledge Society*, *21*(2), 18-30.
https://doi.org/10.20368/1971-8829/1136015

## 1. Introduction

In recent years, the integration of artificial intelligence (AI) in educational settings has garnered considerable attention for its potential to enhance teaching and learning processes, as well as teacher competence (Guillén-Gámez, Tomczyk, et al., 2024). The emergence of AI has not only transformed the way information is delivered but also redefined the roles of educators and students (Alenezi et al., 2023). As technology continues to evolve, the competence of teachers in utilizing AI tools has become crucial in influencing student outcomes (Dimitriadou & Lanitis, 2023). Teacher AI competence refers to the ability of educators to effectively implement AI-driven methodologies in their instructional practices (Kim, 2024). This competence is not just about familiarity with AI technologies, but also about the ability to leverage these tools to foster a conducive learning environment that meets the diverse needs of learners.

The integration of AI in education has the potential to personalize learning experiences, thereby improving student engagement and enhancing academic achievement (Almusaed et al., 2023; Kim, 2024). However, the effectiveness of AI in education is also dependent on student factors, such as students' learning

[1] corresponding author - email: akhmad.habibi@unja.ac.id

agility, which refers to their ability to adapt and thrive in dynamic learning environments. Learning agility is a critical attribute in the digital age, where the pace of change demands that students be quick learners, able to apply knowledge in novel situations, and continually evolve their skill sets.

This study aims to investigate the intricate relationships between teacher AI competence (TAC), student learning agility (SLA), and student engagement (SE) to student academic performance (SAP) from the perspectives of three Indonesian university lecturers. The existing literature highlights the significant role that teacher competence plays in influencing student outcomes; however, there is a need to explore how specific competencies, such as those related to AI, impact student achievement in technologically advanced learning environments. Furthermore, while student engagement has long been recognized as a critical factor in academic success, understanding how AI-enhanced engagement interacts with students' learning agility to affect academic performance remains an area ripe for exploration.

By examining these interrelationships, this study aims to contribute to the growing body of knowledge on AI in education and offer insights into how educational stakeholders can optimize the use of AI to improve student learning outcomes. Ultimately, the findings of this research can inform policy and practice, guiding the development of teacher training programs and student support initiatives that align with the demands of the AI-driven educational landscape.

## 2. Literature review

In the development of AI, teacher proficiency or competence using the technology has emerged as an essential factor that significantly influences learning agility, engagement, and performance. Nazaretsky et al., (2022) emphasize the influence of AI competence on the development of students' learning agility, revealing a significant correlation between the two variables. Kitcharoen et al., (2024) present a compelling case for ensuring a smooth and effective transition towards integrating advanced technologies into the learning process, thereby promoting the efficient use of technology in education. On the other hand, educational models that prioritize student interaction have also attracted significant attention. (J. Kim, 2024) examined the potential of AI support in enhancing student engagement in a blended learning context, drawing on the theoretical framework of self-determination theory. This implies that, in addition to having AI proficiency, practical strategies and techniques in utilizing AI are also crucial in optimizing student engagement and achievement (J. Kim, 2024; Sun et al., 2024; Wang et al., 2023).

### 2.1 TAC towards SLA, SE and SP

AI expertise has become essential in modern education, influencing learning agility, student engagement, and performance. Teachers need AI skills to effectively apply these technologies in educational settings. Teacher AI competence includes ethical and responsible development, use, and assessment of AI in education (Delcker et al., 2025). Research indicates that teachers' technical, pedagogical, content, and ethical understanding of AI develops to varying extents. Consequently, to fully cultivate these skills, teachers require professional learning opportunities (Delcker et al., 2025). Previous research has explored teacher competence (Guillén-Gámez et al., 2024; Kim, 2024). Teachers who utilize AI to personalize learning and offer real-time feedback can enhance student engagement (Hanaysha et al., 2023; Long et al., 2025; Ali et al., 2025). AI can also automate administrative tasks, allowing teachers to focus on dynamic and engaging lessons (Gowthambalagi et al., 2025). Teacher support, including emotional and competency assistance, significantly boosts student engagement and academic success (Guo et al., 2025). Learner agility mediates the link between teacher technological skills and learning outcomes, according to Ng et al. (2023). In a technology-driven era, Jamal (2023) described instructor digital learning agility. Montilla et al. (2023) linked teacher technology competence to motivation and academic achievement, particularly in the context of education.

Along with instructor competence, student AI competence is becoming increasingly important in education. Recently validated measures of students' AI competence self-efficacy emphasize the importance of students' confidence in their AI technology skills (Chiu et al., 2025). AI in higher education has also been shown to enhance students' self-efficacy, creativity, and learning performance, demonstrating that both institutional support and individual competence are necessary to maximize the benefits of AI in education (Wang et al., 2023). Lee et al. (2024) found that technology competence parameters influence SLA, SE, and SP in student informal digital learning. Their findings support Falloon's (2020) shift from digital literacy to technical competence, which established a comprehensive framework to capture the diversity of digital education. Koh et al. (2023) found that technology competence has a strong impact on student performance. Qureshi et al. (2023) found that collaborative learning enhances student performance, demonstrating that successful engagement and learning experiences are interrelated. Wu et al. (2020) identified a complex relationship among motivation, academic performance, self-efficacy, and engagement, underscoring their significance in learning. High learning agility enables students to adapt to new learning environments and challenges, thereby enhancing their long-term engagement and academic success (Jian, 2022). AI-enabled adaptive learning paths and problem-solving opportunities foster student engagement and academic achievement (Long et al., 2025; Posekany, 2025). Student engagement, particularly cognitive engagement, predicts academic success, while emotional and behavioral engagement contribute less (Huang, 2025). AI-assisted language learning environments enhance student engagement and speaking skills by providing personalized and engaging learning experiences (Ali et al 2025).

Collectively, these studies highlight the complex interactions between teacher and student technology competence, emphasizing their importance in shaping learning agility, student engagement, and overall academic performance in education. In this study, we identified AI as a technology-based component that reflects the novelty of modern technology used by educational users. Three hypotheses were proposed based on the background information provided by the current work perceived by teachers who used AI in teaching.

H1: TAC influences SLA

H2: TAC influences SE

H3: TAC influences SAP

2.2 SLA, SE towards SP

Student learning agility – a fast-growing educational concept – is linked to student engagement and performance. The digital age encourages instructors and students to adapt quickly to new digital platforms and technologies (Greener & MacLean, 2013). In the era of exponential technology, Khambari et al. (2022) argue that adaptability is essential to digital pedagogy. SLA irectly affects SE and SP (Patwardhan et al., 2022). Oppici et al. (2022) found that exergaming technology affects children's foundational movement skill development, demonstrating the many uses of agility. Student involvement is crucial in online learning environments, according to Martínez-Zarzuelo et al. (2022), who note that students perceive different engagement tactics as affecting their learning experience (Korlat et al., 2021). Thornberg et al. (2022) found a substantial correlation between teacher-student relationship quality and student involvement, suggesting interpersonal aspects are essential. Several studies have demonstrated that participation has a direct and indirect impact on student performance. Maricuțoiu & Sulea (2019) use multilevel structural equation modeling to study student engagement, burnout, and performance. Paloș et al. (2019) found complex relationships between academic performance, student involvement, and burnout. T. K. F. Chiu (2021) tested and confirmed the association between student engagement and learning results. Tharapos et al. (2023) highlighted the importance of effective teaching and student participation during the COVID-19 pandemic, emphasizing the link between engagement and performance, particularly in critical times. As shown in various academic situations, SLA, SE, and SP are interconnected (Figure 1). Two hypotheses were proposed regarding SLA, SE, and SP in the context of AI technology use in teaching.

H4: LA influences SAP

H5: SE influences SAP

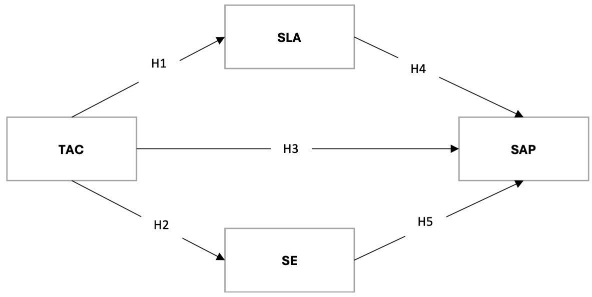


**Figure 1** - Proposed model.

## 3. Methods

3.1 Instrumentation process

Adjusting and creating survey items was the initial step in developing the instrument for a survey investigation. Thus, we included some demographic questions and 28 statements for the primary data analysis. The instrument was designed to suit the study objectives. TAC was developed and adapted from a prior study (Cabero-Almenara et al., 2021). SLA and SE items were adapted with five statements, respectively (H. J. Kim et al., 2018). SAP or student academic performance factor was included to assess the achievement of the students who are taught in their class using AI technology (Mehrvarz et al., 2021). The survey instrument employed a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree) (Dawes, 2008; Drumm et al., 2022). We used back-translation to translate the instrument from English to Indonesian for linguistic correctness (Habibi et al., 2023). This project employed two translators to assess the accuracy of the questionnaire's translation.

The instrument was carefully tested with five experts who scored statements for relevance, clarity, and simplicity. In two group conversations, five teachers who resembled the main respondents rated the statement clarity to ensure face validity. Two teachers, one researcher, and two students verified the study. We used the content validity index to validate instruments (Hertzog, 2008; Polit & Beck, 2006). The results of the assessment of the content validity index exceeded the 0.8 (threshold), confirming the statement items' authenticity and emphasizing the value of expert opinions in judging relevance, clarity, and simplicity

3.2. Population and sample

The population of this study consisted of lecturers at three universities in one Indonesian province, approximately 2,210 lecturers. The inclusion criteria were active lecturers at the three universities during data collection, while those on leave, retired, or inactive were excluded. The sample was chosen for representativeness and accessibility. We utilized GPower, a tool commonly used in social and behavioral science research, to assist researchers in selecting the sample size (Erdfelder et al., 2009; Kang, 2021).(Erdfelder et al., 2009; Kang, 2021) The software calculated the sample size for the analysis of 380 samples. We increased sample diversity by stratified random sampling. This involved taking samples from each gender group of the target population. Systematic responses were coded in Excel. Table 1 provides the demographics of the participants. The data provided offers a demographic breakdown of the respondents, categorized by four key factors: gender, institution, education, and teaching experience. Among the respondents, a majority are women, comprising 68.42% (260 respondents), compared to 31.58% (120 respondents) men. The respondents are predominantly affiliated with University B, which constitutes 47% (178 respondents) of the total sample, followed by University A at 30% (114 respondents), and University C at 23% (88 respondents). In terms of educational background, most respondents (80.53%, 306) have pursued or completed a Master's degree, while the remaining 19.47% (76) are pursuing or have completed a Doctoral degree.

**Table 1** - Demography.

| *Respondents* | *Category* | *n.* | *(%)* |
|---|---|---|---|
| Gender | Male | 120 | 35.87% |
| | Female | 260 | 68.42% |
| Institution | University A | 114 | 30% |
| | University B | 178 | 47% |
| | University C | 88 | 23% |
| Education | Master | 304 | 80.53% |
| | Doctorate | 76 | 19.47% |
| Teaching experience | < 5 years | 202 | 53% |
| | 5 or more years | 178 | 47% |

Regarding teaching experience, a slight majority of the respondents (53%, 202 respondents) have less than 5 years of teaching experience, while 47% (178 respondents) have five or more years of experience. Respondents were selected randomly within each stratum, ensuring that each group was proportionally represented in the sample, based on gender, institution, educational level, and teaching experience. This process was carried out to minimize bias and to ensure that the findings could be generalized to the entire population However, it is essential to note that this study did not specifically test or analyze the effects of these demographic factors – such as gender, educational background, and teaching experience – on the research outcomes This diverse sample provides a comprehensive view of the demographic distribution across gender, institutional affiliation, academic level, and teaching experience, which can be instrumental in analyzing trends, attitudes, and behaviors in the study population.

3.2 Data analysis

The data was quantitatively analyzed using SEM. PLS-SEM estimates structural models more accurately than CB-SEM (Sayginer, 2023). The strong multivariate statistical method uses factor analysis and multiple regression to study structural relationships between measurable and latent variables. SEM aims to determine variable correlations/covariances and correct for variance. Like traditional statistical procedures, missing data, outliers, and sample size might affect the results. SEM is widely used in economics, education, finance, and healthcare. Endogenous and exogenous latent components make up SEM. Independent factors are exogenous, while dependent variables are endogenous. The PLS-SEM protocol recommends measurement and structural assessment. Before presenting the steps, data preparation and descriptive statistics are shown. Variable associations were examined using path coefficients (β), t-value, p-value, coefficient of determination (R2), predictive relevance (Q2), and effect size (f2). SPSS also performed a t-test on geographical areas for instructional use, material access, motivational access, and skills access.

## 4. Findings

4.1 Measurement Model

We evaluated the reliability of the data through the measurement model (Habibi, Mailizar, et al., 2024; Habibi, Mukminin, et al., 2024; Sayginer, 2023). Table 2 and Figure 2 display important statistical indicators for the measurement model, such as Composite Reliability (CR), Average Variance Extracted (AVE), Means ($\bar{x}$), Variance Inflation Factor (VIF), and Loadings. These metrics are essential for assessing the reliability and validity of the measurement model, ensuring that items accurately represent the constructs and are consistent and distinct. CR measures the internal consistency of items that represent a latent construct. It is similar to Cronbach's Alpha but is more accurate when using SEM because it accounts for item loadings. Each factor has CR values in the Table 2. TAC, SLA, SE, and SAP have CR values of 0.922, 0.876, 0.864, and 0.850, respectively. These values all exceed the 0.7 threshold, suggesting good internal consistency. High CR values indicate that items within each construct measure the same concept, which is essential for valid representations of theoretical variables.

AVE compares a construct's variance to measurement error. AVE measures convergent validity, which determines if construct items are representative. AVE values for each construct are listed in the table. TAC, SLA, SE, and SAP had AVEs of 0.663, 0.669, 0.649, and 0.691, respectively. AVE values above 0.5 indicate high convergent validity because the construct explains more than half of the item variation. Each construct has an AVE value above the threshold, indicating that the items are good predictors of their respective constructs.

**Table 2** - x̄, VIF, and loads, CR and AVE.

| Factor | Code | x̄ | VIF | Loads | CR | AVE |
|---|---|---|---|---|---|---|
| TAC | TAC1 | 4.155 | 1.602 | 0.886 | 0.922 | 0.663 |
| | TAC2 | 3.697 | 2.070 | 0.597 | | |
| | TAC3 | 4.263 | 2.040 | 0.843 | | |
| | TAC4 | 4.118 | 2.190 | 0.780 | | |
| | TAC5 | 3.884 | 1.969 | 0.809 | | |
| | TAC6 | 4.026 | 2.118 | 0.754 | | |
| | TAC7 | 3.621 | 2.051 | 0.638 | | |
| | TAC8 | 3.532 | 2.472 | 0.550 | | |
| | TAC9 | 3.753 | 1.717 | 0.616 | | |
| | TAC10 | 3.861 | 1.487 | 0.678 | | |
| | TAC11 | 3.650 | 1.990 | 0.585 | | |
| | TAC12 | 3.771 | 3.214 | 0.704 | | |
| | TAC13 | 3.595 | 2.376 | 0.618 | | |
| | TAC14 | 3.774 | 3.513 | 0.696 | | |
| SLA | SLA1 | 3.771 | 2.350 | 0.799 | 0.876 | 0.669 |
| | SLA2 | 3.595 | 2.186 | 0.830 | | |
| | SLA3 | 3.774 | 1.951 | 0.822 | | |
| | SLA4 | 4.146 | 2.053 | 0.864 | | |
| | SLA5 | 4.187 | 3.457 | 0.772 | | |
| SE | SE1 | 4.111 | 3.120 | 0.723 | 0.864 | 0.649 |
| | SE2 | 4.145 | 2.315 | 0.808 | | |
| | SE3 | 3.974 | 3.379 | 0.848 | | |
| | SE4 | 4.097 | 3.748 | 0.843 | | |
| | SE5 | 3.658 | 3.480 | 0.801 | | |
| SAP | SAP1 | 3.850 | 3.266 | 0.785 | 0.850 | 0.691 |
| | SAP2 | 3.908 | 3.404 | 0.847 | | |
| | SAP3 | 3.684 | 3.430 | 0.836 | | |
| | SAP4 | 3.979 | 3.831 | 0.855 | | |

The table includes the mean values (x̄) for each item. These are the sample-wide average replies for each item. TAC1 has a mean score of 4.155, TAC2 has a mean score of 3.697. These methods show how respondents rate items. Depending on the scale, higher mean scores imply agreement or positive perceptions, whereas lower values indicate the reverse. The mean values can also reveal the subjective nature of the concept being measured. If all TAC items have high mean scores, it may indicate a positive view of the construct.

Multicollinearity is detected via VIF. Multicollinearity arises when two or more variables are highly correlated, which increases the standard errors of regression model coefficients and reduces construct reliability. Each item has VIF values in the table. The VIFs of TAC2 and SLA1 are 2.070 and 2.350, respectively. Multicollinearity is typically not a problem when the VIF is below 5. All VIF values in this table are below this threshold, indicating that the elements do not exhibit multicollinearity and each contributes uniquely to the construct. The coefficients that represent the link between each item and its latent concept are called factor loadings. Items with higher loadings are strong indicators of a strong build. SEM loadings above 0.7 are considered good, but those above 0.5 may be acceptable depending on the situation. The table shows each item's loading, indicating its relevance to the construct. TAC1, SLA1, and SE1 have loadings of 0.886, 0.799, and 0.723, respectively. These results suggest that most items have strong loadings, indicating solid construct indicators. TAC2 (0.597) and TAC8 (0.550) exhibit lower loadings, suggesting they are weaker markers of

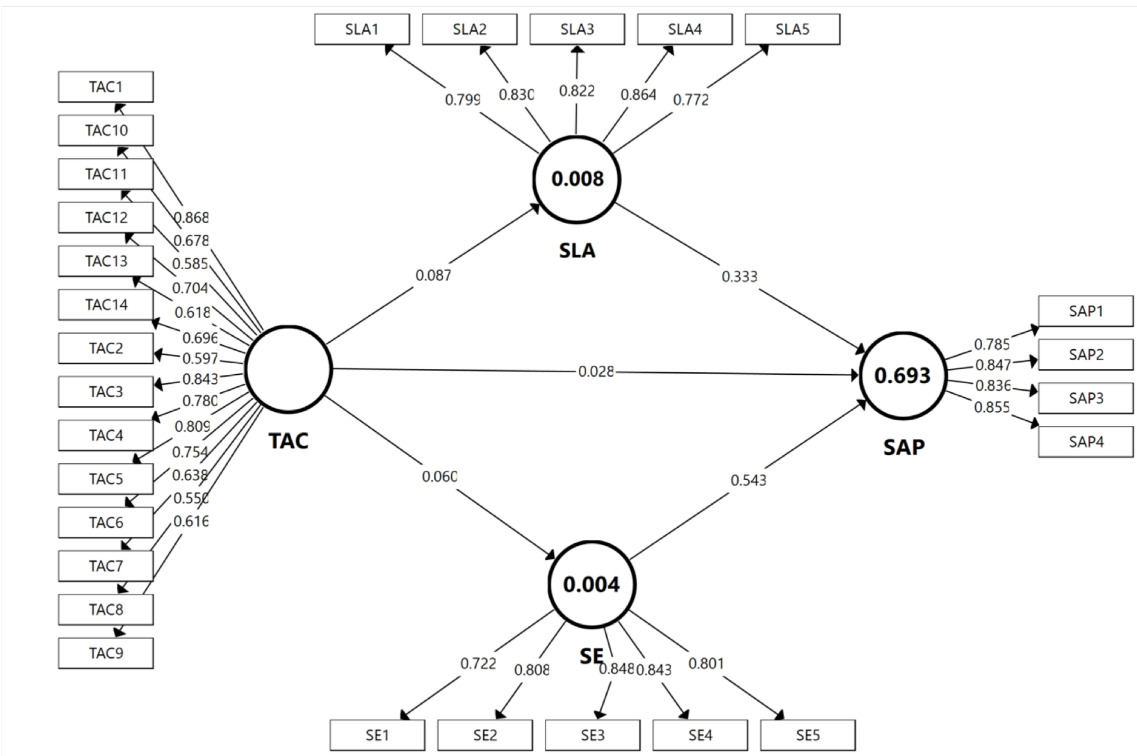


**Figure 2** - Measurement model reflective indicator loadings.

the TAC construct. Depending on their theoretical value, these items may be kept or changed.

TAC, SLA, SE, and SAP are measured using statistically examined items for reliability and validity. TAC (TAC1–TAC14) has a CR of 0.922 and an AVE of 0.663, indicating good reliability and validity. Some elements have lesser loadings, suggesting they may not be as powerful a building indicator. SLA, SE, and SAP likewise have high reliability and validity, with CR values above 0.7 and AVE values above 0.5. Most items substantially reflect the constructs they assess, indicating well-defined constructs. The measurement properties of the constructions are shown. AVE values suggest that the constructs are valid representations of the theoretical variables, while high CR values imply that items within each construct consistently measure the same notion. Means give an overview of respondents' perceptions, whereas VIF values indicate low multicollinearity. Most items' factor loadings indicate their structures well, but others may need extra analysis. The results demonstrate that the measurement model comprises trustworthy and valid constructs, as supported by the data. This approach is essential for precisely measuring constructs and confidently interpreting SEM results.

Discriminant validity tests distinguish unrelated constructs (Sarstedt et al., 2019, 2020). We employed the heterotrait-monotrait ratio (HTMT) as the most robust assessment for discriminant validity. Discriminant validity is considered good when the value is below 0.900 (Afthanorhan et al., 2020, 2021; Roemer et al., 2021). This study found all HTMT values between 0.569 and 0.889 (Table 3). The measurement model exhibited no validity issues, indicating our study's survey method is reliable. Based on the results obtained, it can be concluded that the research instrument used has adequate discriminant validity. In this study, all HTMT values are less than 0.9, indicating good discriminant validity. Items of the survey are attached in Appendix 1.

**Table 3** - HTMT.

| | SAP | SE | SLA |
|---|---|---|---|
| SE | 0.879 | | |
| SLA | 0.838 | 0.898 | |
| TAC | 0.051 | 0.044 | 0.054 |

## 4.2 Structural model

This study estimated the structural model using bootstrapping PLS selection and 5000 samples. PLS-SEM recommends bootstrapping, which involves randomly selecting and replacing subsamples from the original dataset (Sarstedt et al., 2019). Hair et al. (2019) recommend reporting model fit indices before providing the structural model. PLS-SEM studies should evaluate model fit using SRMR (Standardized Root Mean Square Residual), with a maximum of 0.08. Geodesic and squared Euclidean distances (d_ULS and d_G) were also reported, supporting the HTMT. Table 4 shows that SRMR is below 0.08 and d_ULS and d_G are excellent at 0,785 and 0.416, respectively.

**Table 4** - Model Fit.

| Category | Value |
|---|---|
| SRMR | 0.061 |
| d_ULS | 0.785 |
| d_G | 0.416 |
| Chi-Square | 844.839 |

Table 5 details a Structural Equation Modeling (SEM) path analysis. This study examines the links between TAC, SLA, SE, and SAP. The table displays standardized path coefficients (β), p-values, significance levels, and impact sizes ($f^2$) for five predicted associations, assessing their statistical significance and practical relevance. H1 compares TAC and SLA. A weak positive association is indicated by the path coefficient (β) of 0.087. The observed link may have been random due to the non-significant p-value of 0.449. TAC has a minimal impact on SLA, as indicated by the effect size ($f^2$) of 0.006. This shows that TAC does not affect SLA in this model.

**Table 5** - Structural model.

| H | Path | β | p-value | Sig. | $f^2$ |
|---|---|---|---|---|---|
| H1 | TAC → SLA | 0.087 | 0.449 | No | 0.006 |
| H2 | TAC → SE | 0.060 | 0.722 | No | 0.002 |
| H3 | TAC → SAP | 0.028 | 0.341 | No | 0.002 |
| H4 | SLA → SAP | 0.333 | 0.000 | Yes | 0.140 |
| H5 | SE → SAP | 0.543 | 0.000 | Yes | 0.375 |

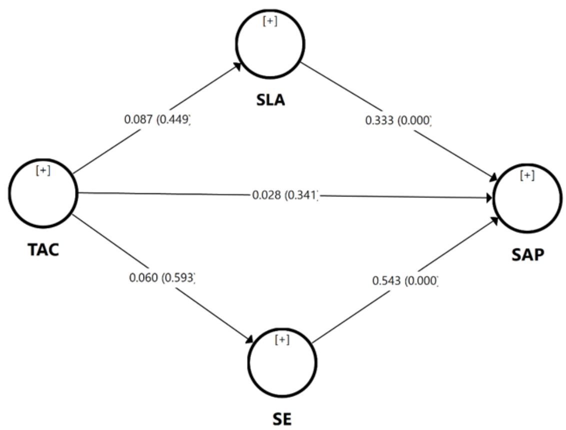

**Figure 3** - Structural model.

TAC had little effect on SLA, suggesting that other factors may be more critical. Hypothesis 2 examines TAC and SE. This association's path coefficient is 0.060, indicating a weak positive relationship, consistent with H1. The effect size is 0.002, indicating that TAC has little practical influence on SE. This suggests that technology acceptance does not significantly affect SE in this study, and any observed association is likely due to random fluctuation. The third hypothesis (H3) examines the relationship between TAC and SAP. The path coefficient of 0.028 is the smallest positive association among all examined paths. This association is not statistically significant ($p = 0.341$). The low effect size ($f^2$) of 0.002 suggests that TAC has a minimal impact on SAP. These results indicate that TAC does not significantly alter SAP in this investigation. This matches H1 and H2, when TAC had little to no effect on SLA and SE.

H4 compares SLA with SAP. This link has a significantly higher positive path coefficient ($\beta = 0.333$) than earlier hypotheses. A substantial association is indicated by the $p < .001$. The effect size is 0.140, indicating a medium effect, which demonstrates that SLA has a significant impact on SAP. The last hypothesis (H5) examines the relationship between SE and SAP. This association has the highest positive path coefficient ($\beta = 0.543$) among the investigated hypotheses. A p-value of $<.001$ indicates that this association is significant. SE has a considerable impact on SAP, as evidenced by the substantial effect size ($f^2$) of 0.375. This suggests that academically confident individuals perform better in social academic settings. The considerable significance and large effect size underscore the relevance of student self-efficacy in improving academic performance. The path analysis shows that TAC did not significantly affect SLA, SE, and SAP. The moderate effect size for SLA and the significant effect size for SE show their value in SAP. These findings suggest that educational interventions to improve outcomes should focus on SLA and SE to improve SAP.

Table 6 displays $R^2$ and $Q^2$ values for SAP, SLA, and SE factors. The model's explanatory capacity and predictive significance depend on these values.

**Table 6** - $R^2$ and $Q^2$.

| Factor | $R^2$ | $Q^2$ |
|---|---|---|
| SAP | 0.693 | 0.019 |
| SLA | 0.006 | 0.021 |
| SE | 0.002 | 0.019 |

The coefficient of determination ($R^2$) measures the proportion of variance in the dependent variable that is accounted for by the independent variables in the model. A high $R^2$ value indicates a strong relationship between the independent variables and the dependent variable, explaining a significant portion of the variability in the results. The $R^2$ value for SAP is 0.693, indicating that the SAP factor accounts for 69.3% of the variance in the dependent variable. The high $R^2$ value indicates that SAP is a significant predictor in the model, accounting for a substantial portion of the variation in the dependent variable. SAP is vital to the model; thus, 0.693 is a significant value. SLA has an $R^2$ value of 0.006, indicating that it explains just 0.6% of the variance in the dependent variable. A low $R^2$ value suggests SLA is not a reliable predictor in this model. It explains little of the variance, suggesting that other factors, either outside or inside the model, explain more. The $R^2$ value for SE is much lower, at 0.002. SE explains only 0.2% of the variation in the dependent variable, indicating its low explanatory power. SE does not forecast the outcome like SLA.

Key measure $Q^2$ evaluates model predictive relevance using the Stone-Geisser criterion. $R^2$ measures the model's ability to explain variance in estimation data, whereas $Q^2$ assesses its ability to forecast new data. A positive $Q^2$ score implies predictive relevance in the model. The $Q^2$ value for SAP is 0.019, indicating a low but acceptable level of predictive relevance. This result suggests that the model can predict SAP-based data with some accuracy. Compared to SAP, SLA has a slightly higher $Q^2$ value (0.021), indicating improved predictive relevance, although it remains poor. Although SLA does not explain much variance in the model (as seen by its $R^2$), it is marginally more effective at predicting fresh data. SE and SAP have the same $Q^2$ value of 0.019, showing equivalent predictive relevance. While SE has a low $R^2$, the $Q^2$ value suggests that it can still predict new outcomes, albeit to some extent. The model demonstrates that SAP is a significant explanatory factor but that SAP, SLA, and SE have limited predictive relevance. This indicates that SAP accounts for a substantial portion of the variance in current data; however, none of the components can accurately predict new data. Thus, the model may require adjustment or additional features to enhance its explanatory power and predictive relevance.

## 5. Discussion

A fascinating glimpse into the processes at play within the educational environment, particularly in the context of AI integration, is provided by the investigation of the relationship between teacher AI competency (TAC) and various student outcomes. The route analysis's findings highlight several significant conclusions that warrant an in-depth explanation. According to the first hypothesis (H1), student learning agility (SLA) is expected to be positively impacted by teachers' AI competency. At the usual levels, the relationship's path coefficient ($\beta$) is 0.087, with a p-value of 0.449, indicating that it is not statistically significant. This implies that the idea that teachers' proficiency with AI directly improves students' learning agility is not well-supported by data (Guillén-Gámez, et al., 2024; Kim, 2024). This outcome may indicate several underlying issues. Firstly, while instructor AI proficiency is essential, its direct impact on student learning agility may not always be clear. Learning agility is the ability of students to absorb, process, and apply new information quickly. It is possible that intrinsic elements, such as students' motivation, cognitive capacities, and prior knowledge, have a greater impact on learning agility than do teachers' technological expertise (Greener & MacLean, 2013). On the other hand, it's possible that AI integration in the classroom is not yet advanced enough to significantly enhance students' learning capacity. Another argument is that the ineffective use of AI tools could prevent pupils from being adequately challenged to improve their agility, thereby limiting the potential influence of teacher AI competency in this area.

The second hypothesis (H2) looked at the relationship between student engagement (SE) and teacher AI competency. Here, the p-value of 0.722 and the path coefficient of 0.060 both show that there is no significant link. A key element of academic achievement is student engagement, defined as the degree of interest, enthusiasm, and involvement that students exhibit in their learning activities. This lack of a substantial association shows that higher levels of student involvement are not always correlated with a teacher's AI skill (Koh et al., 2023). This study may suggest that involvement is more intricate and multidimensional, necessitating from educators more than just technological know-how. Interpersonal relationships between teachers and students, curricular relevance, classroom atmosphere, and teaching style are perhaps more critical factors in promoting engagement. Furthermore, because AI in education is still relatively new, both educators and learners may still be adjusting to the technology, meaning that its full potential for engaging pupils has not yet been reached. Furthermore, AI technologies may struggle to hold students' attention if they are not user-friendly or integrated adequately into pedagogy, which may account for their limited influence.

The direct relationship between TAC and SAP was investigated in Hypothesis 3 (H3). The study reveals a path coefficient of 0.028 with a p-value of 0.341, which is also not statistically significant. This result implies that raising students' academic success is not directly correlated with instructor AI competency. A wide range of factors outside the purview of teacher AI competency likely influence academic performance, which serves as a gauge of students' success in their educational pursuits (Alam & Mohanty, 2023; Garrison, 2019). This finding suggests that, even if AI technologies can enhance instruction, their ability to immediately improve student achievement may be limited in the absence of additional beneficial variables. A well-organized curriculum, ongoing evaluation, feedback systems, and a positive learning environment are a few examples of these. Furthermore, the subject matter, the way AI is integrated, and the general level of digital literacy among teachers and students may all impact how well AI improves academic performance (Casal-Otero et al., 2023). The results suggest that academic success can be achieved through AI proficiency alone, potentially due to the need for a more comprehensive strategy that incorporates AI with other educational techniques.

The association between student learning agility and academic achievement is examined in the fourth hypothesis (H4), which demonstrates a substantial positive path coefficient ($\beta = 0.333$, p-value $< 0.001$). This suggests a positive correlation between learning agility and academic success among students. This association is further supported by the f2 value of 0.140, indicating a medium effect size and suggesting that learning agility is a significant predictor of academic performance. The ability of pupils to absorb new material, adapt to various learning situations, and apply their knowledge effectively is reflected in their learning agility. This result is consistent with educational theories that highlight the role adaptive learning habits have in helping students succeed academically (Alam, 2022; Linnenbrink-Garcia et al., 2016; Schwartz et al., 2013; Van Der Vorst & Jelicic, 2019). Agile learners are better equipped to navigate the complexities of academic challenges, effectively manage their learning processes, and apply their knowledge in diverse situations. This finding highlights the importance of helping students develop their learning agility as a means of enhancing their academic achievement. Teachers may need to focus on developing curricula and instructional methods that foster adaptability, such as problem-based learning, adaptive learning technologies, and other active learning techniques.

The relationship between academic achievement and student participation was the subject of the last hypothesis (H5). A considerable positive path coefficient ($\beta = 0.543$, p-value $< 0.001$) is revealed by the research, suggesting that improved academic achievement is strongly correlated with higher levels of student engagement. The significant contribution of involvement to academic performance is highlighted by the f2 value of 0.375, which indicates a strong impact size. This finding aligns with the extensive body of research that demonstrates student engagement as a crucial factor in predicting academic success. Increased motivation, active participation in class, meticulous completion of homework, and seeking assistance when needed are all characteristics of engaged students that lead to better academic results (August & Tsaima, 2021; Demartini et al., 2024; Wei, 2023). Since there is a direct correlation between engagement and performance, tactics such as individualized learning plans, interactive teaching techniques, and the use of engaging digital tools can all be highly effective in enhancing student achievement.

## 6. Conclusion

This study investigated the relationships among teacher AI competence (TAC), student learning agility (SLA), student engagement (SE), and student academic performance (SAP) in higher education. The results provide robust evidence that student learning agility and engagement are significant predictors of academic performance. Specifically, the path analysis revealed that both SLA ($\beta = 0.333$, $p < 0.001$) and SE ($\beta = 0.543$, $p < 0.001$) have strong, positive, and statistically significant effects on SAP, jointly explaining 69.3% of the variance in academic performance ($R^2 = 0.693$). These findings underscore the importance of cultivating learning agility and engagement in students to enhance their academic outcomes.

In contrast, teacher AI competence was not found to have a statistically significant direct effect on student learning agility, engagement, or academic performance (all $p > 0.3$). This suggests that, in the context of this study, teacher AI competence alone may not directly determine student outcomes. Nevertheless, AI competence remains a relevant and increasingly necessary professional skill for educators in the digital era. Therefore, efforts to enhance teachers' AI competence remain essential to ensure that educators are well-prepared to integrate technology effectively and adapt to future developments in education. Its influence on student achievement may operate indirectly or in conjunction with other factors, such as the overall learning environment and instructional approaches.

It is essential to note that demographic characteristics, such as gender, institution, educational background, and teaching experience, were not analyzed as moderating variables due to limitations in sample distribution. The uneven distribution of respondents in several categories, such as the predominance of female participants and the majority coming from a single institution or educational level, could introduce bias if demographic effects were analyzed. For this reason, the influence of demographic characteristics was excluded from the analysis to maintain the study's validity and focus. Future research with larger and more balanced samples is needed to examine the potential moderating effects of these demographic factors.

In summary, while teacher AI competence is an essential attribute for educators, this study demonstrates that student engagement and learning agility are more critical determinants of academic success in the era of AI. Educational policies and practices should therefore adopt a holistic approach that supports these student-centered factors to maximize learning outcomes as AI becomes increasingly integrated into higher education.

## The availability of data

The dataset used in the present work can be accessed in the Figshare repository.

## Authors' Contributions

Conceptualization by R.H. and A.H.; methodology by R.H., A.H.; software by T.M.A.; validation by R.H., A.H.; formal analysis by T.M.A.; investigation by L.N.Y.; data curation by L.N.Y.; original draft preparation by A.S.A.; writing-review and editing by A.S.A.; visualization by A.M.; supervision by A.M. All authors have read and approved the publication.

## Informed Consent Statement

All subjects included in the study provided informed consent.

## Conflict of Interest

The authors declare no conflicts of interest.

## References


Afthanorhan, A., Awang, Z., & Aimran, N. (2020). An extensive comparison of cb-sem and pls-sem for reliability and validity. *International Journal of Data and Network Science*. https://doi.org/10.5267/j.ijdns.2020.9.003

Afthanorhan, A., Ghazali, P. L., & Rashid, N. (2021). Discriminant Validity: A Comparison of CBSEM and Consistent PLS using Fornell & Larcker and HTMT Approaches. *Journal of Physics: Conference Series*, *1874*(1). https://doi.org/10.1088/1742-6596/1874/1/012085

Alam, A. (2022). Employing Adaptive Learning and Intelligent Tutoring Robots for Virtual Classrooms and Smart Campuses: Reforming Education in the Age of Artificial Intelligence. *Lecture Notes in Electrical Engineering*, *914*. https://doi.org/10.1007/978-981-19-2980-9_32

Alam, A., & Mohanty, A. (2023). Educational technology: Exploring the convergence of technology and pedagogy through mobility, interactivity, AI, and learning tools. In *Cogent Engineering* (Vol. 10, Issue 2). https://doi.org/10.1080/23311916.2023.2283282

Alenezi, M. A. K., Mohamed, A. M., & Shaaban, T. S. (2023). Revolutionizing EFL special education: how ChatGPT is transforming the way teachers approach language learning. *Innoeduca. International Journal of Technology and Educational Innovation*, *9*(2). https://doi.org/10.24310/innoeduca.2023.v9i2.16774

Almusaed, A., Almssad, A., Yitmen, I., & Homod, R. Z. (2023). Enhancing Student Engagement: Harnessing "AIED"'s Power in Hybrid Education—A Review Analysis. In *Education Sciences* (Vol. 13, Issue 7). https://doi.org/10.3390/educsci13070632

August, S. E., & Tsaima, A. (2021). Artificial Intelligence and Machine Learning: An Instructor's Exoskeleton in the Future of Education. https://doi.org/10.1007/978-3-030-58948-6_5

Cabero-Almenara, J., Gutiérrez-Castillo, J. J., Palacios-Rodríguez, A., & Barroso-Osuna, J. (2021). Comparative European digcompedu framework (JRC) and common framework for teaching digital competence (INTEF) through expert judgment. *Texto Livre*, *14*(1). https://doi.org/10.35699/1983-3652.2021.25740

Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: a systematic literature review. In *International Journal of STEM Education* (Vol. 10, Issue 1). https://doi.org/10.1186/s40594-023-00418-7

Chiu, T. K. F. (2021). Digital support for student engagement in blended learning based on self-determination theory. *Computers in Human Behavior*, *124*. https://doi.org/10.1016/j.chb.2021.106909

Dawes, J. (2008). Do data characteristics change according to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales. *International Journal of Market Research*, *50*(1). https://doi.org/10.1177/147078530805000106

Demartini, C. G., Sciascia, L., Bosso, A., & Manuri, F. (2024). Artificial Intelligence Bringing Improvements to Adaptive Learning in Education: A Case Study. *Sustainability (Switzerland)*, *16*(3). https://doi.org/10.3390/su16031347

Dimitriadou, E., & Lanitis, A. (2023). A critical evaluation, challenges, and future perspectives of using artificial intelligence and emerging technologies in smart classrooms. In *Smart Learning Environments* (Vol. 10, Issue 1). https://doi.org/10.1186/s40561-023-00231-3

Drumm, S., Bradley, C., & Moriarty, F. (2022). 'More of an art than a science'? The development, design and mechanics of the Delphi Technique. *Research in Social and Administrative Pharmacy*, *18*(1). https://doi.org/10.1016/j.sapharm.2021.06.027

Erdfelder, E., FAul, F., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4). https://doi.org/10.3758/BRM.41.4.1149

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*, *68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Garrison, B. (2019). Review of Teaching AI: Exploring new frontiers for learning. *Education Review*, *26*. https://doi.org/10.14507/er.v26.2627

Greener, S., & MacLean, P. (2013). The digital carrot and survival stick for increased learning and teaching agility. *Proceedings of the European Conference on E-Learning, ECEL*.

Guillén-Gámez, F. D., Colomo-Magaña, E., Cívico-Ariza, A., & Linde-Valenzuela, T. (2024). Which is the Digital Competence of Each Member of Educational Community to Use the Computer? Which Predictors Have a Greater Influence? *Technology, Knowledge and Learning*, *29*(1). https://doi.org/10.1007/s10758-023-09646-w

Guillén-Gámez, F. D., Tomczyk, Ł., Ruiz-Palmero, J., & Connolly, C. (2024). Digital Security in Educational Contexts: digital Competence and Challenges for Good Practice. In *Computers in the Schools*. Routledge. https://doi.org/10.1080/07380569.2024.2390319

Habibi, A., Mailizar, M., Yaqin, L. N., Alqahtani, T. M., Abrar, M., Hamuddin, B., & Failasofah, F. (2024). UNLOCKING ENGLISH PROFICIENCY: YOUTUBE'S IMPACT ON SPEAKING SKILLS AMONG INDONESIAN UNIVERSITY STUDENTS. *Journal of Technology and Science Education*, *14*(1). https://doi.org/10.3926/jotse.2485

Habibi, A., Mukminin, A., & Sofyan, S. (2024). Access to the digital technology of urban and suburban vocational schools. *Education and Information Technologies*, *29*(4). https://doi.org/10.1007/s10639-023-12006-x

Habibi, A., Riady, Y., Samed Al-Adwan, A., & Awni Albelbisi, N. (2023). Beliefs and Knowledge for Pre-Service Teachers' Technology Integration during Teaching Practice: An Extended Theory of Planned Behavior. *Computers in the Schools*, *40*(2). https://doi.org/10.1080/07380569.2022.2124752

Hertzog, M. A. (2008). Considerations in determining sample size for pilot studies. *Research in Nursing and Health*, *31*(2). https://doi.org/10.1002/nur.20247

Jamal, A. (2023). The Role of Artificial Intelligence (AI) in Teacher Education: Opportunities & Challenges. *International Journal of Research and Analytical Reviews (IJRAR)*, *10*(1).

Kang, H. (2021). Sample size determination and power analysis using the G*Power software. In *Journal of Educational Evaluation for Health Professions* (Vol. 18). https://doi.org/10.3352/JEEHP.2021.18.17

Khambari, M. N. M. D., Wong, S. L., Zakaria, N. S., Abdullah, K., Moses, P., & Hamzah, S. R. ah. (2022). Identifying the Dimensions of Teachers' Digital Learning Agility in the Age of Exponential Technology Use. *30th International Conference on Computers in Education Conference, ICCE 2022 - Proceedings*, *2*.

Kim, H. J., Hong, A. J., & Song, H. D. (2018). The relationships of family, perceived digital competence and attitude, and learning agility in sustainable student engagement in higher education. *Sustainability (Switzerland)*, *10*(12). https://doi.org/10.3390/su10124635

Kim, J. (2024). Leading teachers' perspective on teacher-AI collaboration in education. *Education and Information Technologies*, *29*(7). https://doi.org/10.1007/s10639-023-12109-5

Kitcharoen, P., Howimanporn, S., & Chookaew, S. (2024). Enhancing Teachers' AI Competencies through Artificial Intelligence of Things Professional Development Training. *International Journal of Interactive Mobile Technologies*, *18*(2). https://doi.org/10.3991/ijim.v18i02.46613

Koh, J., Cowling, M., Jha, M., & Sim, K. N. (2023). The Human Teacher, the AI Teacher and the AIed-Teacher Relationship. *Journal of Higher Education Theory and Practice*, *23*(17). https://doi.org/10.33423/jhetp.v23i17.6543

Korlat, S., Kollmayer, M., Holzer, J., Lüftenegger, M., Pelikan, E. R., Schober, B., & Spiel, C. (2021). Gender Differences in Digital Learning During COVID-19: Competence Beliefs, Intrinsic Value, Learning Engagement, and Perceived Teacher Support. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.637776

Lee, Y. J., Davis, R. O., & Ryu, J. (2024). Korean in-Service Teachers' Perceptions of Implementing Artificial Intelligence (AI) Education for Teaching in Schools and Their AI Teacher Training Programs. *International Journal of Information and Education Technology*, *14*(2). https://doi.org/10.18178/ijiet.2024.14.2.2042

Linnenbrink-Garcia, L., Patall, E. A., & Pekrun, R. (2016). Adaptive Motivation and Emotion in Education: Research and Principles for Instructional Design. *Policy Insights from the Behavioral and Brain Sciences*, *3*(2). https://doi.org/10.1177/2372732216644450

Maricuțoiu, L. P., & Sulea, C. (2019). Evolution of self-efficacy, student engagement and student burnout during a semester. A multilevel structural equation modeling approach. *Learning and Individual Differences*, *76*. https://doi.org/10.1016/j.lindif.2019.101785

Martínez-Zarzuelo, A., Rodríguez-Mantilla, J. M., & Fernández-Díaz, M. J. (2022). Improvements in climate and satisfaction after implementing a quality management system in education. *Evaluation and Program Planning*, *94*. https://doi.org/10.1016/j.evalprogplan.2022.102119

Mehrvarz, M., Heidari, E., Farrokhnia, M., & Noroozi, O. (2021). The mediating role of digital informal learning in the relationship between students' digital competency and their academic performance. *Computers and Education*, *167*. https://doi.org/10.1016/j.compedu.2021.104184

Montilla, V. R., Rodriguez, R., C. Aliazas, J. V., & Gimpaya, R. (2023). Teachers' Pedagogical Digital Competence as Relevant Factors on Academic Motivation and Performance in Physical Education. *International Journal of Scientific and Management Research*, *06*(06). https://doi.org/10.37502/ijsmr.2023.6604

Nazaretsky, T., Ariely, M., Cukurova, M., & Alexandron, G. (2022). Teachers' trust in AI-powered educational technology and a professional development program to improve it. *British Journal of Educational Technology*, *53*(4). https://doi.org/10.1111/bjet.13232

Ng, D. T. K., Leung, J. K. L., Su, J., Ng, R. C. W., & Chu, S. K. W. (2023). Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. *Educational Technology Research and Development*, *71*(1). https://doi.org/10.1007/s11423-023-10203-6

Oppici, L., Stell, F. M., Utesch, T., Woods, C. T., Foweather, L., & Rudd, J. R. (2022). A Skill Acquisition Perspective on the Impact of Exergaming Technology on Foundational Movement Skill Development in Children 3–12 Years: A Systematic Review and Meta-analysis. In *Sports Medicine - Open* (Vol. 8, Issue 1). https://doi.org/10.1186/s40798-022-00534-8

Paloș, R., Maricuţoiu, L. P., & Costea, I. (2019). Relations between academic performance, student engagement and student burnout: A cross-lagged analysis of a two-wave study. *Studies in Educational Evaluation*, *60*. https://doi.org/10.1016/j.stueduc.2019.01.005

Patwardhan, V., Mallya, J., Shedbalkar, R., Srivastava, S., & Bolar, K. (2022). Students' Digital Competence and Perceived Learning: The mediating role of Learner Agility. *F1000Research*, *11*. https://doi.org/10.12688/f1000research.124884.1

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing and Health*, *29*(5). https://doi.org/10.1002/nur.20147

Qureshi, M. A., Khaskheli, A., Qureshi, J. A., Raza, S. A., & Yousufi, S. Q. (2023). Factors affecting students' learning performance through collaborative learning and engagement. *Interactive Learning Environments*, *31*(4). https://doi.org/10.1080/10494820.2021.1884886

Roemer, E., Schuberth, F., & Henseler, J. (2021). HTMT2–an improved criterion for assessing discriminant validity in structural equation modeling. *Industrial Management and Data Systems*, *121*(12). https://doi.org/10.1108/IMDS-02-2021-0082

Sarstedt, M., Hair, J. F., Cheah, J. H., Becker, J. M., & Ringle, C. M. (2019). How to specify, estimate, and validate higher-order constructs in PLS-SEM. *Australasian Marketing Journal*, *27*(3). https://doi.org/10.1016/j.ausmj.2019.05.003

Sarstedt, M., Hair, J. F., Nitzl, C., Ringle, C. M., & Howard, M. C. (2020). Beyond a tandem analysis of SEM and PROCESS: Use of PLS-SEM for mediation analyses! *International Journal of Market Research*, *62*(3), 288–299. https://doi.org/10.1177/1470785320915686

Sayginer, C. (2023). Acceptance and use of cloud-based virtual platforms by higher education vocational school students: application of the UTAUT model with a PLS-SEM approach. *Innoeduca. International Journal of Technology and Educational Innovation*, *9*(2). https://doi.org/10.24310/innoeduca.2023.v9i2.15647

Schwartz, D. L., Lin, X., Brophy, S., & Bransford, J. D. (2013). Toward the development of flexibly adaptive instructional designs. In *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory* (Vol. 2). https://doi.org/10.4324/9781410603784-15

Sun, F., Tian, P., Sun, D., Fan, Y., & Yang, Y. (2024). Pre-service teachers' inclination to integrate AI into STEM education: Analysis of influencing factors. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.13469

Tharapos, M., Peszynski, K., Lau, K. H., Heffernan, M., Vesty, G., & Ghalebeigi, A. (2023). Effective teaching, student engagement and student satisfaction during the Covid-19 pandemic: Evidence from business students' qualitative survey evaluations. *Accounting and Finance*, *63*(3). https://doi.org/10.1111/acfi.13025

Thornberg, R., Forsberg, C., Hammar Chiriac, E., & Bjereld, Y. (2022). Teacher–Student Relationship Quality and Student Engagement: A Sequential Explanatory Mixed-Methods Study. *Research Papers in Education*, *37*(6). https://doi.org/10.1080/02671522.2020.1864772

Van Der Vorst, T., & Jelicic, N. (2019). Artificial Intelligence in Education Can AI bring the full potential of personalized learning to education? *30th European Conference of the International Telecommunications Society (ITS): "Towards a Connected and Automated Society", Helsinki, Finland, 16th-19th June, 2019.*

Wang, X., Li, L., Tan, S. C., Yang, L., & Lei, J. (2023). Preparing for AI-enhanced education: Conceptualizing and empirically examining teachers' AI readiness. *Computers in Human Behavior*, *146*. https://doi.org/10.1016/j.chb.2023.107798

Wei, L. (2023). Artificial intelligence in language instruction: impact on English learning achievement, L2 motivation, and self-regulated learning. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1261955

 

# Appendix: survey

| | |
|---|---|
| Gender (Sex) | Male<br>Female |
| Institution | University A<br>University B<br>University C |
| Highest Education Level | Master<br>Doctorate |
| Teaching Experience | Less than 5 years<br>5 years or more than 5 years |
| TAC | 1. AI technology is used to improve classroom learning.<br>2. AI-based applications or platforms (such as AI quiz generators and AI tutors) are used to explain material or offer exercises.<br>3. AI-based learning resources are selected by curriculum requirements.<br>4. AI-based materials are modified or adapted with attention to ethics, accuracy, and copyright.<br>5. AI-based learning materials are managed with a focus on student data privacy and security.<br>6. AI is used to facilitate communication and collaboration between educators.<br>7. AI is used to support interactions between teachers and students, as well as between students.<br>8. AI is used to enhance collaborative learning among students.<br>9. AI-based tools are used for formative and summative assessments.<br>10. AI is utilized to analyze learning outcomes and provide rapid and accurate feedback.<br>11. AI-based learning activities are selected or generated according to students abilities.<br>12. AI-based tools used in learning foster student learning interests.<br>13. AI is used to facilitate learning for students with special needs, making it more inclusive.<br>14. AI is used to adapt materials to students' competency levels, interests, and learning needs. |
| SLA | 1. New experiences with AI technology become learning opportunities.<br>2. Information obtained through AI (e.g., chatbots, learning apps) is easy to remember and understand.<br>3. Students are optimistic about the potential benefits of AI for learning new topics.<br>4. Students enjoy researching or seeking out new information related to AI technology.<br>5. Students strive to find ways to apply the new knowledge gained through AI to academic pursuits. |
| SE | 1. Students can find ways to make learning materials relevant to their daily lives with the help of AI.<br>2. Students can apply learning materials to real-life situations with the support of AI technology.<br>3. Students can enhance their learning experience by utilizing AI applications or tools.<br>4. Students often search for or explore materials through AI before the lesson begins.<br>5. Students have a strong desire to learn the material using AI technology. |
| SAP | 1. Students trust their academic skills, including using AI to support learning.<br>2. Students can complete academic assignments, both independently and with the assistance of AI technology.<br>3. Students learn how to utilize AI to complete academic assignments more efficiently and effectively.<br>4. Students demonstrate academic achievement as expected by utilizing AI technology appropriately in the learning process. |

JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 21, No. 2 (2025), pp. 31-43

# Assessing the Usability of Federated Access to T4EU Online Courses in Higher Education Mobility Programs

Federica Mancini[1], Riccardo Fattorini, Michele Bava

*University of Trieste – Trieste (Italy)*

*(submitted: 16/11/2024; accepted: 19/8/2025; published: 31/8/2025)*

**Abstract**

Facilitating access to online courses in higher education mobility programs is essential for creating a more interconnected educational ecosystem within the European Education Area. Federated e-infrastructures have emerged as effective solutions to enhance the interoperability, accessibility, and scalability of academic services under a standardized trust model. However, assessing their usability for end-users is critical. This study aims to identify and adapt an instrument for measuring the usability of federated access to a Moodle ecosystem implemented by the Transform4Europe alliance for students participating in mobility programs. The paper outlines the process of adapting and validating a questionnaire based on Nielsen's Usability Attributes model to meet the unique characteristics of this context. An iterative, multi-method approach was employed, incorporating feedback from students and usability experts for content validation. The resulting instrument was administered to 145 students at the University of Trieste during lectures. Exploratory factor analysis confirmed the tool's reliability and validity while highlighting the need for refinements, including revising two items with low factor loadings, methodological adjustments in questionnaire administration, and increased sample size for more robust results. Although further validation of the final instrument is recommended, the results obtained in this study provide a significant starting point for advancing usability assessment practices in federated learning environments aimed at enhancing the student mobility experience.

**KEYWORDS:** European Universities, e-Learning, Federated Access, Moodle, Online Courses, Usability.

**DOI**
https://doi.org/10.20368/1971-8829/1136104

**CITE AS**
Mancini, F., Fattorini, R., & Bava, M. (2025). Assessing the Usability of Federated Access to T4EU Online Courses in Higher Education Mobility Programs. *Journal of e-Learning and Knowledge Society*, *21*(2), 31-43.
https://doi.org/10.20368/1971-8829/1136104

## 1. Introduction

The digital transformation of university campuses and the increasing adoption of distance learning, supported by European Universities Alliances (EUAs), are essential for creating a more interconnected and student-centered educational ecosystem in the European Higher Education Area (EHEA) (Gaebel et al., 2021). However, developing joint campuses and exchanging electronic data across systems remains challenging for Higher Education Institutions (Berger et al., 2023).

To address the need for a global learning environment, the Transform4Europe (T4EU) alliance implemented a Moodle ecosystem accessible exclusively to alliance members through federated authentication, leveraging the eduGAIN inter-federation service. After the testing phase, we evaluated the usability of this federated ecosystem based on students' experiences at the University of Trieste (UniTS), before extending the study to other institutions. This evaluation involved identifying a usability instrument tailored to the specific context.

Usability, as defined by ISO 9241-11, refers to the degree to which a user can utilize a product to achieve specific goals with effectiveness, efficiency, and satisfaction within a defined context of use (ISO, 2018). Usability evaluation focuses on users' ability to learn and use a product to accomplish their objectives and the satisfaction they experience during use. Several methods can be used for such evaluations, with usability questionnaires being a widely adopted and cost-effective option that provides valuable insights

[1] corresponding author - email: federica.mancini@units.it

 

into user perceptions (Aziz et al., 2021). However, selecting the most appropriate usability questionnaire can be challenging.

The literature offers limited guidance on the best questionnaire for evaluating usability in federated Moodle ecosystems for mobility students. For example, Ruoti et al. (2015) use the Systems Usability Scale (SUS) to assess the usability of web authentication systems, confirming its reliability. Galende et al. (2023) and Vlachogianni and Tselios (2023) also use SUS, highlighting its widespread adoption for perceived usability evaluation in educational platforms.

Despite the popularity of questionnaires, Sagar and Saha (2017) found no consensus on the models used for usability analysis. Hodrien and Fernando (2021) suggest selecting the right instrument involves analysing the study context and systems and evaluating the questionnaire's content, advantages, disadvantages, and psychometric properties. The questionnaire should also be easy to administer and adaptable to the context.

Considering this scenario, the main research questions guiding this research are:

R1. How can the usability of federated access for online courses in higher education mobility programs be accurately evaluated using a questionnaire?

R2. How does the re-adapted Nielsen Attributes of Usability (NAU)-based questionnaire measure the usability of federated access to online courses in higher education mobility programs?

## 2. Materials and methods

### 2.1 Selection and Adaptation of the Instrument

Inquiry methods for collecting quantitative data from both students and experts were crucial for our study. Selecting the most appropriate questionnaire required a thorough review of widely used usability instruments (Brooke, 1996; Chin et al., 1988; Kirakowski & Cierlik, 1998; Kirakowski, 1995; Laugwitz et al., 2008; Lewis, 1992; Lund, 2001; Nielsen & Kaufmann, 1993). The research team assessed the items based on their relevance to our context, where navigation spans multiple screens and services rather than a single system. Furthermore, attention was given to the number of items, as the instrument needed to be completed quickly during lectures, while also capturing both utilitarian (performance-focused) and experiential (satisfaction-focused) aspects (Chung & Sahari, 2015).

Each researcher independently evaluated the questionnaires, after which the team discussed the results to reach a consensus. This process led to the selection of Nielsen's Usability Attributes (NAU) (Nielsen & Kaufmann, 1993), a flexible framework featuring five customizable attributes in a concise format. Additionally, NAU assesses both functional and experiential aspects, making it well-suited for evaluating federated access systems where functionality, security, and privacy are critical.

Although various NAU-based questionnaires exist in the literature (Benmoussa et al., 2019; Gonzalez-Holland et al., 2017; Halim et al., 2021; Latiar et al., 2024; Munir et al., 2019), none have been formally validated. Furthermore, while NAU attributes have been translated into multiple languages, no validated Italian version was available. For this study, we adopted Benmoussa's version and translated it into Italian. Two independent translators worked on the translation, and the drafts were merged by the research team to ensure consistency and accuracy. The term "system" was replaced with "procedure" to better suit the evaluation context.

A multi-method approach (Palmieri et al., 2020) was adopted for iterative data collection and adjustments over three phases, refining the instrument for optimal use.

### 2.2 Phase 1: Content Validation with Students

After completing the basic adaptation and translation, a content validity analysis was conducted to evaluate the instrument's coverage of usability domains (Bandalos, 2018) and to eliminate irrelevant items (Boudreau et al., 2001; Lewis et al., 1995). Additionally, the language was reviewed for clarity to ensure readability and comprehension.

Between September and December 2023, ten UniTS students participating in the T4EU mobility programs tested the federated access procedures for Moodle courses at four alliance institutions: the University of Alicante (UA), the University of Silesia (USil), Sofia University 'St. Kliment Ohridski' (SU), and Vytautas Magnus University (VMU). These universities were chosen for the pilot due to their successful implementation of federated authentication through EduGain. As such, five students tested each procedure, a sample size deemed sufficient to uncover approximately 85% of usability issues (Nielsen, 2012). The testing was conducted in moderated, face-to-face sessions, which were recorded for subsequent analysis. Usability feedback was collected in three stages:

- First Procedure Test and Overall Clarity Feedback: After testing the first federated access procedure, students completed the usability questionnaire and provided feedback on its overall clarity.
- Second Procedure Test and Item Clarity Feedback: In the second stage, students tested the procedure at a second institution, re-completed the questionnaire, and rated the clarity of each item on a five-point Likert scale. The moderator conducted cognitive interviews for items that received a score below 3.
- Coverage and Relevance Assessment: Students answered targeted questions to evaluate the relevance and coverage of the questionnaire items.

Recordings were qualitatively analysed using Atlas.ti. Two researchers independently coded the data, generating keywords a posteriori (Creswell, 2013). Inter-rater reliability reached 80%. Insights from this process informed a refined second version of the questionnaire.

### 2.3 Phase 2: Content Validation with Experts

The revised questionnaire was evaluated by ten UniTS usability experts, all with a minimum B2 level of English. Each expert tested one federated access procedure and assessed the questionnaire based on two criteria:

Language Clarity: Experts used a dichotomous scale ("Yes" for clear, "No" for unclear), providing justifications and reformulations for unclear items (Taherdoost, 2016). Clarity scores were averaged across all items to provide an overall assessment.

Content Validity: Experts rated item relevance using a 4-point Likert scale (Lawshe, 1975). Scores of 1-2 were considered irrelevant, while 3-4 were deemed relevant. The Content Validity Ratio (CVR) was calculated using Lawshe's formula, with items scoring $\geq$0.78 regarded as valid (Wilson et al., 2012). The Content Validity Index (CVI) was also calculated to assess the validity of the items.

Experts also recommended additional items to more effectively capture the user experience. Items with high CVR and CVI scores were either retained or refined for the development of the third version of the instrument.

### 2.4 Phase 3: Construct Validation with Students

Construct validity was evaluated through factor analysis (Strauss & Smith, 2009).

From March to April 2024, the revised questionnaire was administered to 145 UniTS students enrolled in *Computer Literacy*, *Introduction to Sports Psychology*, and *Perception*. Students tested one of four federated access procedures during face-to-face lectures, with absent participants completing the questionnaire via email.

Data analysis was performed using Jamovi 2.3.28. Confirmatory Factor Analysis (CFA) assessed the model fit of the 10-item instrument, applying absolute, incremental, and parsimonious fit indices. Exploratory Factor Analysis (EFA) was then conducted on a 12-item version to examine its data structure (Harman, 1976; Polit & Beck, 2006). EFA suitability was verified using the Kaiser-Meyer-Olkin (KMO) and Bartlett's test.

## 3. Results

### 3.1 Phase 1

The translation and adaptation of Benmoussa's (2019) NAU-based questionnaire resulted in the first version of the quesionnaire (VERSION 1), as detailed in Table 1A of the Appendix. The test results show that students consistently rated the language clarity highly, indicating effective comprehension of the items (Fig. 1 of the Appendix).

Despite the strong endorsement of language clarity, this finding is somewhat undermined by the user experience analysis and the overall feedback from participants during the test sessions. While only four items (2, 4, 6, and 10) received low clarity ratings from a single student, nearly all participants raised concerns. Specifically, the terms "procedure" and "screen" were frequently questioned. As students navigated multiple interfaces – moving from the partner university's Moodle login page to the home university for attribute authorization and back to Moodle to access the course – the term "procedure" failed to capture the full navigation path. This led to some confusion, with students uncertain whether they were evaluating the login process or the broader navigation within the LMS to reach the course. Similarly, "screen" was unclear, with participants unsure whether it referred to the login or course display.

The content validity analysis revealed a need for additional context-specific items. Some students suggested including items to assess navigation tools, layout clarity, translations, the logout confirmation message, and course registration details. For instance, one student recommended evaluating the interface's ability to inform users about their navigation context, while another noted the absence of an item clarifying the enrolment process (e.g., whether students are automatically enrolled or need to take action). Additionally, feedback from the Likert scale revealed the absence of a "not applicable" option for items related to errors (items 7 and 8), as some students were unable to provide a rating when no errors occurred.

Based on these findings, the research team revised the questionnaire, resulting in a second version (VERSION 2). To improve clarity, terms like "procedure" and "screen" were replaced with "navigation". It was clarified that "navigation" and "procedure", when retained, referred to the entire user journey, from federated login to course access. The questionnaire was also updated to cover all relevant domains, introducing the attribute 'Effectiveness' with two new items focused on evaluating information quality, including service descriptions and data privacy management during login (see Table 1A of the Appendix). Additionally, the Likert scale was modified to include a "not applicable" option, enhancing the tool's ability to capture the full range of user experiences.

3.2. Phase 2

The results demonstrate strong consensus among usability experts regarding the clarity of the items. Each item was evaluated on a scale where 1 indicates "clear" and 0 represents "unclear." The average score for each item was calculated from these ratings, offering a comprehensive assessment of clarity based on expert feedback (see Table 1).

**Table 1** - Language Clarity.

| | *ITEMS* | *Proportion of experts rating as clear* |
|---|---|---|
| *Learnability* | ITEM 1 | 1 |
| | ITEM 2 | 1 |
| *Efficiency* | ITEM 3 | 1 |
| | ITEM 4 | 1 |
| *Effectiveness* | ITEM 5 | 1 |
| | ITEM 6 | 1 |
| *Memorability* | ITEM 7 | 1 |
| | ITEM 8 | 1 |
| *Errors* | ITEM 9 | 1 |
| | ITEM 10 | 1 |
| *Satisfaction* | ITEM 11 | 1 |
| | ITEM 12 | 0.9 |

The findings regarding item relevance demonstrate that each item meets the established threshold, validating their inclusion in the final instrument (see Table 2A of the Appendix).

The content validity index (CVI) for the entire instrument was accurately calculated as the average of the CVR values for all items that reached the threshold of 0.78 and were retained in the final version (Kaiser, 1970). With a CVI score of 0.91, the instrument exhibits outstanding content validity, confirming its efficacy in assessing usability.

3.3. Phase 3

A total of 145 students completed the second version of the questionnaire after testing the access procedures for their assigned institutions, with responses detailed in Table 2. Five outliers were removed due to mean scores below 1 or above 3.90 (specifically 0.00, 0.75, 0.75, 0.92, and 4.00).

An ANOVA was conducted to assess potential differences in mean scores across institutions, which could indicate environmental impacts on the user experience. However, results showed no significant differences, with mean scores ranging from 2.44 to 2.66 (see Table 3A of the Appendix; see Figure 1), suggesting a consistent user experience across the institutions' access procedures.

**Table 2** - Number of tests of each access procedure.

| INSTITUTIONS | TESTS |
|---|---|
| UA | 38 |
| USil | 42 |
| VMU | 36 |
| JMU | 29 |
| TOTAL | 145 |

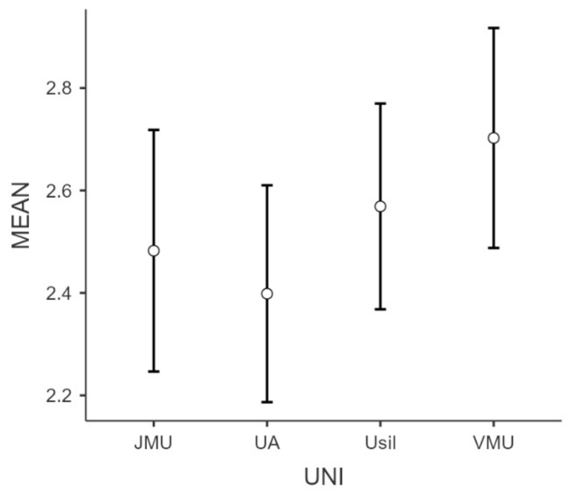


**Figure 1** - Graphic representation of the Anova.

A Confirmatory Factor Analysis (CFA) was performed on the data, excluding the two items related to the 'effectiveness' attribute. The objective was to evaluate how well the original five-dimensional NAU model aligned with the data and to determine whether the inclusion of an additional dimension was truly necessary. Absolute fit indices, including RMSEA (0.129) and SRMR (0.0729), indicated poor model fit, as values typically should be below 0.10 and 0.05, respectively (Browne & Cudeck, 1989; Creswell, 2013; Hu & Bentler, 1995; Miles & Huberman, 1994). Incremental fit indices, such as the CFI (0.861) and TLI (0.821), were below the acceptable threshold of 0.90 (Bentler, 1990; Browne & Cudeck, 1989). The parsimonious fit index, derived from the normalized chi-square ($\chi^2$ = 116) and Degrees of Freedom (DF = 35), gave a value of 3.31, indicating a slightly inadequate fit (Cole, 1987; Schermelleh-Engel et al., 2003).

These results showed that the five-dimensional NAU model did not fit well, prompting an Exploratory Factor

Analysis (EFA) that included items 5 and 6 from the new 'Effectiveness' dimension. Factor analysis suitability was confirmed with a KMO value above 0.80, indicating sufficient sample size for the EFA (Polit & Beck, 2006; Harman, 1976) (see Table 3).

Bartlett's sphericity test produced a p-value below 0.05, confirming significant relationships among the items and supporting the factorability of the variables (see Table 4).

**Table 3** - KMO Sampling Adequacy Measure.

| | MSA |
|---|---|
| Global | 0.868 |
| ITEM 1 | 0.859 |
| ITEM 2 | 0.880 |
| ITEM 3 | 0.925 |
| ITEM 4 | 0.784 |
| ITEM 5 | 0.871 |
| ITEM 6 | 0.898 |
| ITEM 7 | 0.892 |
| ITEM 8 | 0.864 |
| ITEM 9 | 0.773 |
| ITEM 10 | 0.844 |
| ITEM 11 | 0.868 |
| ITEM 12 | 0.904 |

**Table 4** - Bartlett's Test of Sphericity.

| $\chi^2$ | df | p |
|---|---|---|
| 695 | 66 | < .001 |

EFA was performed using the 'maximum likelihood' extraction method with 'oblimin' rotation. Before this, skewness and kurtosis analysis confirmed the normal distribution of the data (see Table 4A of the Appendix). Oblique rotation was chosen to account for inter-factor relationships, providing a more accurate representation of the theoretical constructs. Factor loadings of 0.4 or higher were considered significant.

The responses to items 9 and 10, where no error occurred, were treated as missing data in the EFA to maintain the integrity of the dataset and avoid the exclusion of incomplete cases (Bentler & Mooijaart, 1989). Removing these responses could introduce biases and result in the loss of valuable information. To mitigate this risk and in accordance with 'Guideline 1: Use All Available Data' (Newman, 2009, 2014), all 140 cases were included in the analysis. The results confirmed that six factors should be retained (see Table 5A in the Appendix).

The scree plot (Figure 2) shows the relationship between the number of factors and their eigenvalues.

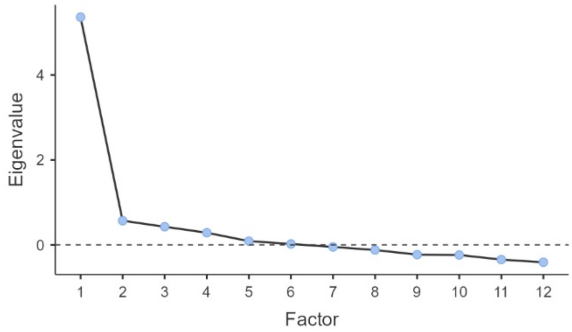


**Figure 2** - Scree plot.

The first six factors collectively explain 72.8% of the total variance (see Table 6A in the Appendix), which falls within the commonly accepted range of 70% to 80% for factor extraction (Geisen & Bergstrom, 2017), although according to the Kaiser–Guttman rule (Kaiser, 1960), only the first factor shows an eigenvalue greater than 1. The results also indicate that Items 3 and 12 should be removed, as their factor loadings fall below the acceptable threshold of 0.4.

## 4. Discussion

The process of selecting the most appropriate instrument for assessing the usability of federated access in online courses within higher education mobility programs has proven highly effective for our purposes, given the specific characteristics of the scenario. A key takeaway is the critical importance of adopting a rigorous, context-driven approach when choosing a usability instrument.

Indeed, a thorough analysis of the Moodle ecosystem, revealed several crucial considerations. For instance, federated access to online courses involves a relatively straightforward procedure consisting of sequential actions, which users are likely to repeat across various local Moodle environments. Navigation spans multiple screens and services rather than being confined to a single system. Furthermore, the authentication and access processes are governed by the eduGain Policies Framework, which necessitates addressing critical issues such as informed consent, cookie usage, and compliance with privacy regulations—factors that significantly influence the navigation and the overall user experience.

As such, the usability evaluation of utilitarian aspects that are linked to the functionality, security, and privacy compliance plays a fundamental role in federated access systems. Given the routine nature of the tasks and their sequential nature, efficiency also emerged as a pivotal usability criterion. Measuring these aspects is therefore a priority over more "hedonic" aspects, which instead concern the pleasure, engagement, and emotional satisfaction derived from interacting with the system. The analysis also underscored the need for a concise usability instrument with a limited number of items to ensure the evaluation remains both comprehensive and manageable. These insights helped address the first research question, ultimately leading to the selection of the NAU questionnaire as the most suitable instrument for measuring the usability of federated access in online courses after a deliberative process involving consensus among the researchers.

The content validation results also highlighted the need for a change in the test administration method. Given that students perceived authentication and course access as distinct phases, future studies could improve usability assessments by gathering feedback at two separate points in the process: once immediately after federated access and again after course access (see Table 7A in the Appendix). Adopting a ‘usability testing with prompt’ approach (Hair et al., 2010; Lazar et al., 2017; Shneiderman et al., 2017), supported by specialized software (e.g., UserTesting, Maze, Lookback, Hotjar, UXTweak), would allow questions to be asked at critical navigation points, providing real-time feedback and clearer insights into user interactions and decision-making.

The assessment of the instrument’s effectiveness in measuring the usability of federated access to online courses in higher education mobility programs was crucial for addressing the second research question. Furthermore, regarding the validation of the six-factor solution — Learning, Efficiency, Memorability, Error, Satisfaction, and Effectiveness (see Tables 1 and 9 in the Appendix) although the Kaiser criterion was not met for five of the factors, retaining all six was considered appropriate. This decision was supported by the scree plot analysis, which revealed an elbow indicative of a multifactorial solution, and by the cumulative variance explained which meets the commonly accepted threshold for adequately representing the latent structure.

In line with the ISO 9241-11 standard (ISO, 1998), ‘effectiveness’ emerged as a crucial attribute in measuring usability, particularly in online or hybrid mobility contexts. The cognitive interviews also underscored the importance of clear instructions and timely responses in effectively guiding users through the federated access. Given the complexity and unfamiliarity of the procedure for students, the information provided should not only address basic navigation but also offer comprehensive support that spans the entire virtual mobility experience, ensuring students feel confident and informed at every stage.

The findings also indicated that to improve model accuracy, only 10 of the original 12 items should be retained. Items 3 and 12 were found to inadequately capture key aspects, due to low factor loadings, and require rewording to reduce misinterpretation.

Item 3, “I easily found the information I was looking for,” under ‘Efficiency,’ originally from the NAU questionnaire (Benmoussa et al., 2019), focuses on searching for information, which is more relevant to web navigation than to the task of accessing a course. A reworded version removing “information” would better reflect the task at hand.

Item 12, originally measuring satisfaction with “This system has all the functions and potential corresponding to my expectations,” faced issues based on expert feedback. The term “potential” was deemed inappropriate for an access procedure, and users had unclear expectations. Replacing “potential” with “effectiveness” still did not capture satisfaction adequately. A revised item, such as “The features available for accessing the course meet my expectations,” would perhaps more accurately measure satisfaction, especially when combined with Item 11, which assesses interface pleasantness.

Rewording items 3 and 12 requires thorough re-evaluation to ensure they align with the usability construct. Content validation by subject matter experts and a new factor analysis are needed to verify the items’ validity and ensure they contribute meaningfully to the overall measurement.

The factor loadings of items 3 and 12, while valuable, suggest an opportunity to enhance the robustness of the findings. Factor analysis benefits from a larger sample size, with recommendations typically ranging from 100 to 400 participants, depending on the number of variables and data characteristics (Guilford, 1956; Stevens, 2002). By expanding the sample size, future analyses could offer even more precise population estimations and more reliable inferences, further strengthening the validity of the results.

In summary, the study’s findings suggest the following actions:

- Methodological Modification: Implement a ‘usability testing with prompt’ approach (Geisen & Bergstrom, 2017; Lazar et al., 2017; Shneiderman et al., 2017) to administer questions at critical navigation points, which will be evaluated in future surveys.
- Item Reformulation: Revise the problematic items to better align with the model’s construct, improving accuracy and consistency. This revision will require expert validation and a new factor analysis with a larger student sample.

## 5. Conclusions

This study aimed to identify effective methods for assessing the usability of federated access to online courses in higher education mobility programs and to develop a validated instrument for academic institutions to evaluate the usability of their federated online offerings. The outcome is a tailored questionnaire created through an iterative process that included contextual analysis, instrument selection, adaptation, user feedback, re-adaptation, and final validation. Participants completed a scenario-based task comprising two key steps: (a) authenticating via institutional credentials on a partner university's login page, and (b) locating and accessing T4EU courses on the partner university's Moodle platform.

The study also recommends adopting a "usability test with prompts" approach in future implementations to streamline question administration. Factor analysis revealed multiple dimensions consistent with the adapted NAU model, while also indicating the need for replication with larger samples. Some items did not fully capture key aspects of the latent variable, suggesting the need for targeted refinement in subsequent testing.

This work establishes a foundational instrument for evaluating the usability of interoperable Single Sign-On (SSO) LMS solutions. Its application to the T4EU federated Moodle—which continues to expand across partner institutions and courses—offers opportunities for further insights and comprehensive validation. The findings underscore the importance for T4EU member institutions to regularly use this instrument, as ongoing testing not only refines the evaluation process but also identifies specific areas for improvement within the Transform4Europe Moodle ecosystem, ultimately enhancing the user experience across the alliance.

Future research should explore variations in EFA scores across partner countries and academic disciplines, as well as factors influencing these differences, including users' ICT skills, fields of study, and prior experience with federated access interfaces. Additional usability dimensions—such as accessibility, device and browser compatibility, and support for users with disabilities—also warrant investigation. These efforts will strengthen the usability assessment framework and contribute to improving the overall experience for students engaging with federated access within a European University Alliance.

## Acknowledgements

This research was carried out within the framework of the Transform4Europe project (Grant Agreement No. 101035805). The authors wish to express their sincere appreciation to the partner universities of the Transform4Europe Alliance for their collaboration and support. Special thanks are extended to Prof. Tiziano Agostini and Prof. Carlo Fantoni, both from the University of Trieste (Italy), whose contribution in recruiting students for their courses and facilitating the collection of valuable feedback during lectures was essential to this study. The content of this article reflects solely the views of the authors, and the European Commission as well as the Transform4Europe Alliance bear no responsibility for any use that may be made of the information contained herein.

## References

Bandalos, D. L. (2018). *Measurement theory and applications for the social sciences*. Guilford.

Benmoussa, K., Laaziri, M., Khoulji, S., Kerkeb, M. L., & Yamami, A. E. (2019). AHP-based approach for evaluating ergonomic criteria. *Procedia Manufacturing, 32*, 856-863. https://doi.org/10.1016/j.promfg.2019.02.294

Berger, F., Galati, N., & Witteler, S. (2023). *Making interoperability work, challenges and solutions for an interoperable higher education system*. https://hochschulforumdigitalisierung.de/sites/default/files/dateien/HFD_report_no.72_Making_interoperability_work.pdf

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238–246. https://doi.org/10.1037//0033-2909.107.2.238

Bentler, P. M., & Mooijaart, A. B. (1989). Choice of structural model via parsimony: A rationale based on precision. *Psychological Bulletin, 106*(2), 315–317.

Boudreau, M., Gefen, D., & Straub, D. (2001). Validation in IS research: A state-of-the-art assessment. *MIS Quarterly, 25*, 1–24.

Brooke, J. (1996). SUS: A "quick and dirty" usability scale. In P. Jordan, B. Thomas, & B. Weerdmeester (Eds.), *Usability evaluation in industry* (pp. 189-194). Taylor & Francis.

Browne, M. W., & Cudeck, R. (1989). Single sample cross-validation indices for covariance structures. *Multivariate Behavioral Research, 24*(4), 445–455.

Byne, B. M. (2010). *Structural equation modeling with Amos: Basic concepts, applications, and programming* (2nd ed.). Routledge-Taylor and Francis Group.

Chin, J. P., Diehl, V. A., & Norman, K. L. (1988). Development of an instrument measuring user satisfaction of the human-computer interface. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 213-218).

Chung, T. K., & Sahari, N. (2015). Utilitarian or experiential? An analysis of usability questionnaires. *International Journal of Computer Theory and Engineering, 7*(2), 167-171.

Cole, D. A. (1987). Utility of confirmatory factor analysis in test validation research. *Journal of Consulting and Clinical Psychology, 55*(4), 584–594.

Comrey, A. L., & Lee, H. B. (1992). *A first course in factor analysis* (2nd ed.). Erlbaum.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage Publications.

Diamantopoulos, A., & Siguaw, J. A. (2000). *Introducing LISREL*. Sage Publications.

Gaebel, M., Zhang, T., Stoeber, H., & Morrisroe, A. (2021). *Digitally enhanced learning and teaching in European higher education institutions*. European University Association absl.

Galende, B. A., Mayoral, S. U., García, F. M., & Lottmann, S. B. (2023). FLIP: A new approach for easing the use of federated learning. *Applied Sciences, 13*(6), 3446. https://doi.org/10.3390/app13063446

Geisen, E., & Bergstrom, J. R. (2017). *Usability testing for survey research*. Morgan Kaufmann.

Gilbert, G. E., & Prion, S. (2016). Making sense of methods and measurement: Lawshe's content validity index. *Clinical Simulation in Nursing, 12*(12), 530–531.

Gonzalez-Holland, E., Whitmer, D., Moralez, L., & Mouloua, M. (2017). Examination of the use of Nielsen's 10 usability heuristics & outlooks for the future. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 61, No. 1, pp. 1472-1475). https://doi.org/10.1177/1541931213601853

Gorsuch, R. L. (1983). *Factor analysis* (2nd ed.). W. B. Saunders.

Guadagnoli, E., & Velicer, W. F. (1988). Relation of sample size to the stability of component patterns. *Psychological Bulletin, 103*(2), 265–275.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2010). *Multivariate data analysis* (7th ed.). Pearson.

Halim, E., Soeprapto Putri, N. K., Anisa, N., Arif, A. A., & Hebrard, M. (2021). Usability testing of vocabulary game prototype using the Nielsen's attributes of usability (NAU) method. In *Proceedings of the 2021 International Conference on Information Management and Technology* (pp. 590-594). https://doi.org/10.1109/ICIMTech53080.2021.9534970

Harman, H. H. (1976). *Modern factor analysis*. University of Chicago Press.

Hodrien, A., & Fernando, T. (2021). A review of post-study and post-task subjective questionnaires to guide assessment of system usability. *Journal of Usability Studies, 16*(3), 203-232.

Hu, L. T., & Bentler, P. M. (1995). Evaluating model fit. In R. Hoyle (Ed.), *Structural equation modeling: Issues, concepts, and applications* (pp. 76–99). Sage.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1–55.

ISO. (2018). *Ergonomic requirements for office work with visual display terminals (VDTs)—Part 11: Guidance on usability* (ISO 9241-11).

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement, 20*(1), 141–151. https://doi.org/10.1177/001316446002000116

Kaiser, H. F. (1970). A second generation little jiffy. *Psychometrika, 35*, 401–415.Kass, N. L., & Tinsley, R. L. (1979). Factor analysis of psychological and educational data. *Journal of Educational Psychology, 71*(6), 844–855.

Kirakowski, J. (1995). Evaluating usability of the human-computer interface. In *Advances in Human-Computer Interaction: Human Comfort and Security* (pp. 21-32). Springer Berlin Heidelberg.

Kirakowski, J., & Cierlik, B. (1998). Measuring the usability of web sites. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 42, No. 4, pp. 424-428).

Latiar, H., Dwi, M., & Nining, S. (2024). Evaluation of repository usability test using Nielsen's attributes of usability (NAU) model in libraries. *Jurnal Ilmu Perpustakaan dan Informasi, 9*(1).

Laugwitz, B., Held, T., & Schrepp, M. (2008). Construction and evaluation of a user experience questionnaire. In *Proceedings of the 4th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society* (pp. 63-76). Springer Berlin Heidelberg.

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology, 28*(4), 563–575.

Lazar, J., Feng, J. H., & Hochheiser, H. (2017). *Research methods in human-computer interaction*. Morgan Kaufmann.

Lewis, B. R., Snyder, C. A., & Rainer, K. R. (1995). An empirical assessment of the Information Resources Management construct. *Journal of Management Information Systems, 12*, 199-223.

Lewis, J. R. (1992). Psychometric evaluation of the post-study system usability questionnaire: The PSSUQ. In *Proceedings of the Human Factors Society Annual Meeting* (Vol. 36, No. 16, pp. 1259-126

Lund, A. (2001). Measuring usability with the USE questionnaire. *Usability Interface, 8*, 3-6.

MacCallum, R. C., Widaman, K. F., Zhang, S., & Hong, S. (1999). Sample size in factor analysis. *Psychological Methods, 4*(1), 84–99.

Medsker, G. J., Williams, L. J., & Holahan, P. J. (1994). A review of current practices for evaluating causal models in organizational behavior and human resource management research. *Journal of Management, 20*, 439–464.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Sage Publications.

Munir, S., Rahmatullah, A., Saptono, H., & Wirani, Y. (2019). Usability evaluation using NAU method on web design technique for web portal development in STT Nurul Fikri. In *Proceedings of the 2019 Fourth International Conference on Informatics and Computing* (pp. 1-6). https://doi.org/10.1109/ICIC47613.2019.8985913

Newman, D. A. (2009). Missing data techniques and low response rates: The role of systematic nonresponse parameters. In C. E. Lance & R. J. Vandenberg (Eds.), *Statistical and methodological myths and urban legends: Doctrine, verity, and fable in the organizational and social sciences* (pp. 7–36). New York, NY: Routledge.

Newman, D. A. (2014). Missing data: Five practical guidelines. *Organizational Research Methods, 17*(4), 372–411.

Nielsen, J. (2012). How many test users in a usability study. Nielsen Norman Group. https://www.nngroup.com/articles/how-many-test-users/

Nielsen, J., & Kaufmann, M. (1993). *Usability engineering*. Morgan Kaufmann.

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). New York, NY: McGraw-Hill.

Osborne, J. L., & Costello, M. S. (2004). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research, and Evaluation, 9*(1), 1–10.

Palmieri, P. A., Leyva-Moral, J. M., Camacho-Rodriguez, D. E., Granel-Gimenez, N., Ford, E. W., Mathieson, K. M., & Leafman, J. S. (2020). Hospital survey on patient safety culture (HSOPSC): A multi-method approach for target-language instrument translation, adaptation, and validation to improve the equivalence of meaning for cross-cultural research. *BMC Nursing, 19*, 1-13.

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing & Health, 29*, 489–497.

Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing & Health, 30*, 459–467.

Ruoti, S., Roberts, B., & Seamons, K. (2015). Authentication melee: A usability analysis of seven web authentication systems. In *Proceedings of the 24th International Conference on World Wide Web* (pp. 916-926).

Sagar, K., & Saha, A. (2017). A systematic review of software usability studies. *International Journal of Information Technology*, 1-24. https://doi.org/10.1007/s41870-017-0048-1

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online, 8*(2), 23–74.

Shneiderman, B., Plaisant, C., Cohen, M. S., Jacobs, S. M., & Elmqvist, N. (2017). *Designing the user interface: Strategies for effective human-computer interaction*. Pearson.

Stevens, J. (2002). *Applied multivariate statistics for the social sciences* (4th ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Strauss, M. E., & Smith, G. T. (2009). Construct validity: Advances in theory and methodology. *Annual Review of Clinical Psychology, 5*, 1-25. https://doi.org/10.1146/annurev.clinpsy.032408.153639

Tabachnick, L., & Fidell, C. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Pearson.

Taherdoost, H. (2016). Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in a research. *International Journal of Academic Research in Management (IJARM), 5*.

Vlachogianni, P., & Tselios, N. (2023). Perceived usability evaluation of educational technology using the post-study system usability questionnaire (PSSUQ): A systematic review. *Sustainability, 15*(17), 12954. https://doi.org/10.3390/su151712954

Wilson, F. R., Pan, W., & Schumsky, D. A. (2012). Recalculation of the critical values for Lawshe's content validity ratio. *Measurement and Evaluation in Counseling and Development, 45*(3), 197–210.

# Appendix: tables and figures

**Figure 1** - Average rate of language clarity per item.

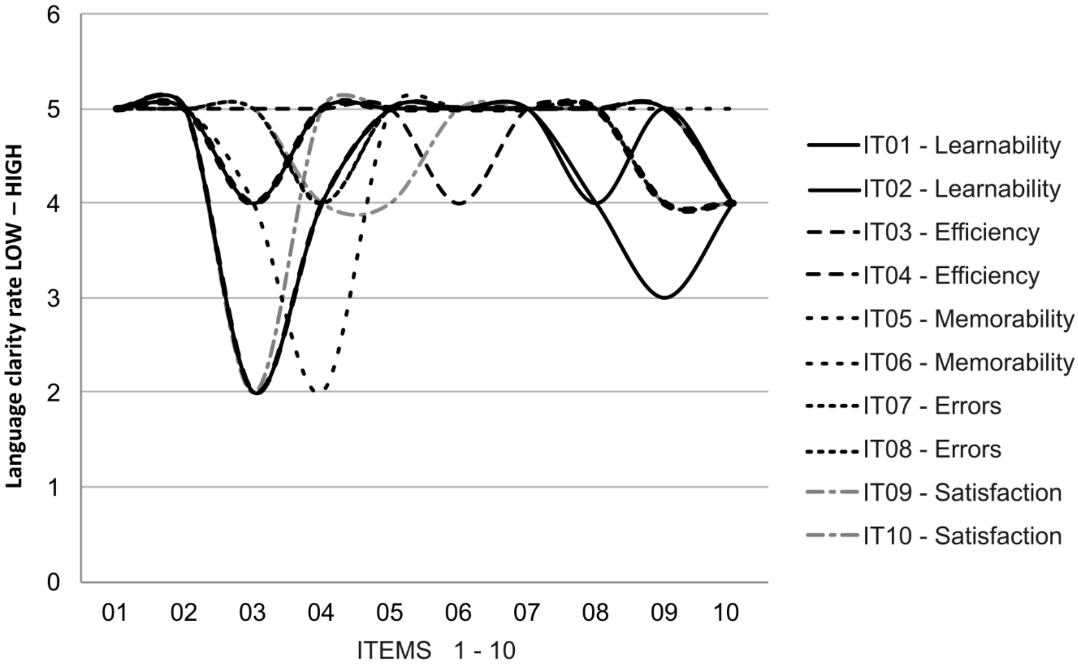


**Table 1A** - Translation and adaptations of the NAU-based questionnaire.
VERSION 1: after 1st translation and adaptation, administered to students in Phase 1.
VERSION 2: after 2nd translation and adaptation, administered to usability experts in Phase 2.

| *ATTRIBUTES* | *ITEMS* | *VERSION 1* | *VERSION 2* | *N.* |
|---|---|---|---|---|
| Learning | This system is simple to use | Questa procedura di accesso è semplice da svolgere<br><br>This access procedure is easy to perform. | Questa procedura di accesso al corso è facile da svolgere<br><br>This procedure for accessing the course is easy to perform | 1 |
| | The information provided with this system is easy to understand | Le informazioni fornite durante la procedura sono facili da capire<br><br>The information provided during the procedure is easy to understand | Le informazioni fornite durante la navigazione sono facili da capire<br><br>The information provided during navigation is easy to understand | 2 |
| Efficiency | I easily found the information I am looking for | Ho trovato facilmente le informazioni che cercavo<br><br>I easily found the information I was looking for | Ho trovato facilmente le informazioni che cercavo<br><br>I easily found the information I was looking for | 3 |
| | I was able to quickly complete my task with this system | Svolgendo questa procedura sono riuscito/a ad accedere rapidamente al corso<br><br>By carrying out this procedure I was able to quickly access the course | Sono riuscito/a ad accedere rapidamente al corso erogato dall'ateneo partner<br><br>I was able to quickly access the course provided by the partner university | 4 |

| *ATTRIBUTES* | *ITEMS* | *VERSION 1* | *VERSION 2* | *N.* |
|---|---|---|---|---|
| Effectiveness | | | Le informazioni fornite durante la navigazione mi hanno permesso di accedere al corso<br><br>The information provided during navigation allowed me to access the course | 5 |
| | | | Il layout delle schermate (icone, pulsanti, barre di navigazione, selezione della lingua e link) mi ha aiutato ad accedere al corso<br><br>The layout of the screens (icons, buttons, navigation bars, language selection and links) helped me access the course | 6 |
| Memorability | The organisation of information in the system screens is clear | L'organizzazione delle informazioni nelle schermate è chiara<br><br>The organisation of information in the screens is clear | L'organizzazione delle informazioni incontrate durante la navigazione è chiara<br><br>The organisation of information encountered during navigation is clear | 7 |
| | The system is easy to remember | La procedura è facile da ricordare<br><br>The procedure is easy to remember | La procedura di accesso al corso è facile da ricordare<br><br>The course access procedure is easy to remember | 8 |
| Error | The error messages presented by this system tell me clearly how to solve problems | I messaggi di errore presentati nello svolgimento della procedura mi dicono chiaramente come risolvere i problemi<br><br>The error messages presented in the procedure clearly tell me how to solve the problems | I messaggi di errore presentati durante la navigazione mi dicono chiaramente come risolvere i problemi<br><br>The error messages presented during navigation clearly tell me how to solve the problems | 9 |
| | When I made a mistake using this system, it was easy and quick to correct it | Quando ho commesso un errore durante la procedura, è stato facile e veloce correggerlo<br><br>When I made a mistake during the procedure, it was quick and easy to correct it | Quando ho commesso un errore durante la procedura di accesso al corso, è stato facile e veloce correggerlo<br><br>When I made a mistake during the course access procedure, it was quick and easy to correct it | 10 |
| Satisfaction | The interface of this system is nice | Le interfacce per questa procedura sono piacevoli<br><br>The interfaces for this procedure are nice | Le interfacce per questa procedura sono piacevoli<br><br>The interfaces for this procedure are nice | 11 |
| | This system has all the functions and the potential corresponding to my expectations | Questa procedura di accesso ha tutte le funzioni e le potenzialità che corrispondono alle mie aspettative<br><br>This access procedure has all the functions and potential to match my expectations | Questa procedura di accesso al corso ha l'efficacia e le funzioni che mi aspetterei<br><br>This course access procedure has the effectiveness and functions I would expect | 12 |

**Table 2A** - Content Validity Ratio.

| | ITEMS | CVR per ITEM | CVI |
|---|---|---|---|
| Learnability | ITEM 1 | 1 | 0.91 |
| | ITEM 2 | 1 | |
| Efficiency | ITEM 3 | 1 | |
| | ITEM 4 | 1 | |
| Effectiveness | ITEM 5 | 1 | |
| | ITEM 6 | 1 | |
| Memorability | ITEM 7 | 1 | |
| | ITEM 8 | 0.80 | |
| Errors | ITEM 9 | 0.80 | |
| | ITEM 10 | 0.80 | |
| Satisfaction | ITEM 11 | 1 | |
| | ITEM 12 | 0.60 | |

**Table 3A** - Anova.

| | UNI | N | Mean | SD | SE |
|---|---|---|---|---|---|
| MEAN | USil | 40 | 2.57 | 0.528 | 0.0834 |
| | VMU | 36 | 2.66 | 0.648 | 0.1081 |
| | JMU | 29 | 2.48 | 0.718 | 0.1333 |
| | UA | 35 | 2.44 | 0.705 | 0.1192 |

**Table 4A** - Skewness and kurtosis.

| Items | N | Missing | Skewness | Kurtosis |
|---|---|---|---|---|
| 1 | 140 | 0 | -0.759 | 0.128 |
| 2 | 140 | 0 | -0.693 | 0.148 |
| 3 | 140 | 0 | -0.429 | -0.350 |
| 4 | 140 | 0 | -0.549 | -0.401 |
| 5 | 140 | 0 | -0.734 | 0.554 |
| 6 | 140 | 0 | -0.576 | -0.0501 |
| 7 | 140 | 0 | -0.477 | -0.091 |
| 8 | 140 | 0 | -0.848 | 0.830 |
| 9 | 117 | 23 | -0.460 | 0.0443 |
| 10 | 120 | 20 | -0.450 | 0.0328 |
| 11 | 140 | 0 | -0.518 | 0.275 |
| 12 | 140 | 0 | -0.740 | 0.283 |

**Table 5A** - Exploratory Factor Analysis.

| | 1 | 2 | 3 | 4 | 5 | 6 | Uniqueness |
|---|---|---|---|---|---|---|---|
| ITEM 1 | | | 0.578 | | | | 0.37554 |
| ITEM 2 | | | 0.833 | | | | 0.17098 |
| ITEM 3 | | | | | | | 0.37433 |
| ITEM 4 | | 0.975 | | | | | 0.00945 |
| ITEM 5 | | | | | | 0.526 | 0.39368 |
| ITEM 6 | | | | | | 0.600 | 0.29579 |
| ITEM 7 | | | | | 0.772 | | 0.20622 |
| ITEM 8 | | | | | 0.400 | | 0.60186 |
| ITEM 9 | 0.967 | | | | | | 0.10034 |
| ITEM 10 | 0.615 | | | | | | 0.40322 |
| ITEM 11 | | | | 0.985 | | | 0.00500 |
| ITEM 12 | | | | | | | 0.32645 |

**Table 6A** - Factor Loadings.

| Factor | SS Loadings | % of Variance | Cumulative % |
|---|---|---|---|
| 1 | 1.702 | 14.18 | 14.2 |
| 2 | 1.535 | 12.79 | 27.0 |
| 3 | 1.639 | 13.66 | 40.6 |
| 4 | 1.406 | 11.72 | 52.4 |
| 5 | 1.523 | 12.69 | 65.0 |
| 6 | 0.932 | 7.77 | 72.8 |

**Table 7A** - Proposed rewording for items 3 and 12.

| Attribute | ITEM | | Reformulation |
|---|---|---|---|
| Efficiency | 3 | Ho trovato facilmente le informazioni che cercavo<br><br>I easily found the information I was looking for | Ho trovato facilmente quello che cercavo<br><br>I easily found what I was looking for |
| Satisfaction | 12 | Questa procedura di accesso al corso ha l'efficacia e le funzioni che mi aspetterei<br><br>This course access procedure has the effectiveness and functions I would expect | Le funzionalità disponibili per l'accesso al corso corrispondono alle mie aspettative<br><br>The features available for accessing the course meet my expectations. |

JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 21, No. 2 (2025), pp. 44-60

# Conceptual Knowledge Representation: a semantic model for Smart Learning Environments in an IoT-enabled Smart Campus

Soulakshmee Nagowah[a,1], Hatem Ben Sta[b], Baby Gobin-Rahimbux[a]

[a]*University of Mauritius (Mauritius)*

[b]*University of Tunis (Tunisia)*

*(submitted: 16/8/2024; accepted: 31/8/2025; published: 27/10/2025)*

**Abstract**

Smart learning environments (SLE) have been greatly enhanced lately by the adoption of cutting-edge technologies such as Internet-of-Things (IoT), Artificial Intelligence, Augmented Reality, Cloud Computing and Learning Analytics among others. Huge amounts of heterogeneous data are being exchanged between numerous devices, sensors and "things" used by students, educators and educational institutions. This heterogeneity hinders seamless communication among different systems pertaining to SLE. A smart campus is an example of a smart learning environment involving different systems such as smart learning management system, personalized learning, e-learning, assessment, smart classroom and smart library system among others. These systems often need to collaborate to enhance the teaching and learning process. To allow seamless communication among these systems, semantic interoperability has to be tackled by the adoption of a shared common data model. Ontologies are viewed as a potential way to ensure semantic interoperability. Several ontologies exist in the smart learning domain. However, none of them represents a smart learning environment for an IoT-enabled smart campus. This paper presents a semantic model entitled *SmartLearningOnto* that aims to model different aspects of a smart learning environment in a smart campus. The proposed ontology facilitates exchange of data among several systems in a smart campus by defining the concepts related to smart learning in an appropriate way. Furthermore, it infers new knowledge to enrich the learning experience of learners. SPARQL queries have been used to answer competency questions. Furthermore, several metrics along with expert evaluation have been used to evaluate *SmartLearningOnto*.

**KEYWORDS:** Smart Learning Environment, Smart Learning, IoT, Semantic Interoperability, Ontology.

**DOI**
https://doi.org/10.20368/1971-8829/1136004

**CITE AS**
Nagowah, S., Ben Sta, H., & Gobin-Rahimbux, B. (2025). Conceptual Knowledge Representation: a semantic model for Smart Learning Environments in an IoT-enabled Smart Campus. *Journal of e-Learning and Knowledge Society*, *21*(2), 44-60. https://doi.org/10.20368/1971-8829/1136004

## 1. Introduction

With the emergence of ICT in education, learning has changed considerably in the past years. The usage of advanced technologies such as mobile devices and IoT in learning has reshaped the learning and teaching process and has given rise to SLE. With the adoption of digital, context-aware and adaptive devices supported by proper tools and AI techniques, the learning process is enhanced (Tabuenca et al., 2024). SLE further allows appropriate adjustments with respect to the learner's knowledge and ability, facilitating student-learning experience (Kavashev, 2024). A smart campus is an example of a SLE where smart education services are delivered to students to nurture innovative skills and talents (Dong et al., 2020). The smart campus promotes smart learning where usage of cutting-edge technologies predominates to allow learners to acquire knowledge and gain a richer learning experience (Çelik & Baturay, 2024).

Several systems in the Smart Learning domain collaborate to support learning and make the learning and teaching process more efficient. Based on a systematic literature review, Muhamad et al. (2017) classify the following systems under the Smart Learning domain: Smart Learning Management, Personalized Learning, Assessment, Smart Classroom

[1] corresponding author - email: s.ghurbhurrun@uom.ac.mu

and Smart Library. Smart Learning management refers to activities that help to support the teaching process such as course syllabus, meeting schedule and student attendance among others (Iqbal et al., 2020). Personalized learning refers to education tailored and adjusted based on an individual learner's conditions, abilities, preferences, background knowledge, interests, goals, evolving skills and knowledge (Shemshack & Spector, 2020). Personalized learning aims to increase the learner's motivation and engagement. Assessment refers to the evaluation of the learner's work and make appropriate judgement regarding the quality of work (Nagowah & Nagowah, 2009). Smart classroom represents a transition from the traditional ways of working to a digital way of working using classroom resources (Hossenally et al., 2022). Smart libraries support the teaching and learning process by providing additional resources such as books and other materials (Sungkur et al., 2019). Both smart classrooms and smart libraries have the capability of capturing the needs of the users to promote personalized learning. These different systems in the Smart Learning domain are inter-connected. Therefore, they need to collaborate to share data in order to take proper decisions.

Interoperability is reported as one major challenge to be addressed to ensure seamless communication among the different systems in SLE (Chituc, 2020). Semantic interoperability is one type of interoperability linked with the meaning of data that is being exchanged by communicating parties (Kiljander et al., 2014). Different vocabularies are used to represent data in different systems. Therefore, to achieve semantic interoperability, it is of paramount importance that the exact meaning of the data be precisely understood so that the data can be exchanged and translated among systems (Heflin & Hendler, 2000). Ontology-based models can be used to represent knowledge and promote semantic interoperability (Ghawi & Cullot, 2007).

Developing an ontology is the first step in the journey for interoperability (Scrocca et al., 2021). An ontology plays an important role in providing a common shared data model of a particular domain where the whole knowledge of the domain can be represented (Carbonaro, 2020). Gruber (1993) define an ontology as an ''explicit specification of a conceptualization''. Ontologies are capable of resolving semantic heterogeneity of the information coming from underlying devices in SLE due to the agreed vocabulary and common understanding they provide (Elsaleh et al., 2020). Furthermore, ontologies provide numerous benefits such as reasoning, reusability, sharing and machine-understandable (Ouf et al., 2017). This paper thus suggests an ontology that represents the smart learning domain in an IoT-enabled smart campus environment to allow data from different systems to be interconnected in that environment.

The remaining part of the paper is structured as follows: Section 2 describes related ontologies developed in the domain of smart learning. Section 3 describes the materials and methods section where the methodology to come up with a new semantic model to represent the knowledge in the smart learning domain along with rules adopted for reasoning is detailed. In section 4, results and discussions are presented along with the evaluation of the ontology. Finally, section 5 presents the conclusion of the paper and elaborates on future work.

## 2. Background

Ontologies are viewed as the future of learning environment (Ouf et al., 2016). To come up with an ontology for the smart learning domain, this section reviews existing ontologies in the learning/smart learning domain. Figure 1 shows a summary of ontologies related to Smart Learning domain.

Kultsova et al. (2015) have proposed an ontology-based content management system to manage the learning process. Ouf et al. (2017) made use of ontologies namely the *Learner Model Ontology*, the *Learning Object Ontology,* the *Learning Activities Ontology* and the *Teaching Methods Ontology* to personalize learning environments based on the preferences and needs of learners. Yu et al. (2007) have proposed three ontologies in the context of e-learning namely the *Learner Ontology*, the *Learning Content Ontology* and the *Domain Ontology*. Castellanos-Nieves et al. (2011) have proposed an ontology entitled *OeLe*. The ontology defines vocabulary for concepts such as course, teacher, student, exam, questions, answers and so on. Litherland et al. (2013) have used *OeLe* for e-assessment of the accounting domain. Both summative and formative assessment were tackled. Khdour (2020) presented the *Expanded Course Ontology* where concepts like Course, Student, Teacher, Exam and Question are described. A number of ontologies have been developed to represent course information. One example is the *OLOUD* ontology proposed by Fleiner et al. (2017). *OLOUD* represents course information such as curricula, subjects, courses, semesters, personnel, buildings and events in a university campus, based on Hungarian concepts. *CURONTO* is another ontology designed for Curriculum Representation (Al-Yahya et al., 2014).

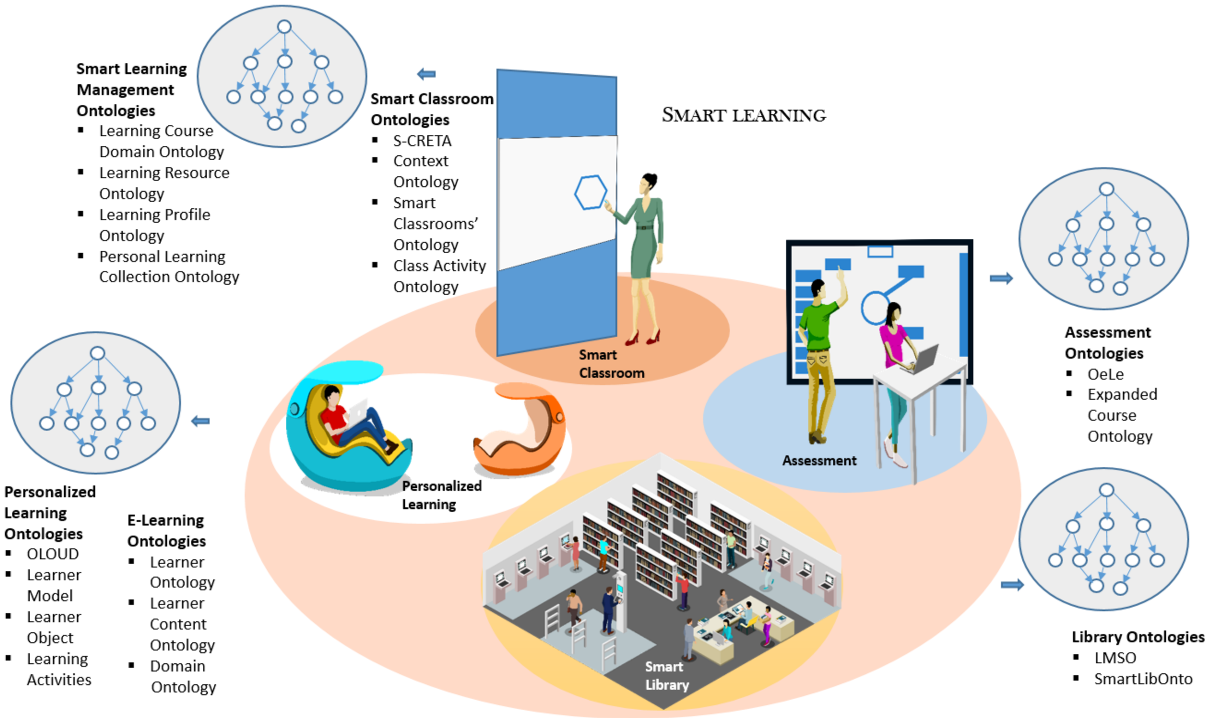


**Figure 1** - Ontologies in the Learning/Smart Learning domain.

Several ontologies have been proposed in the context of smart classroom namely *S-CRETA* (Maria et al., 2012), *Context Ontology* (Shi et al., 2010), *Smart Classrooms' Ontology* (Uskov et al., 2015) and *Class Activity Ontology* (Martinez et al., 2024). While *S-CRETA* and *Class Activity Ontology* focus mainly on activity detection in a smart classroom and laboratory respectively, *Context Ontology* lays emphasis mainly on capturing contextual information to promote reasoning. Uskov et al. (2015) proposed the *Smart Classrooms' Ontology* but did not implement the ontology. Nagowah et al. (2019) proposed the Smart Classroom ontology that fits the context of an IoT-enabled smart classroom. Banu et al. (2013) presented *LMSO*, which stands for a Library Management System Ontology. The semantic model defines concepts for library personnel, library member, library resources and library services. Nagowah et al. (2021) have proposed *SmartLibOnto* to cater for a smart library system.

It can be observed that the different ontologies developed tackle one particular aspect of a smart campus. None of the existing ontologies cover several (if not all) aspects related to smart learning such smart learning management, personalized learning, e-Learning, assessment, smart classroom and smart library, thus hindering information exchange through the different inter-connected systems in the Smart Learning domain. Since these ontologies have all been developed to address a particular aspect of the Smart Learning domain, it is likely that the ontologies have some commonalities. Certain concepts will exist in different ontologies, for example, the Course and Teacher concepts exist in both *OLOUD* and *OeLe* ontologies. A student who follows a particular Course in the *OLOUD* ontology will have to be assessed at some point to get an insight of his performance. The *OeLe*, on the other hand, includes assessment details for a student following a particular course but lacks details regarding the programme, the attendance pattern of the student or where the course is being held. Thus by integrating *OLOUD* and *OeLe*, each ontology will complement the lacking functionalities of the other one.

Vast amounts of data in SLE originate from different systems and devices used by students, tutors and educational institutions. This data being heterogeneous in nature, hinders seamless communication among various systems in SLE. The data has to be semantically enriched to enable automation of activities between the systems. With the usage of a common data model for the Smart Learning domain, the knowledge about the different systems can be properly represented in order to resolve semantic heterogeneity of the information coming from underlying devices and systems. This paper thus proposes an ontology entitled *SmartLearningOnto* that aims firstly to integrate data from inter-connected systems in the Smart Learning domain and secondly to facilitate flow of information among these systems allowing for informed decision-making.

## 3. Materials and Methods

This section details the methodology to develop the proposed ontology.

### 3.1 Methodology

To be able to properly develop an ontology and define a knowledge base, it is fundamental to follow a proper methodology. Several methodologies exist for ontology development and maintenance such as TOVE Methodology (Gruninger & Fox, 1994), METHONTOLOGY methodological framework (Fernández-López et al., 1997), Uschold and King methodology (Uschold & King, 1995), Noy and McGuinness methodology (Noy & McGuinness, 2001) and NeOn Methodology (Suárez-Figueroa et al., 2012) amongst others.

The NeOn Methodology framework is a highly flexible framework. After reviewing the existing methodologies for ontology development, the NeOn Waterfall Model has been selected for developing the *SmartLearningOnto* for the following reasons: This model favours projects where several different domains are involved. These domains might not be well understood and there are possibilities that the requirements change during the development process. For the development of *SmartLearningOnto,* some of the sub domains are already known while some might be incorporated later on during the development process. The NeOn methodology also encourages the reuse of both ontological and non-ontological resources. The different phases of the methodology are described in detail in the following sections.

### 3.2 Initiation Phase

The initiation phase of the NeOn methodology consists of spotting the essential requirements for the ontology. A motivation scenario justifying the need for an ontology for Smart Learning domain and an ontology requirement specification document (ORSD) are produced in this phase.

*A. Motivation Scenario*

Rita James is a student enrolled for a study programme offered by a faculty at the university. Once enrolled on a study programme, she will belong to that faculty. The programme will consist of a curriculum, which specifies how the programme will be completed. The curriculum consists of several subjects.

Courses which are based on a subject will have temporal attributes and can be delivered by one or more teachers either online, on campus or hybrid. The teacher can be a full-time staff belonging to a faculty or a part-timer. To follow a course, Rita first needs to register for the course. The course will be evaluated based on assessment such as class tests, assignment/ project, presentation and/or written examinations. The teacher creates questions for the assessment consisting of open-ended questions, closed questions and problem solution questions. Rita is given her performance details and feedback on her performance during the course.

Some courses are held in smart classrooms. The classrooms are equipped with sensors, which observe the environmental conditions of the classroom. The room conditions are automatically adjusted. For instance, lights are switched off when nobody is present in the room, air conditioner is adjusted with respect to room temperature and projector is switched on upon the entrance of an instructor. The smart classroom is equipped with an RFID reader sensor that keeps track of when someone is entering and leaving the room.

Upon registration of a particular course, Rita is recommended resources based on the subject matter from the smart library to help her in her studies. She can query about availability of resources and reserve the resources via an online reservation system. She additionally receives suggestions regarding resources based on her user profile, which includes her preferences.

*B. Ontology Requirements Specification Document (ORSD)*

The ORSD defines several elements such the purpose, the scope, the implementation language among others of the proposed ontology. Table 1 shows the ORSD.

### 3.3 Reuse and Reengineering Phase

Rather than developing an ontology from scratch, ontology reuse promotes the adoption of existing ontologies or knowledge models as input to new ontologies or knowledge representations (Katsumi and Grüninger, 2016). A number of ontologies exist for the different systems in Smart Learning domain as described in Section 2. However, not all are available online, hindering reuse of the ontologies. To demonstrate integration and interoperability among the interconnected systems and to show how the ontologies can “talk to each other”, one candidate source ontology is selected from each of the different sub domains as discussed in the following sections.

*A. Smart Learning Management/Personalized Learning*

From the motivation scenario, it is clear that one ontology in the field of smart learning management is required. The *OLOUD* ontology describes vocabulary for course information such as curricula, subjects, courses, semesters, personnel, buildings and events in a university campus. Some of the main concepts of the *OLOUD* ontology are described as follows (Fleiner et al., 2017):

- Curriculum: A student enrolls on a Study Programme in a university and the Study Programme has a Curriculum, which specifies how the Study Programme will be completed.
- Specialization: The Curriculum specifies Specializations, which comprise of a number of compulsory and optional Subjects.
- Degree: Following the Curriculum will result in a Degree (BSc, BA, MA, MSc, MRes, MPhil, PhD).
- Attendance Pattern: The Curriculum has a specific Attendance Pattern, which refers to the mode in which the Curriculum will be followed (full-time, part-time, correspondence).
- Course: A Course is based on a particular Subject. It is taught by one or more Teachers. It is offered at a particular time and in a particular Location. The Course has a CourseType which refers to the type of the Course, whether an ExamCourse, Seminar, Laboratory or Practice.

The *OLOUD* ontology partially fits the motivation scenario described. The ontology models courses that are delivered at a particular location while the motivation scenario describes three delivery modes for courses: online, face-to-face or hybrid. An additional concept *DeliveryMode* is the required. While *OLOUD* models the different aspects related to *Course*, it lacks concepts with respect to assessment of the *Course*.

*B. Assessment*

The *Expanded Course Ontology* can be considered to model the assessment components. It caters for concepts related to assessment such as Exam and Exam questions (Open-ended questions, Multiple Choice questions and problem solving questions) along with their answers. According to Davis (2002), the term '*Exam*', '*Test*' and '*Quizzes*' are used interchangeably as they all test the students' knowledge with a series of questions but they are limited in scope. Other modes of evaluation include assignments, projects, seminars, orals among others. These evaluation methods will also include questions, though projects and orals emphasize more on the demonstration capability. *Teacher* refers to the individual who teaches a particular *Course* and who sets *Questions* for *Exam*.

### *Ontology transformation*

Izza (2009) defines on ontology transformation as "*changing the structure of the ontology to make it compliant with another*". To fit the motivation scenario defined, the '*Exam*' concept is changed to 'Assessment' and the latter will consist of several subclasses such as Exam, Test, Quizzes, Assignments, Projects, Seminars and Presentations.

**Table 1** - Ontology Requirements Specification Document.

| **Ontology Requirements Specification Document** | |
|---|---|
| **1** | **Purpose** |
| The need for developing the Smart Learning Ontology is to represent knowledge among different collaborating systems in the smart learning domain. | |
| **2** | **Scope** |
| The ontology will focus on different aspects such as Smart Learning Management, Assessment, Smart Classroom, Smart Library and Personalised Learning. | |
| **3** | **Implementation Language** |
| OWL 2 will be used as the implementation language for developing the proposed ontology. | |
| **4** | **Intended End-Users** |
| The intended set of end-users for the ontology will include students, academic staff, non-academic staff and visitors of a smart campus. | |
| **5** | **Intended Uses** |
| Users of a smart campus will use the semantic model to find out about services offered by a panoply of applications in the smart learning domain. | |
| **6** | **Ontology Requirements** |
| **a. Non-Functional Requirements** | |
| Appropriate standards related to smart learning should be used for the development of the ontology. | |
| **b. Functional Requirements: Set of Competency Questions** | |
| The competency questions will be those targeting more than one sub domains. Some examples are listed as follows:<br>1. Smart Learning Management System<br>a. For which programme, did a particular student enroll?<br>b. Which faculty is offering which programme?<br>c. To which subject is a particular course related to?<br>d. When will the course be delivered?<br>e. What is the delivery mode of a particular course?<br>f. When did a particular student register for a particular course?<br><br>2. Course Assessment<br>a. List the assessments and the assessment types related to a particular course.<br>b. List the exams questions for a particular course.<br>c. List the performance details for a particular student with respect to a course assessment.<br><br>3. Smart Classroom<br>a. Which sensors are placed in a particular smart classroom?<br>b. List the observable properties and their results that are observed in the SmartClassroom1 at a particular time and by which sensors?<br>c. Who attended a particular event in a particular SmartClassroom and when?<br><br>4. Smart Library<br>a. Who are the users of the smart library?<br>b. List services provided by the smart library.<br>c. List the sensors deployed in the smart library.<br>d. Is a particular resource available in the library?<br><br>5. Inter-connected systems (Some examples)<br>a. List the exam questions and answers set by teacher '*Smith*' for the subject '*Knowledge Engineering*'.<br>b. What are the observable properties such as noise and temperature of the smart classroom where the teacher '*Smith*' is teaching the '*Database Systems*' course and at what time were the observable properties captured?<br>c. Which study books from the smart library could be used by students following the courses under subject '*Knowledge Engineering*' taught by teacher '*Smith*' in SmartClassroom1? | |

*Teacher* sets the *Assessment* which will be taken by *Student*. *Assessment* consists of *Question* and each *Question* has *Question_Annotation*. *Question* has *Answer* and each *Answer* has *Answer_Annotation*. The transformed assessment ontology is shown in Figure 2.

*C. Smart Classroom*

As described in the Introduction section, IoT has turned the traditional classroom to smart classroom which is enhanced by technology to facilitate the learning process. The *Smart Classroom Ontology* from Nagowah et al. (2019) is considered to model the motivation scenario. The main concepts are described as follows:

- Classroom: *Classroom* represents the class where a particular lecture or event will be held. It has a *Location* and it is reserved for a particular time duration.
- Activity: *Activity* represents a particular event involving a *User* occurring at a particular *Location* and *Time*.
- Context: *Context* represents an observable property that can be observed by a *Sensor.*
- Platform*: Platform* represents a computer resource (hardware or software) present in the classroom or used by the User. It can be an RFID reader for tracking attendance or a software used to generate a *LearnerProfile* consisting of *Performance* details, *Attendance* details and *Leaning Analytics*.
- Service*:* Based on context information, different services such as adjusting room conditions can be triggered.
- User: The *User* represents anyone using the smart classroom such as the Teacher/Lecturer or the Student.
- Sensor: The smart classroom is deployed with sensors, which are modelled by SOSA: Sensor.

*D. Smart Library*

A smart library uses IoT to capture real-time data about the library resources and its users. The *SmartLibOnto* from Nagowah et al. (2021) is considered to model the motivation scenario. The main classes are listed as follows:

- Academic Library: An *Academic Library* provides *Services* to its *Users* and manages different *Resources*.
- Services: The services consists of *General*, *Educational* and *Scientific* services.
- Resources: *Resources* include Study Book, Thesis, Manuscript, Newspaper among others.
- Platform: *Platform* refers to a computer resource that is used by Users and *the Academic Library*.
- Sensor: The smart library is dispersed with sensors, which are modelled by SOSA: Sensor.

In this phase we thus started by reusing the *OLOUD* ontology (which is available online) and transformed *Expanded Course Ontology* (Khdour, 2020). However, both ontologies *OLOUD* and *Expanded Course Ontology* do not include concepts of smart communities such as smart classroom and smart library. *Smart Classroom Ontology* defines vocabulary for context and sensor information in a smart classroom while *SmartLibOnto* include concepts such as resources and services for a smart library as well as sensor concepts.

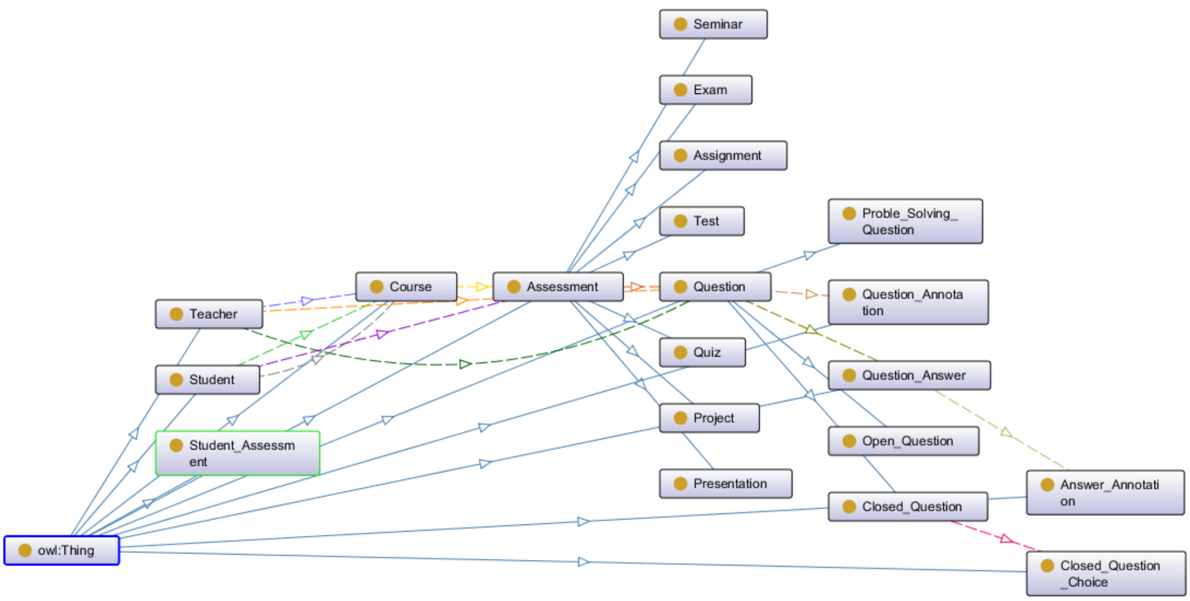


**Figure 2** - Transformed Expanded Course Ontology.

### 3.4 Merging and Modelling Phases

Ontology merging is a method that fuses two ontologies to produce a third one (Guzmán-Arenas & Cuevas, 2010). According to Chatterjee et al. (2017), ontology merging can be performed accurately only after aligning the concepts of the source ontologies. Prior to alignment and merging, ontology mapping is performed. Mappings are computed after an analysis of similarity between concepts in compared ontologies (Bagüés et al., 2006). Semantic similarity refers to the "*degree of relatedness*" (Rhee et al., 2009). The semantic matches/mappings can represent relations of equivalence (is-a) and specialization and/or generalization (part of) (Amrouch & Mostefai, 2013).

***Correspondence or Mapping***

Given the ontologies $O_1$ and $O_2$, a correspondence or mapping among the entities $e_1$ and $e_2$ from ontologies $O_1$ and $O_2$ is defined as $<id, e_1, e_2, r, n>$

Where id is a unique identifier,

r is a relation for example $=, >=, <=$,

n is a confidence measure (typical in the range of (0,1)) holding for the correspondence between $e_1$ and $e_2$ (Euzenat, 2007). Matching ontologies promote interoperability of the knowledge and data expressed in the matched ontologies (Shvaiko & Euzenat, 2008). LogMap (http://krrwebtools.cs.ox.ac.uk/logmap/) is an example of a matching system that can handle semantically rich ontologies comprising of tens (and even hundreds) of thousands of classes (Jiménez-Ruiz & Cuenca Grau, 2011). For the purpose of matching and merging ontologies in this work, two tools namely Protégé 5.5.0 and LogMap were used. Both tools provide GUI based ontology merging. The tools promote pairwise ontology integration. Manual intervention was also carried out to match the classes.

***Step1***

For a start, *OLOUD* ontology was first merged with the transformed *Expanded Course Ontology* (Figure 2) as they define vocabulary for *Course* (as highlighted in yellow in Figure 3). *Expanded Course Ontology* adds the assessment elements in the *OLOUD* ontology. Concepts from *OLOUD ontology* are shown in green in Figure 3 while concepts from *Expanded Course Ontology* are shown in blue in Figure 3. The concepts '*Course'* and '*Teacher'* are common in both two ontologies and the relationship 'course teacher' from *OLOUD* and 'teaches' from *Expanded Course Ontology* is equivalent. Grey lines model relationships while black lines illustrate ISA relationships.

By merging the two ontologies, assessment of the course is modelled. A new concept *DeliveryMode* has been introduced to model the delivery mode of the course. The two ontologies merged together can now answer the competency question 5.a listed below, which could not be answered by the ontologies separately:

> **Competency Question 5.a** List the exam questions and answers set by teacher '*Smith'* for the subject '*Knowledge Engineering*'.

***Step 2***

As a second step, *Smart Classroom Ontology* has been merged with *OLOUD_Expanded Course Ontology.* Concepts from *Smart Classroom Ontology* are shown in orange in Figure 4. The following mappings have been made:

- *Context* from *Smart Classroom Ontology* has been mapped to *ObservableProperty* in *SOSA*.
- *Student* from *Smart Classroom Ontology* has been mapped to *Student* in *OLOUD_Expanded Course Ontology.*
- *Lecturer* from *Smart Classroom Ontology* has been mapped to *Teacher* in *OLOUD_Expanded Course Ontology.*
- *Time* from *Smart Classroom Ontology* has been mapped to *Course time* in *OLOUD_Expanded Course Ontology.*

The merged together can now answer the following competency question 5.b:

> **Competency Question 5.b.** What are the observable properties such as noise and temperature of the smart classroom where the teacher '*Smith'* is teaching the '*Database Systems'* course and at what time were the observable properties captured?

***Step 3***

As the last step, *OLOUD_Expanded Course Ontology_Smart Classroom Ontology* was merged with *SmartLibOnto* to form the *SmartLearningOnto* as shown in Figure 5. Concepts from *SmartLibOnto* are shown in purple and the common concepts between ontologies are shown in yellow color. *SmartLearningOnto* represents a common model where concepts of a smart learning domain are modelled. The following mappings have been made:

- *User* from *Smart Library ontology* has been mapped *to User* in *OLOUD_Expanded Course Ontology_Smart Classroom Ontology.*
- *Services* from *Smart Library ontology* has been mapped *to Services* in *OLOUD_Expanded Course Ontology_Smart Classroom Ontology.*
- *KPI* from *Smart Library ontology* has been mapped *to KPI* in *OLOUD_Expanded Course Ontology_Smart Classroom Ontology.*
- *Platform* from *Smart Library ontology* has been mapped *to Platform* in *OLOUD_Expanded Course Ontology_Smart Classroom Ontology.*

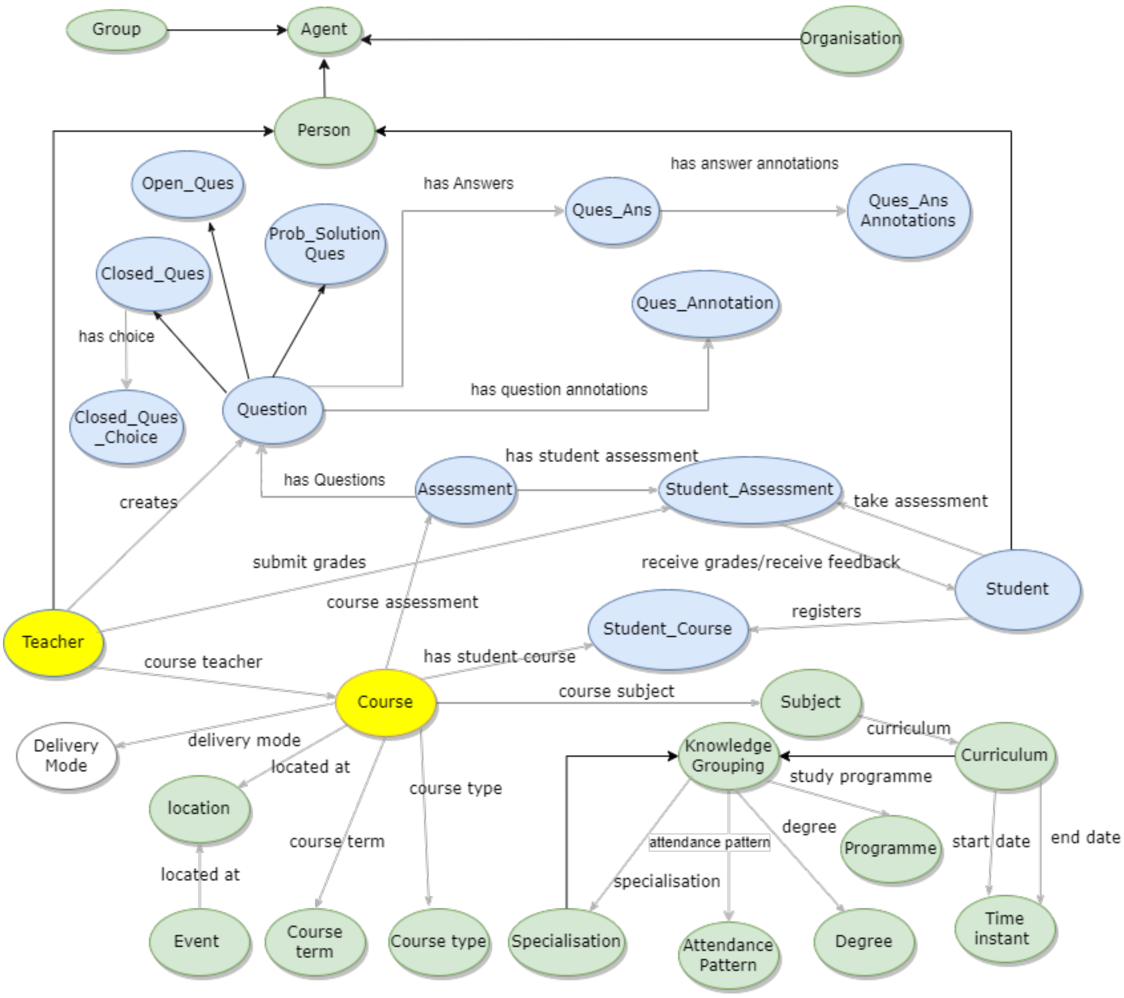


**Figure 3** - Concept Mapping –*OLOUD_Expanded Course Ontology.*

A new concept *SmartCommunity* has been introduced to group Smart Classroom and Smart Library. A new relationship *Categorisation* has been created to categorise *Resources* based on *Subject*.

The four ontologies merged together can now answer the following competency question 5.c, which could not be answered by the ontologies separately:

| |
|---|
| **Competency Question 5.c.** Which study books could be used by students following the courses under subject *'Knowledge Engineering'* taught by teacher '*Smith*' in *SmartClassroom1*? |

## 3.5 Implementation Phase

In this phase, the conceptual model from the previous phase is implemented in OWL using Protégé tool. Protégé 5.5.0 and Logmap are used to merge the four ontologies described in section 3.2. Both tools yielded to more or less the same merged ontology. Anomalies identified were manually corrected to yield best results. The taxonomy of *SmartLearningOnto* is formalized, whereby the class hierarchy, object property hierarchy and data property hierarchy are developed as shown in Figure 6. Classes model concepts in the domain while object property model relationships between concepts. Data properties represent features and attributes of the concepts. Individuals represent instances of classes.

### *Semantic Reasoning*

Semantic reasoning enables the transformation of low-level data into high-level knowledge, promoting informed decision-making (Bonte et al., 2017). Protégé 5.5.0 includes a number of reasoners in its standard distribution. Reasoners such as Pellet (Sirin et al., 2007) and HermiT (Glimm et al., 2014) are two examples available that can be adopted for effective reasoning. Knowledge can be expressed in the form of rules using the Semantic Web Rule Language (SWRL, http://www.w3.org/Submission/SWRL/). SWRL is an expressive OWL-based rule language, which supports more powerful deductive reasoning capabilities than OWL alone (Zhang et al., 2013).

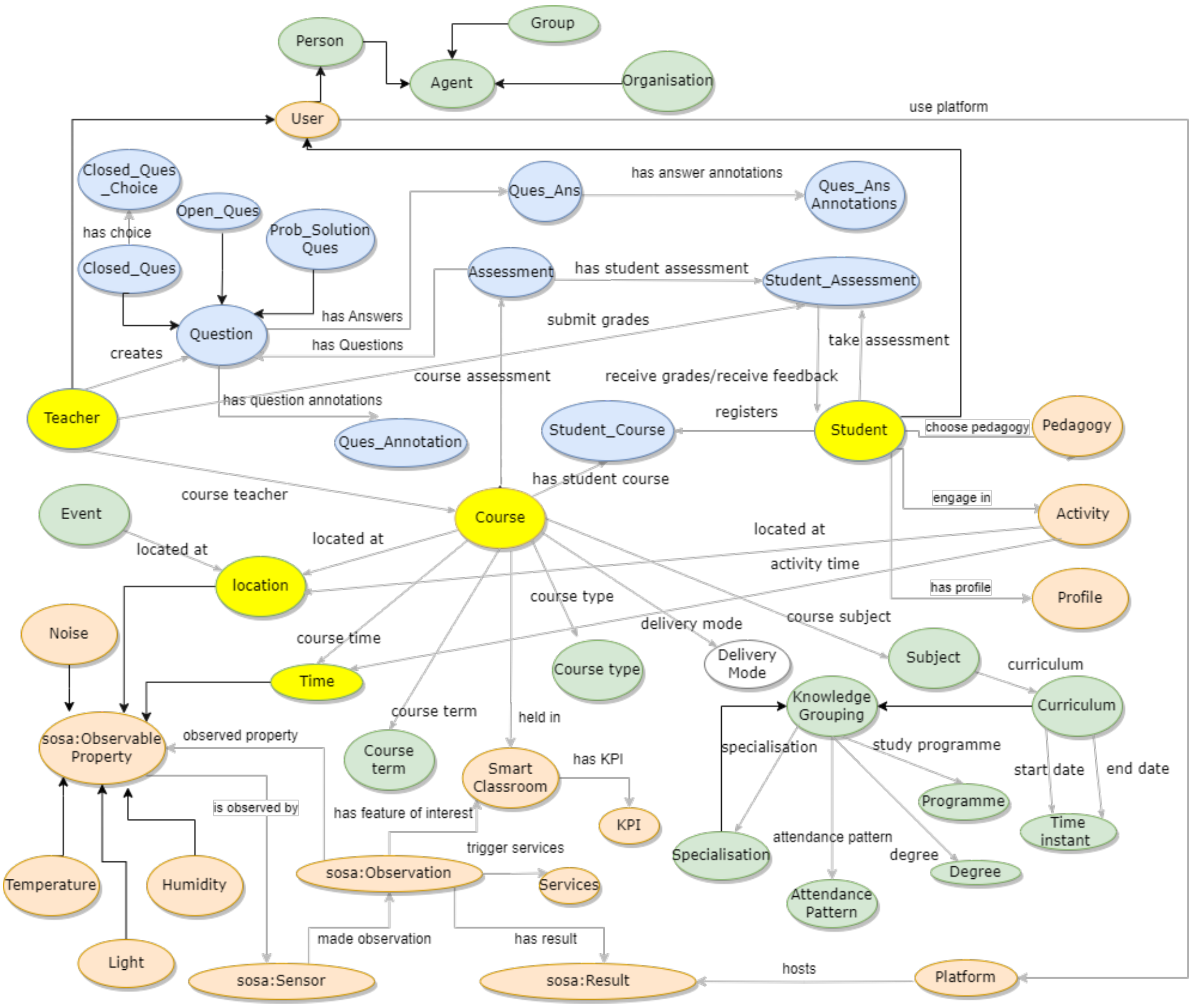


**Figure 4** - Concept Mapping –*OLOUD_Expanded Course Ontology_Smart Classroom Ontology*.

Reasoners adopt rule-based reasoning where they interpret the defined rules along with asserted facts from knowledge bases to extract new knowledge (De Farias et al., 2016). Reasoners such as Pellet and Hermit use forward chaining inference method to infer the new facts to the knowledge base based on defined facts and the rules (Sherimon et al., 2020).

Some rules are defined as follows.

**Rule 1**

| |
|---|
| When a student registers for a course, she is recommended a number of resources from the smart library related to the subject.<br>Student(?x) ^ Course (?y) ^ Student_Course(?z) ^ Subject(?a) ^Resources(?b) ^ registers(?x,?z) ^hasStudentCourse(?y,?z) ^ oloud:courseSubject(?y,?a) ^ categorisation (?b,?a) -> recommendResources(?x,?b) |

Figure 7 shows student Rita has registered for the *Database Systems* course and as per Rule 1 she is recommended resources (the study book entitled "*Fundamentals of Database Systems*") for the course.

**Rule 2**

| |
|---|
| A student is recommended a number of resources from the smart library related to her preference set.<br>Student(?x) ^ Profile(?y) ^hasProfile(?x, ?y) ^ Subject(?a) ^ SameAs (?y, ?a) ^ categorisation(?b, ?a) -> recommendResources(?x, ?b) |

Figure 8 shows student Sarah has set her preference *Semantic Web* in her profile and as per Rule 2 she is recommended resources (the study book entitled "*An Introduction to Ontology Engineering*").

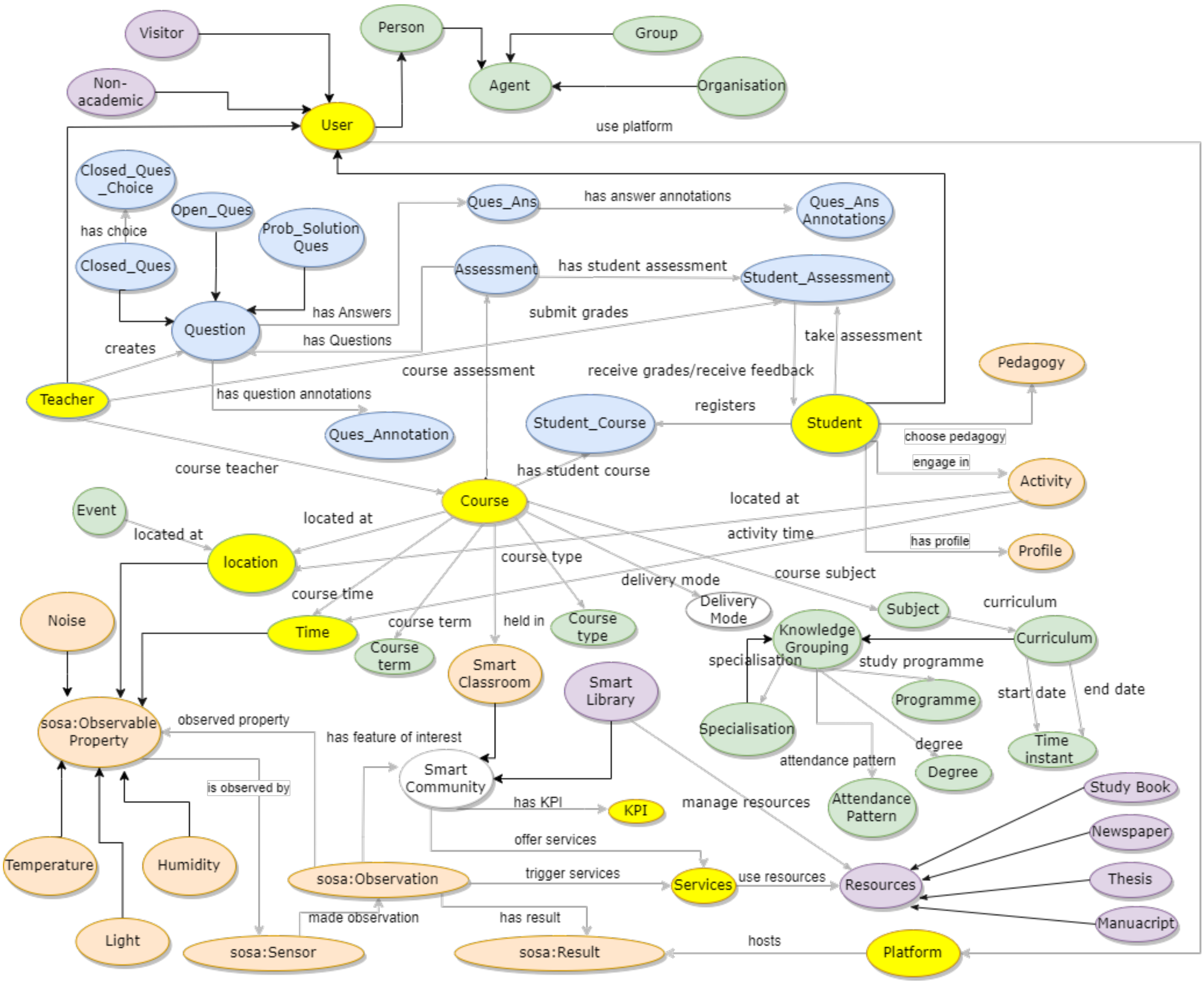


**Figure 5** - *SmartLearningOnto* Concept Mapping.


**Figure 6** - Concepts, Object and Data Properties of *SmartLearningOnto.*

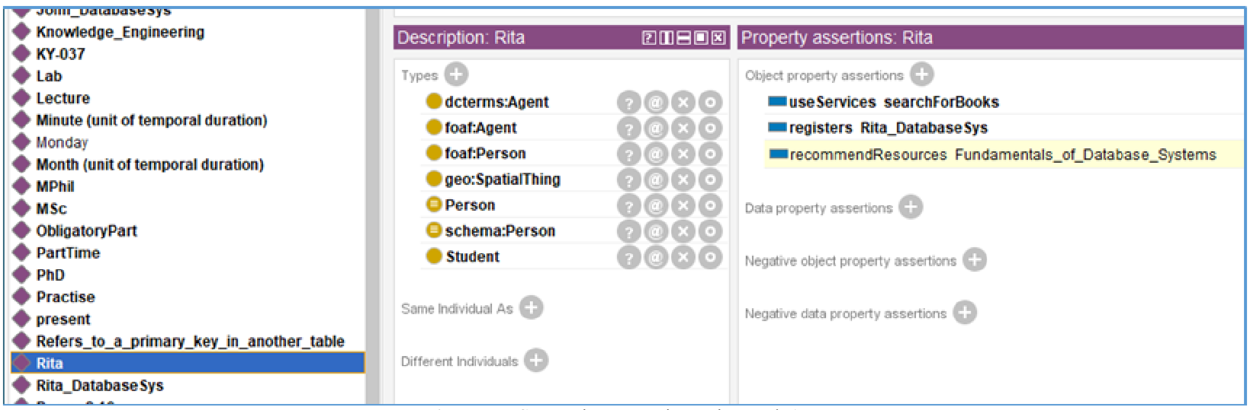


**Figure 7** - Semantic Reasoning using Rule1.

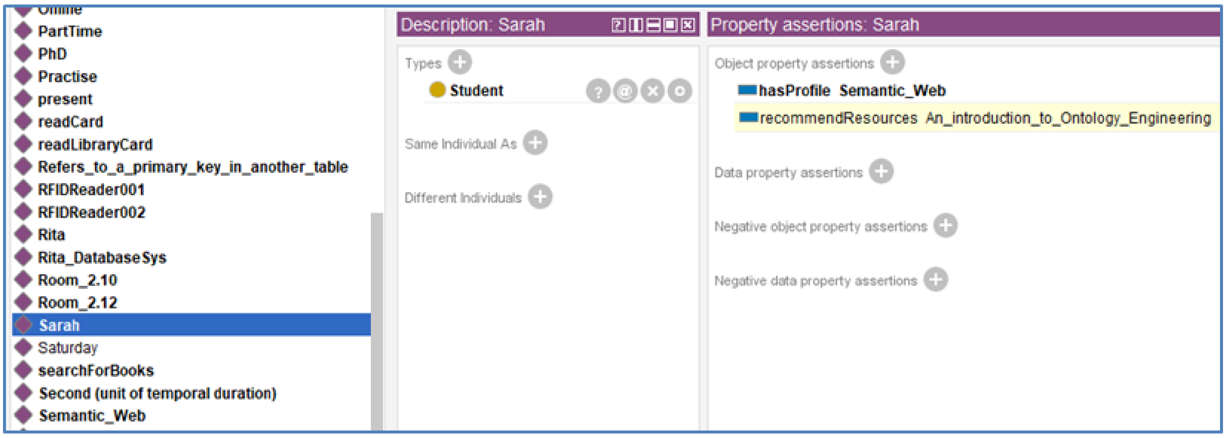


**Figure 8** - Semantic Reasoning using Rule 2.

## 4. Results and Discussions

The developed ontology has been evaluated using (1) semantic querying with respect to competency questions set, (2) domain expert evaluation and (3) a set of metrics.

### 4.1 Evaluation of Requirements based on Semantic Querying

Query languages are used for retrieving information from ontology repositories (Sheeba & Krishnan, 2015). The SPARQL has been proposed by the World Wide Web Consortium (W3C) and it is used to service an OWL query (O'Connor & Das, 2009). The different Prefixes used are listed as follows:

Prefix:
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX oloud: <http://lod.nik.uni-obuda.hu/oloud/oloud#>
PREFIX ta: <http://ontology.ihmc.us/temporalAggregates.owl#>
PREFIX time: <http://www.w3.org/2006/time#>
PREFIX sm:
<http://www.semanticweb.org/snagowah/ontologies/2021/10/sm#>
PREFIX sosa:<http://www.w3.org/ns/sosa/>

The following listings show the SPARQL queries implemented in in Protégé. The result for competency question 5c is shown in Figure 9. The data obtained by executing the SPARQL queries validates the purpose fulfillment of the ontology.

**(i) Smart Learning Management System**

| **Competency question 1a** | **SPARQL** |
|---|---|
| For which programme, did a particular student enroll? | SELECT ?x ?p where { ?x sm:enrollProgramme ?p} |

| **Competency question 1b** | **SPARQL** |
|---|---|
| Which faculty is offering which programme? | SELECT ?f ?p where {?f sm:offers ?p} |

| **Competency question 1c** | **SPARQL** |
|---|---|
| To which subject is a particular course related to? | SELECT ?c ?s where {?c oloud:courseSubject ?s} |

| **Competency question 1d** | **SPARQL** [Query taken from http://lod.nik.uni-obuda.hu/] |
|---|---|
| When will the course be delivered? | SELECT DISTINCT ?course ?day ?beginhour ?beginminute ?durationhour ?durationminute WHERE {<br>?course oloud:courseTime ?ct .<br>?ct ta:hasTemporalAggregateDescription ?tad .<br>?tad ta:hasithTemporalUnit ?day ;<br>ta:hasStart ?start .<br>?start time:hasDurationDescription ?dd ;<br>time:hasBeginning ?begin .<br>?dd time:hours ?durationhour ;<br>time:minutes ?durationminute .<br>?begin time:inDateTime ?begindatetime .<br>?begindatetime time:hour ?beginhour ;<br>time:minute ?beginminute .<br>} |

| **Competency question 1e** | **SPARQL** |
|---|---|
| What is the delivery mode of a particular course? | SELECT DISTINCT ?c ?dm where {?c sm:delivery_mode ?dm} |

| **Competency question 1f** | **SPARQL** |
|---|---|
| When did a particular student register for a particular course? | SELECT DISTINCT ?s ?sc ?registrationdate where {?s sm:registers ?sc. ?sc sm:registrationDate ?registrationdate} |

**(ii) Course Assessment**

| **Competency question 2a** | **SPARQL** |
|---|---|
| List the assessments and the assessment types related to a particular course. | SELECT ?c ?a where {?c sm:course_assessment ?a} |

| **Competency question 2b** | **SPARQL** |
|---|---|
| List the exams questions for a particular course. | SELECT ?e ?q ?a where {?e sm:hasQues?q. ?q sm:has_question_annotations ?a} |

| **Competency question 2c** | **SPARQL** |
|---|---|
| List the performance details for a particular student with respect to a course assessment. | SELECT ?c ?a ?s ?totalmarks ?marksscored where {<br>?c sm:course_assessment ?a.<br>?a sm:hasAssessment ?sa.<br>?s sm:takeAssessment ?sa.<br>?a sm:assessmentTotalMarks ?totalmarks .<br>?sa sm:marks_scored ?marksscored} |

**(iii) Smart Classroom**

| **Competency question 3a** | **SPARQL** |
|---|---|
| Which sensors are placed in a particular smart classroom? | SELECT ?SmartClassroom ?sensor where {<br>?SmartClassroom sosa:isFeatureOfInterestOf ?Observation.<br>?Observation sosa:madeBySensor ?sensor} |

| **Competency question 3b** | **SPARQL** |
|---|---|
| List the observable properties and their results that are observed in the SmartClassroom1 at a particular time and by which sensors? | SELECT ?ObservableProperty ?Sensor ?Result ?Resultime where{<br>?Observation sosa:hasFeatureOfInterest ?SmartClassroom.<br>?SmartClassroom owl:sameAs sm:SmartClassroom1.<br>?Observation sosa:observedProperty ?ObservableProperty.<br>?ObservableProperty sosa:isObservedBy ?Sensor.<br>?Observation sosa:hasResult ?Result.<br>?Observation sosa:resultTime ?Resultime<br>} |

| **Competency question 3c** | **SPARQL** |
|---|---|
| Who attended a particular event in a particular SmartClassroom and when? | SELECT ?SmartClassroom ?Result ?User ?Resultime where{<br>?SmartClassroom sosa:isFeatureOfInterestOf ?Observation.<br>?Observation sosa:observedProperty ?ObservableProperty.<br>?ObservableProperty owl:sameAs sm:classroomPresence.<br>?ObservableProperty sosa:isObservedBy ?Sensor.<br>?Observation sosa:hasResult ?Result.<br>?Result sm:is_owned_by ?User.<br>?Observation sosa:resultTime ?Resultime<br>} |

**(iv) Smart Library**

| **Competency question 4a** | **SPARQL** |
|---|---|
| Who are the users of the smart library? | SELECT ?User where{<br>?User sm:useServices ?SmartLibrary} |

| **Competency question 4b** | **SPARQL** |
|---|---|
| List services provided by the smart library. | SELECT ?Services where{<br>?Services sm:servicesOfferedBy ?SmartLibrary} |

| **Competency question 4c** | **SPARQL** |
|---|---|
| List the sensors deployed in a particular smart library. | SELECT ?SmartLibrary ?Observation ?ObservableProperty ?Sensor where{<br>?SmartLibrary sosa:isFeatureOfInterestOf ?Observation.<br>?SmartLibrary owl:sameAs sm:SmartLibrary1.<br>?Observation sosa:observedProperty ?ObservableProperty.<br>?ObservableProperty sosa:isObservedBy ?Sensor.<br>} |

| **Competency question 4d** | **SPARQL** |
|---|---|
| Is a particular resource available in the library? | SELECT ?Resources ?AvailabilityStatus where{<br>?Resources sm:resourceAvailability ?AvailabilityStatus<br>} |

**(v) Interconnected Systems**

| **Competency question 5a** | **SPARQL** |
|---|---|
| List the exam questions and answers set by teacher '*Smith*' for the subject '*Knowledge Engineering*'. | SELECT ?Course ?Question ?Annotation ?Answers ?AnsAnnotations WHERE {<br>?Question rdf:type sm:Question .<br>?Question sm:has_question_annotations ?Annotation .<br>?Question sm:hasAnswers ?Answers .<br>?Answers sm:has_answer_annotations ?AnsAnnotations .<br>?Question sm:isCreatedBy sm:Smith.<br>sm:Smith oloud:courseTeacher ?Course.<br>?Course oloud:courseSubject sm:Knowledge_Engineering.<br>} |

| **Competency question 5b** | **SPARQL** |
|---|---|
| What are the observable properties such as noise and temperature of the smart classroom where the teacher '*Smith*' is teaching the | SELECT ?SmartClassroom ?Noise ?resultTimeNoise ?Temperature ?resultTimeTemperature WHERE {<br>?Noise sosa:observedProperty sm:estimateSound.<br>sm:estimateSound sosa:resultTime ?resultTimeNoise. |

| | |
|---|---|
| ‘*Database Systems*’ course and at what time were the observable properties captured? | ?Temperature sosa:observedProperty sm:estimateTemperature. sm:estimateTemperature sosa:resultTime ?resultTimeTemperature. ?SmartClassroom sosa:isFeatureOfInterestOf sm:estimateTemperature. ?SmartClassroom sosa:isFeatureOfInterestOf sm:estimateSound. ?SmartClassroom sm:helds sm:DatabaseSystems. sm:Smith oloud:courseTeacher sm:DatabaseSystems. } |

| **Competency question 5c** | **SPARQL** |
|---|---|
| Which study books could be used by students following the courses under subject *‘Knowledge Engineering’* taught by teacher ‘*Smith*’ in *SmartClassroom1*? | SELECT ?Study_Book WHERE { ?Study_Book sm:used_Resources ?Services. ?Services sm:used_Services ?Student. sm:Student rdfs:subClassOf sm:User. ?Student sm:follows ?Course. ?Course oloud:courseSubject sm:Knowledge_Engineering. sm:Smith oloud:courseTeacher ?Course. ?Course sm:held_in sm:SmartClassroom1} |

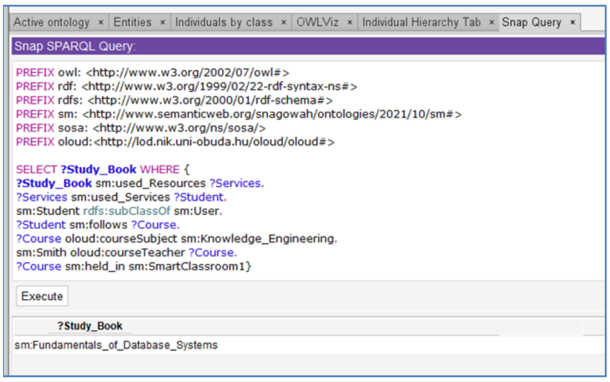


**Figure 9** - Execution of SPARQL for competency question 5c.

## 4.2 Expert Evaluation

A logical evaluation was carried out by two domain experts who have PhD degrees in the field of Computer Science/AI and who have more than 10 years of teaching experience in the field of Information Engineering/Semantic Web. The domain experts have provided critical reviews and after finalizing the ontology, they were in the opinion that

(i) ***Ontology Coverage(Completeness).***

*SmartLearningOnto* describes the main concepts related to smart learning management and assessment (with respect to the motivation scenario).

(ii) ***Consistency.***

All relevant concepts have been modelled related to smart learning management and assessment (with respect to the motivation scenario).

(iii) ***Accuracy***

*SmartLearningOnto* correctly captures and represents aspects of the motivation scenario with respect to smart learning management and assessment.

## 4.3 Metrics and Formal Validation

McDaniel et al. (2018) list a number of criteria that can be used for ontology quality assessment. As shown in Table 2, *SmartLearningOnto* meets all the evaluation criteria defined in the Table 2.

**Table 2** - Evaluation Criteria.

| **Metric** | **Measure** |
|---|---|
| Adaptability | *SmartLearningOnto* has been developed by integrating several ontologies. To cope with changes in future, additional ontologies can easily be mapped and integrated. The concepts have been described to ease mapping of new concepts in future. |
| Cohesion | *SmartLearningOnto* has reused several existing ontologies such as SOSA. Given that *SmartLearningOnto* models different elements of the same domain, these elements have some commonalities and are comprehensible and coherent with each other, facilitating the merging process. |
| Completeness | *SmartLearningOnto* includes all relevant concepts in the smart learning domain as confirmed by domain experts. *SmartLearningOnto* could answer the competency questions defined. |
| Computational Efficiency | Computational efficiency was assessed by the Pellet reasoner. The processing time of the ontology is 1197 ms by Pellet. Defined SWRL rules have been executed properly and have appropriately performed logical inference. |
| Consistency | No sign of inconsistency is shown by Pellet reasoner, implying that there are no contradictions. Furthermore, SPARQL queries were successfully executed to answer all competency questions. |
| Coupling | *SmartLearningOnto* was developed by merging several ontologies and they all worked well when integrated as demonstrated by the SPARQL queries. |
| Coverage | All relevant concepts have been covered, avoiding redundancy as confirmed by domain experts. A number of sub domains have been covered in *SmartLearningOnto*. |

## 4.4 Discussion

Technology has transformed the education environment. Several systems are in place to enhance the learning and teaching process in an innovative way. This paper suggests a semantic model that represents data emerging from different systems (Smart Learning Management, Personalized Learning, Assessment, Smart Classroom and Smart Library) in SLE. By integrating data from these systems, the ontology allows the exchange of data and promotes reasoning based on the data, enhancing semantic interoperability.

Such collaboration among the different systems have the following pedagogical implications:

(i) Active and collaborative Learning

By aligning ontologies from different sub domains in SLE, the proposed ontology allows for semantic querying across the different domains. For example, learners following a particular course, get access to exam questions set for a particular subject to enhance the learning process. This query was possible due to alignment between an ontology from the Personalized Learning domain and one from the Assessment domain.

(ii) Personalized Learning

The proposed ontology infers new knowledge about resources available from the Smart Library upon course registration and based on student preference. The learner can then use the resources to learn about a topic at his own pace, thus enriching his learning experience. Such inference was possible due to ontology alignment between the Personalized Learning domain and the Smart Library Ontology.

(iii) Continuous monitoring of student engagement and performance

Observations from real-time environmental data from the Smart Classroom and Smart Library captured by the proposed ontology provide educators with information about contextual factors like location and noise. Such information can be used to monitor student engagement. Teachers also get details about student progress, learning behaviors and performance and can thus adapt their teaching style with respect to learner needs.

## 5. Conclusions and Future Works

Smart learning domain has evolved in the past years with the advent of advanced technologies such as IoT. Several systems have cropped up to make learning more pleasant and to enhance SLE. This paper presents an ontology for the smart learning domain entitled *SmartLearningOnto.* It regroups knowledge from several sub domains in smart learning namely personalized learning, assessment, smart classroom and smart library. By defining a common data model in the domain, cross-domain communication is now possible across these sub domains and data can be shared to promote semantic interoperability. The proposed ontology was formally validated using metrics and was evaluated based on domain expert feedback. It has fulfilled all requirements defined in the ORSD and has answered all competency questions set. As future works, the proposed ontology will be further extended by incorporating more sub domains in the field of smart learning.

## References


Al-Yahya, M., Al-Faries, A., & George, R. (2013, July). Curonto: An ontological model for curriculum representation. In Proceedings of the 18th ACM conference on Innovation and technology in computer science education (pp. 358-358).

Amrouch, S., & Mostefai, S. (2013). Semantic integration for automatic ontology mapping. Computer Science & Information Technology (CS & IT), Academy & Industry Research Collaboration Center (AIRCC), 387-396.

Bagüés, M. I., Bermúdez, J., Illarramendi, A., Tablado, A., & Goni, A. (2006). Semantic interoperation among data systems at a communication level. In Journal on Data Semantics V (pp. 1-24). Springer Berlin Heidelberg.

Banu, A., Fatima, S. S., & Ur Rahman Khan, K. (2013). Building OWL ontology: LMSO-library management system ontology. In Advances in Computing and Information Technology: Proceedings of the Second International Conference on Advances in Computing and Information Technology (ACITY) July 13-15, 2012, Chennai, India-Volume 3 (pp. 521-530). Springer Berlin Heidelberg.

Bonte, P., Ongenae, F., De Backere, F., Schaballie, J., Arndt, D., Verstichel, S., & De Turck, F. (2017). The MASSIF platform: a modular and semantic platform for the development of flexible IoT services. Knowledge and Information Systems, 51, 89-126.

Carbonaro, A. (2020). Enabling smart learning systems within smart cities using open data. Journal of e-Learning and Knowledge Society, 16(1), 72-77.

Castellanos-Nieves, D., Fernández-Breis, J. T., Valencia-García, R., Martínez-Béjar, R., & Iniesta-Moreno, M. (2011). Semantic Web Technologies for supporting learning assessment. Information sciences, 181(9), 1517-1537.

Çelik, F. & Baturay, M.H. (2024). Technology and innovation in shaping the future of education. Smart Learning Environments, 11(1), 54.

Chatterjee, N., Kaushik, N., Gupta, D., & Bhatia, R. (2018). Ontology merging: A practical perspective. In Information and Communication Technology for Intelligent Systems (ICTIS 2017) 2, (pp. 136-145). Springer International Publishing.

Chituc, C. M. (2020, June). Interoperability Standards in the IoT-enabled Future Learning Environments: An analysis of the challenges for seamless communication. In 2020 13th International

Conference on Communications (COMM) (pp. 417-422). IEEE.

Davis, B.G. (2002). Quizzes, tests, and exams. University of California, Berkeley. https://teaching. berkeley. edu/bgd/quizzes. html

De Farias, T. M., Roxin, A., & Nicolle, C. (2016). SWRL rule-selection methodology for ontology interoperability. Data & Knowledge Engineering, 105, 53-72.

Dong, Z. Y., Zhang, Y., Yip, C., Swift, S., & Beswick, K. (2020). Smart campus: definition, framework, technologies, and services. IET Smart Cities, 2(1), 43-54.

Elsaleh, T., Enshaeifar, S., Rezvani, R., Acton, S. T., Janeiko, V., & Bermudez-Edo, M. (2020). IoT-Stream: A lightweight ontology for internet of things data streams and its use with data analytics and event detection services. Sensors, 20(4), 953.

Euzenat, J. (2007, January). Semantic Precision and Recall for Ontology Alignment Evaluation. In IJCAI, 7, 348-353.

Fernández-López, M., Gómez-Pérez, A., & Juristo, N. (1997). Methontology: from ontological art towards ontological engineering.

Fleiner, R., Szász, B., & Micsik, A. (2017). OLOUD-an ontology for linked open university data. Acta Polytechnica Hungarica, 14(4), 63-82.

Ghawi, R., & Cullot, N. (2007, September). Database-to-ontology mapping generation for semantic interoperability. In Third international workshop on database interoperability (InterDB 2007) (Vol. 91).

Glimm, B., Horrocks, I., Motik, B., Stoilos, G., & Wang, Z. (2014). HermiT: an OWL 2 reasoner. Journal of Automated Reasoning, 53, 245-269.

Gruninger, M., & Fox, M. S. (1994). The design and evaluation of ontologies for enterprise engineering. In Workshop on Implemented Ontologies, European Conference on Artificial Intelligence (ECAI).

Gruber, T. R. (1993). A translation approach to portable ontology specifications. Knowledge acquisition, 5(2), 199-220.

Guzmán-Arenas, A., & Cuevas, A. D. (2010). Knowledge accumulation through automatic merging of ontologies. Expert Systems with Applications, 37(3), 1991-2005.

Heflin, J., & Hendler, J. (2000). Semantic interoperability on the web. Maryland Univ College Park Dept of Computer Science.

Hossenally, T., Subratty, U.K. & Nagowah, S.D. (2022). Learning Analytics for Smart Classroom System in a University Campus. In Machine Learning Techniques for Smart City Applications: Trends and Solutions, Cham: Springer International Publishing, 171-185.

Iqbal, H.M., Parra-Saldivar, R., Zavala-Yoe, R. and Ramirez-Mendoza, R.A. (2020). Smart educational tools and learning management systems: supportive framework. International journal on interactive design and manufacturing (IJIDeM), 14(4), 1179-1193.

Izza, S. (2009). Integration of industrial information systems: from syntactic to semantic integration approaches. Enterprise Information Systems, 3(1), 1-57.

Jiménez-Ruiz, E., & Cuenca Grau, B. (2011). Logmap: Logic-based and scalable ontology matching. In The Semantic Web–ISWC 2011: 10th International Semantic Web Conference, Bonn, Germany, October 23-27, 2011, Proceedings, Part I 10 (pp. 273-288). Springer Berlin Heidelberg.

Kavashev, Z. (2024). Heutagogical design principles for online learning: a scoping review. American Journal of Distance Education, 1-18.

Katsumi, M., & Grüninger, M. (2016). What is ontology reuse?. In FOIS, 9–22.

Khdour, T. (2020). A semantic assessment framework for e-learning systems. International Journal of Knowledge and Learning, 13(2), 110-122.

Kiljander, J., D'elia, A., Morandi, F., Hyttinen, P., Takalo-Mattila, J., Ylisaukko-Oja, A., & Cinotti, T. S. (2014). Semantic interoperability architecture for pervasive computing and internet of things. IEEE access, 2, 856-873.

Kultsova, M., Anikin, A., Zhukova, I., & Dvoryankin, A. (2015). Ontology-based learning content management system in programming languages domain. Communications in Computer and Information Science, 535, 767-777.

Litherland, K., Carmichael, P., & Martínez-García, A. (2013). Ontology-based e-assessment for accounting education. Accounting Education, 22(5), 498-501.

Maria, K., Vasilis, E., & Grigoris, A. (2012). S-CRETA: Smart classroom real-time assistance. In Ambient Intelligence-Software and Applications: 3rd International Symposium on Ambient Intelligence (ISAmI 2012) (pp. 67-74). Springer Berlin Heidelberg.

Martinez, G., Perry, J. and Biryukov, V. (2024, May). Automated IoT-Based Performance Assessments Through Activity Recognition and Semantic Evaluation in Smart Learning Environments. In 2024 International Conference on Control, Automation and Diagnosis (ICCAD) (pp. 1-6). IEEE.

McDaniel, M., Storey, V. C., & Sugumaran, V. (2018). Assessing the quality of domain ontologies: Metrics and an automated ranking system. Data & Knowledge Engineering, 115, 32-47.

Muhamad, W., Kurniawan, N. B., & Yazid, S. (2017, October). Smart campus features, technologies, and applications: A systematic literature review. In 2017 International conference on information technology systems and innovation (ICITSI) (pp. 384-391). IEEE.

Nagowah, S. D., Ben Sta, H., & Gobin-Rahimbux, B. A. (2021, December). An Ontology for an IoT-enabled Smart Library in a University Campus. In 2021 IEEE 23rd Int Conf on High Performance Computing & Communications; 7th Int Conf on Data Science & Systems; 19th Int Conf on Smart City; 7th Int Conf on Dependability in Sensor, Cloud & Big Data Systems & Application (pp. 1952-1957). IEEE.

Nagowah, S. D., Ben Sta, H., & Gobin-Rahimbux, B. A. (2019, December). An ontology for an IoT-enabled smart classroom in a university campus. In 2019 international conference on computational intelligence and knowledge economy (ICCIKE) (pp. 626-631). IEEE.

Nagowah, S.D. & Nagowah, L. (2009). Assessment strategies to enhance students' success. In Proceedings of the IASK International Conference "Teaching and Learning", Porto, Portugal (pp. 7-9).

Noy, N., & McGuinness, D. L. (2001). Ontology development 101. Knowledge Systems Laboratory, Stanford University, 2001.

O'Connor, M. J., & Das, A. K. (2009, October). SQWRL: a query language for OWL. In OWLED (Vol. 529, No. 2009, pp. 1-8).

Ouf, S., Abd Ellatif, M., Salama, S. E., & Helmy, Y. (2017). A proposed paradigm for smart learning environment based on semantic web. Computers in Human Behavior, 72, 796-818.

Rhee, S. K., Lee, J., Park, M. W., Szymczak, M., Ganzha, M., & Paprzycki, M. (2009). Measuring semantic closeness of ontologically demarcated resources. Fundamenta Informaticae, 96(4), 395-418.

Scrocca, M., Baroni, I. & Celino, I. (2021). Urban IoT ontologies for sharing and electric mobility. Semantic Web, (Preprint), 1-22.

Sheeba, T., & Krishnan, R. (2015). Semantic retrieval based on SPARQL and SWRL for learner profile. Int J Appl Eng Res, 10, 34549-54.

Shemshack, A. & Spector, J.M. (2020). A systematic literature review of personalized learning terms. Smart Learning Environments, 7(1), 1-20.

Sherimon, V., Sherimon, P. C., Mathew, R., Kumar, S. M., Nair, R. V., Shaikh, K., ... & Al Shuaily, H. S. (2020). Covid-19 ontology engineering-knowledge modeling of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). International Journal of Advanced Computer Science and Applications, 11(11).

Sirin, E., Parsia, B., Grau, B. C., Kalyanpur, A., & Katz, Y. (2007). Pellet: A practical owl-dl reasoner. Journal of Web Semantics, 5(2), 51-53.

Shi, Y., Qin, W., Suo, Y., & Xiao, X. (2010). Smart classroom: Bringing pervasive computing into distance learning. Handbook of ambient intelligence and smart environments, 881-910.

Shvaiko, P. & Euzenat, J. (2008). Ten challenges for ontology matching. In OTM Confederated International Conferences" On the Move to Meaningful Internet Systems" (pp. 1164-1182). Berlin, Heidelberg: Springer Berlin Heidelberg.

Suárez-Figueroa, M. C., Gómez-Pérez, A., & Fernández-López, M. (2012). The NeOn methodology for ontology engineering. In Ontology engineering in a networked world (pp. 9-34). Berlin, Heidelberg: Springer Berlin Heidelberg.

Sungkur, Y. G., Ozeer, A. M., & Nagowah, S. D. (2021). Development of an IoT-enabled smart library system for a university campus. Journal of Telecommunication, Electronic and Computer Engineering (JTEC), 13(1), 27-36.

Tabuenca, B., Uche-Soria, M., Greller, W., Hernández-Leo, D., Balcells-Falgueras, P., Gloor, P. and Garbajosa, J. (2024). Greening smart learning environments with Artificial Intelligence of Things. Internet of Things, 25, 101051.

Uschold, M., & King, M. (1995). Towards a methodology for building ontologies (pp. 1-13). Edinburgh: Artificial Intelligence Applications Institute, University of Edinburgh.

Uskov, V. L., Bakken, J. P., & Pandey, A. (2015). The ontology of next generation smart classrooms. In Smart education and smart e-learning (pp. 3-14). Springer International Publishing.

Yu, Z., Nakamura, Y., Jang, S., Kajita, S., & Mase, K. (2007). Ontology-based semantic recommendation for context-aware e-learning. In Ubiquitous Intelligence and Computing: 4th International Conference, UIC 2007, Hong Kong, China, July 11-13, 2007. Proceedings 4 (pp. 898-907). Springer Berlin Heidelberg.

Zhang, Y., Luo, X., Li, J., & Buis, J. J. (2013). A semantic representation model for design rationale of products. Advanced Engineering Informatics, 27(1), 13-26.

JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 21, No. 2 (2025), pp. 61-72

# Exploring Generative AI tools in higher education: insights for policies

Ana Luísa Rodrigues[1], Carmen Cavaco, Carolina Pereira

*Universidade de Lisboa, Instituto de Educação – Lisbon (Portugal)*

*(submitted: 12/8/2024; accepted: 14/9/2025; published: 28/10/2025)*

**Abstract**

The public availability of the Generative Artificial Intelligence (Gen-AI) tools, such as ChatGPT, led to diverse reactions in society. In higher education, these emerging technologies have brought several challenges, particularly with regard to ethical considerations, assessment frameworks, and new paradigms in teaching and research practices. In this article, we intend to explore the issues related to integration and ways of using the Gen-AI tools in higher education, especially in initial teacher education, and the implications of this use for education policies.

A qualitative approach was used with recourse to non-participant observation and narrative research methods through the analysis of experiences developed in Initiation to Professional Practice curricular unit of a Master' in Teaching. It was found that future teachers were able to use the ChatGPT as a tool to plan lessons and create digital educational resources, but the results obtained from its use always need careful and rigorous scrutiny and verification. Developing an entrepreneurial mindset in learning is important to increase creativity, innovation, and adaptability among preservice teachers. One also concludes that it is relevant to address and include issues relating to artificial intelligence in higher education, reflecting them particularly in regulations, legislation, and educational policy.

**KEYWORDS:** Generative Artificial Intelligence (Gen-AI), Entrepreneurial Mindset, Initial Teacher education, Education Policy.

**DOI**
https://doi.org/10.20368/1971-8829/1135999

**CITE AS**
Rodrigues, A.L., Cavaco, C., & Pereira, C. (2025). Exploring Generative AI tools in higher education: insights for policies. *Journal of e-Learning and Knowledge Society*, *21*(2), 61-72.
https://doi.org/10.20368/1971-8829/1135999

## 1. Introduction

With the rapid development and widespread accessibility of Generative Artificial Intelligence (Gen-AI), it is paramount to understand its implications in various areas of society, which is particularly important in terms of knowledge creation and contribution to the Sustainable Development Goals (UNESCO, 2021), notwithstanding the necessary epistemological reflection on its use (Figueiredo, 2023).

In higher education, Artificial Intelligence (AI) has the potential to change teaching and learning, according to Rawas (2023). ChatGPT, as one of the best-known tools, offers potential benefits to support teaching and research, automated grading, administrative management, and human-computer interaction (Dempere et al., 2023). On the one hand, it can provide individualized recommendations to students, increase collaboration and communication, and improve their learning outcomes (Rawas, 2023). Ethical concerns and implementation issues have been identified regarding safety in student assessment and plagiarism, misuse, the possibility of misinformation, as well as wider social and economic impacts such as job displacement, digital literacy gap or decreased human interaction (Rawas, 2023; Dempere et al., 2023).

Given the emergence of these new technologies and the fact that technological development is an unavoidable process with repercussions on educational processes, it is imperative to study these issues, whether the benefits of using Gen-AI tools to support this process, with the development of diversified skills and entrepreneurial mindsets, or their possible adverse effects. Namely, the possibility of increasing inequalities in educational success, decreasing creativity, or the dangers it may present for the loss of learning and critical thinking skills (Chomsky, 2023)

[1] corresponding author – email: alrodrigues@ie.ulisboa.pt – address: Alameda da Universidade, 1649-013 Lisboa (Portugal)

or even the risk in the most critical visions of AI being able to gain autonomy (Damásio, 2024). This exploratory study aims to contribute to an objective reflection on how to capitalise on the benefits and promote entrepreneurial and critical mindsets while correcting and controlling all the risk factors.

This article was designed to understand how to integrate Gen-AI tools into higher education pedagogical practices, especially in initial teacher education, from a perspective of promoting critical thinking for a global citizenship education.

This study is qualitative, exploratory, and interpretative in nature, supported by a literature review and empirical data collection in 2024 in a class of thirteen students enrolled in the Master's Degree in Economics and Accounting Teaching in Portugal. Two Gen-AI tools, ChatGPT and Elicit, were trialled and their outputs analysed. The first because it is the best known and most widely used tool among students, and the second because of its potential for scientific writing, given that it identifies references with some reliability.

The final discussion also sought to address the implications of using these tools for educational policies in the light of current guidelines.

### 1.1 Challenges of Gen-AI tools

ChatGPT, as a Gen-AI tool in the educational environment, can bring significant improvements, with added value such as help conversationally with writing, learning, solving and assessment, as an assistant for instructors and a virtual tutor for students (Lo, 2023). In higher education, there are signs that students already use AI tools (De Winter et al., 2023), and the dominant determinant was behavioural intention, above all Habit, according to a study of students' acceptance and use of technology (Strzelecki, 2023a). This was confirmed by another complementary study, which, in addition to habit, mentions performance expectancy, and hedonic motivation (Strzelecki, 2023b).

The challenges, opportunities, disadvantages, and dangers of using this type of AI tools are currently under discussion (Fuchs, 2023), which is why studies at various levels are needed. Some studies have indicated immediate measures to mitigate the negative effects of the impact of ChatGPT. A literature review highlights measures related assessment methods and the necessary institutional policies. Rethinking assessment tasks to reduce the risk of plagiarism by requiring students to demonstrate their skills in real time and in person, for example. At the institutional level, it would be important to make AI-based writing detection tools available to teachers, as well as establishing anti-plagiarism guidelines to clarify the limits of using ChatGPT in teaching and learning (Lo, 2023).

Another study points to the possibility of empowering educators through other strategies, for example supporting them in detecting keywords frequently used by ChatGPT to be able to detect plagiarism. In the same vein, teachers can adapt course content, learning outcomes and assessment methods to circumvent ChatGPT. On the other hand, this chatbot can also be used by teachers to assess students' texts or by using it to generate lesson topics, test and exam questions, homework or product ideas and designs (De Winter et al., 2023).

In turn, one of the critical aspects that arises is the development of critical thinking and an entrepreneurial mindset, considering this as the attitude of people who want to start a new venture and who have a strong desire for autonomy, creativity, and the ability to face challenges. According to Zemlyak et al. (2022), it can be influenced and developed based on three criteria: i) entrepreneurial education, ii) capacity for innovation, and iii) risk-taking. According to Jardim (2022), entrepreneurial skills can include creativity and innovation, initiative, self-efficacy and resilience, strategic planning and evaluation, problem solving, transformational leadership, clear and visual communication, teamwork and networking, and digital communication.

A study on the effect of next-generation AI technology similar to ChatGPT on users' entrepreneurial activities revealed that: entrepreneurial users collect extensive user data through AI technology and analyse it intelligently to make judgements; they use technology to understand users' latent needs and obtain information; and the technology improves entrepreneurial intent, stimulates creative thinking, and drives and enhances the evolution of entrepreneurship (Zhou & Cen, 2023).

In this sense, the use of AI tools to aid the learning process can contribute to the development of critical thinking and entrepreneurial mindset, considering that AI technologies transform individual entrepreneurial capacity, assuming the democratisation of knowledge and the availability of resources (Ganuthula, 2025).

From a more constructive and training perspective, it will also be important to promote students' digital literacy in the use of Gen-AI tools (Ng et al., 2023). It is important to instruct students about the risks of relying on AI-based technologies. These risks include hallucinations, which are false responses generated by AI, presented as facts, not explained by the training data (Dempere et al., 2023).

For this reason, the need for a critical and informed approach to dealing with these evolving issues is emphasised (Chomsky, 2023). It is crucial to integrate these technologies responsibly, as a supplement to and not a replacement for human interaction (Fuchs, 2023), and there is a pressing need to regulate AI in Higher Education Institutions (HEIs).

### 1.2 Learning environments with AI tools and their risks and concerns

As far as initial teacher education is concerned, this phenomenon is even more relevant, since these students, as future teachers, will soon be training pupils in education systems. The use of an application like ChatGPT can help to engage in a complex discussion about the purposes of education and the problem of "education as a product", calling for activities that involve critical reflection on these themes. Simultaneously, political work is needed to guarantee the necessary measures for more meaningful educational changes (Heimans et al., 2023).

Large language models, such as ChatGPT or Elicit, can help create educational content, improve student engagement and interaction, and personalise learning experiences. It requires teachers and students to develop digital competences and literacies, with a strong focus on critical thinking and fact-checking strategies. They can also be used to generate summaries and draft texts in research, writing and problem-solving tasks, as well as providing skills for professional training (Kasneci et al., 2023). This study adds that AI tools can also support teachers in planning lessons and activities, including inclusive ones. As well as in assessment and evaluation tasks, grading, and individualised feedback to students. Not forgetting teacher professional development in updating knowledge and providing teachers with resources, summaries, and explanations of new teaching methodologies, technologies, and materials, for example.

A study on how ChatGPT can contribute to lesson planning, critical thinking, and openness in education found that this type of tool does not pose a threat to teacher education and schools. ChatGPT and other AI models can reduce teachers' workload, for example in creating assessment tasks or supporting feedback work (Banihashem et al., 2024), increases efficiency, simplifies administrative tasks, and allows for personalised learning experiences (Kelley & Wenzel, 2025), allowing them more time for quality teaching (Usher, 2025), and the development of entrepreneurial learning. It should be emphasised, however, that they should be seen as tools to improve and complement teachers' work, but not to replace it (Van den Berg & Du Plessis, 2023).

Also, lesson planning can be used to enable preservice teachers to analyse and think critically as it performs the task more quickly and can provide new ideas that can be used. As mentioned, teachers and future teachers could discuss the functions and working mechanism of the chatbot, as well as the limitations and problems associated with its use, thus developing their critical thinking skills (Hong, 2023).

Much of the literature found on AI in education presents a positive and enthusiastic view of the potential of this interaction, despite the criticisms and concerns of various thinkers from other disciplinary areas, particularly philosophers. More critical currents express concerns about the direction in which technology is evolving, with personalised algorithms and chatbots that simulate human communication, and which consider that this could harm the development of critical thinking and science (Chomsky, 2023). This author refers to AI's lack of concern for understanding and emphasises the importance of cognitive science in this context, insofar as AI, as evidenced by ChatGPT, often focuses on simulation based on a set of data rather than real understanding. Damásio (2018) even says that artificial intelligence is a pale idea of what human intelligence really is.

This highlights the pressing risk of individuals losing their autonomy and also the misinformation that can arise from these tools, particularly due to so-called hallucinations, highlighting the importance of education, the critical thinking required and the organisation of society to combat these risks.

### 1.3 AI, critical thinking and entrepreneurial mindset development

Despite the dangers and risks announced, Gen-AI tools can be both a promoter of an entrepreneurial mindset and an innovative form of professional practice for future teachers. Recent research explores the intersection of artificial intelligence, learning environments, and entrepreneurial mindset development in higher education. AI learning in universities can significantly enhance entrepreneurial performance among students, with entrepreneurial orientation and strategic entrepreneurship playing key mediating roles (Khalid et al., 2020).

On the one hand, entrepreneurship education supported by Generative Artificial Intelligence can be effective in developing the entrepreneurial intentions of university students, emphasising the importance of supportive university ecosystems in fostering student entrepreneurship (Xie & Wang, 2025).

Teaching and learning methodologies used in AI-supported entrepreneurship education can influence the development of entrepreneurial mindset, on the other hand. In a systematic review of the literature, conducted by Park et al. (2025), which specifically explored the educational effects of LLMs (Large Language Models) such as ChatGPT, their integration and the ways in which they enhance students' creative thinking, concluded that they improve self-efficacy, cognitive engagement and creative problem solving, supporting entrepreneurship education in areas such as business model development, market analysis and multicultural communication. Despite these benefits, concerns remain about overconfidence, ethical risks, and the need for critical thinking structures.

Another study investigates the intersection between generative AI tools and experiential learning in business education, examining how students interact with and adapt to different AI modalities in relation to real-world experiences. It was found that this integrated approach enables novice users to overcome creative barriers, accelerates skill acquisition, and creates a dynamic interaction between AI-generated insights and real-world validation. Critical challenges were also identified, particularly regarding prompt engineering patterns and the need for more intuitive AI interfaces for educational contexts (Wang, 2025). In the same vein, Jarvis et al. (2021) found that effective learning environments for developing an entrepreneurial mindset incorporate team-based, student-centered pedagogies and focus on cultivating key capacities such as risk-taking, adaptability, and resilience, that they should also be worked on and developed by students in higher education.

Thus, we can conclude that AI-enabled learning environments, despite the associated risks and concerns that we must minimise, in conjunction with entrepreneurial education and critical thinking development, are relevant to learning and improving the quality of higher education and initial teacher education.

## 2. Method

This exploratory study was based on a qualitative and interpretative approach supported by a literature review complemented by experimentation, non-participant observation and narrative research. This was justified given that some of the participants had no experience in using any generative artificial intelligence tools, so it was necessary to let them experiment with supervision and then non-participant observation in class, after which they were asked to write a narrative about the experience.

Regarding the literature review, given the recent availability of these Gen-AI tools to the public, scientific studies published in the Scopus and WoC on this subject are still scarce, and the relevance of the articles mobilised was prioritised over quantity.

The specific questions of the study focused on: What types of tasks or learning activities can be developed using ChatGPT in teacher education? And How can these pedagogical practices contribute to stimulating critical and entrepreneurial thinking among future teachers?

Data was collected through non-participant observation and narrative research in a class of thirteen preservice-teachers in a master' programme in economics and accounting teaching in the second semester of 2024.

The following criteria were used to categorise the data collected: i) what are the main difficulties and constraints of using ChatGPT; ii) what are the benefits in the planning and preparation of classes; iii) what are the adaptations to instructional methods, form of assessment, and pedagogical practices needed to use ChatGPT in the teaching and learning process in an innovative, ethical and safe way.

In addition to the data from the empirical study supported by the literature review, and given the nature and need for experimentation with these new emerging technologies, two Gen-AI tools, ChatGPT and Elicit, were trialled and their outputs analysed in two moments, December 2023 and July 2025. Elicit is a research assistant using language models like ChatGPT to automate parts of researchers' Literature Review. It shows relevant papers and summaries of key information about those papers, and presents the articles found in a table.

Besides the best known and most used, ChatGPT, we selected Elicit because it is complementary in that it provides the references used in its outputs and can be used by teachers without the necessary critical reflection, which poses an increased risk if the sources are not verified.

The Gen-AI, Elicit and ChatGPT 3.5V/4v tools, both used in the free version (which will probably be the one most used by students), were tested by the researchers, with various objectives and using different prompts, and some exemplary outputs were analysed in the results. ChatGPT 3.5v was also tested by all the pre-service teachers in an academic assignment requested by teacher in the Initiation to Professional Practice unit of the master's degree in teaching, which trains future secondary school teachers, in 2024.

In this course, using the technique of non-participant observation, with field notes, the development of the work requested of the future teachers was monitored, which consisted of the creation of a digital teaching resource, its presentation to the class and final reflection on it. At the same time, narrative research was used through the final work of the course, which consisted of writing a reflective text by the students with the following guidelines: i) Description of the educational resource created in ChatGPT; ii) Main difficulties and constraints in using it; iii) Potential, advantages, and disadvantages of integrating ChatGPT into the teacher's work; iv) Implications of Chat GPT in the teaching and learning process in terms of ethics and safety; and v) Final considerations.

These issues were previously addressed in classes, considering some of the implications mentioned by Ratten and Jones (2023) in their study about implications of ChatGPT for management educators. The challenges encompass the need for incorporating real-life examples in assessment, integrating artificial intelligence into the learning experience, anticipating dilemmas through contextualized resources, integrating recent technologies into management contexts, as well as addressing uncertainty around ChatGPT through open discussions.

The study's qualitative approach took a naturalistic and hermeneutic perspective, using content analysis of the field notes from non-participant observation and of student narratives conducted as a final assignment (Amado & Freire, 2014; Bardin, 2013). This methodology is often used in research in the social sciences and education, as the researcher is dealing with complex situations in which it is difficult to select variables. This way, the researcher seeks to describe and analyse a phenomenon and its interactions (Bogdan & Biklen, 1994), and does not intend to quantify or generalise.

The narrative research method provides in-depth knowledge of the respondents' experiences and is based on a constructivist and interpretive epistemology (Rabelo, 2011). It considers that a narrative can express the complexity of the experience, as well as the relationships and uniqueness of each action (Bolívar et al., 1998). Therefore, knowledge is obtained through an account that captures the details of meanings beyond factual statements or abstract propositions.

The validity and reliability of the study were ensured by the depth, transparency, and reflexivity of the research process, taking into account the deep engagement with the data, reflexivity, and triangulation with three researchers, and the theoretical support studied prior to data collection, complemented by the description of procedures and field notes. The qualitative and interpretative approach of the study values the richness and complexity of the phenomenon studied, rather than its replicability (Morse et al., 2002; Denzin & Lincoln, 2000).

Finally, it should be noted that informed consent was obtained from the study participants, thirteen preservice teachers, and their identity and anonymity were safeguarded, in accordance with the institution's ethics charter and international benchmarks, as Ethical Guidelines for Educational Research (BERA, 2011).

The final discussion also sought to address the implications of using these tools for educational policies in light of current guidelines. Especially given the current spread of these tools among students and the lack of generalised rules and practices regarding the ethical limits of their use.

## 3. Results and Discussion

The results obtained from the data collected were divided into two parts: one relating to experimentation with Gen-AI tools as an example or testing, and other to observation and narratives in master' in teaching. This section presents the data as it was obtained, followed by the interpretation and discussion of these results.

### 3.1 Operation and example outputs from Gen-AI tools

One of the examples tested was to request a short literature review text from both platforms, Elicit and ChatGPT. The output from Elicit, when prompted with the words "ChatGPT teacher education", based on the four articles it selected, was as follows (Elicit, 2023):

> *A range of studies have explored the potential of ChatGPT in teacher education. Berg (2023) and Rahman (2023) both highlight the benefits of ChatGPT, such as providing lesson plans and personalized feedback, but also caution against potential threats, including cheating and diminished critical thinking skills. Pokkakillath (2023) further emphasizes the potential for instant feedback and personalized learning experiences, while calling for further research on its impact. Halaweh (2023) provides strategies for responsible implementation, underscoring the need for a balanced approach to leveraging ChatGPT in education.*

With the same prompt, in 2025, we get the following output:

> *Recent research explores the integration of ChatGPT in teacher education, particularly for language instruction and lesson planning. ChatGPT can enhance teacher preparation by providing personalized feedback and supporting the development of didactic knowledge and self-reflection skills (Schauber, 2025). It offers valuable resources for lesson planning and can promote critical thinking in teacher education (van den Berg & du Plessis, 2023). Pre-service teachers have reported positive experiences using ChatGPT for creating engaging educational materials (Tunjera & Chigona, 2023). The AI tool has the potential to revolutionize personalized learning and provide support for educators in simplifying complex concepts and enhancing student engagement (Govindaraja et al., 2024). However, researchers emphasize the need for careful management and critical evaluation of ChatGPT's limitations and potential biases (Schauber, 2025; van den Berg & du Plessis, 2023). Overall, ChatGPT shows promise in transforming teaching methodologies and*

> *classroom interactions, but its implementation requires thoughtful consideration.*

The articles used exist, the text presented is based on four articles in the free version, and the evolution in text quality is significant, even though the selected articles may include conference proceedings. Other articles are also presented with their abstract summary. We have the option of using some filters, such as publication year, study type and abstract keywords. And we can also add columns with information on intervention, intervention effects, main findings, outcome measured, study design or limitations.

It is a tool that allows you to quickly search for articles and summarise them in a short text with references. Depending on how demanding and rigorous it is, it can be useful as a study aid for students and as a starting point for more complex research. Of course, with the necessary verification of the veracity of the content and questions of ethical transparency ensured.

In turn, ChatGPT 3.5 (OpenAI, 2023) was also asked to help with the literature review on: "the integration and ways of using ChatGPT in initial teacher education by preservice teachers, and the implications of this use for educational policies".

In December 2023, the output from the ChatGPT gives us a text that is acceptable but not linked to references and cannot be qualified as a scientific text because it has no references to support it. We do not know which sources were consulted, although there do not appear to be any noteworthy errors or inconsistencies.

In July 2025, with ChatGPT version 4 free, the output was as follows:

> *The integration of artificial intelligence (AI) tools such as ChatGPT into initial teacher training has attracted growing scholarly attention, particularly regarding how preservice teachers use these technologies to support pedagogical development. Studies by Trust et al. (2023) and Holmberg and Wiese (2024) highlight that preservice teachers commonly use ChatGPT for lesson planning, content clarification, and generating differentiated instructional materials. These tools are seen as extensions of reflective practice and collaborative planning, enabling more efficient preparation and deeper engagement with curriculum design (König et al., 2023). Furthermore, ChatGPT facilitates the acquisition of pedagogical knowledge by offering accessible summaries of teaching theories and classroom management strategies, serving as a supplemental tutor that reinforces academic content.*
>
> *From a policy perspective, the adoption of ChatGPT in teacher training programs prompts critical reconsiderations of assessment protocols, academic integrity, and digital equity. Scholars such as Selwyn (2023) and Williamson and Eynon (2024) argue for the urgent inclusion of AI literacy in teacher education curricula, emphasizing the importance of equipping future educators with the skills to evaluate and ethically implement AI tools in classroom contexts. Educational policies must address the risk of overreliance, biases in AI outputs, and disparities in access to digital tools, particularly in underserved institutions. In response, policy recommendations call for the development of regulatory frameworks that promote responsible AI integration, protect student data, and support inclusive teacher training environments (Luckin et al., 2023). The literature broadly agrees that embracing AI in teacher education holds significant promise, but must be guided by deliberate pedagogical and ethical frameworks.*

The quality of the text and the ability to integrate references and list them at the end was substantially improved. And we could also continue to interact in 'dialogue' with the platform. However, although references are provided, most of them contain errors or do not exist, and some of them have even been invented. In other words, users cannot yet rely on this type of platform to carry out small literature reviews with the required accuracy and minimum quality.

### 3.2 Non-participant observation and narratives in master' in teaching

Based on the observation and narratives constructed by the preservice teachers, it was possible to analyse some educational resources created using ChatGPT. One could analyse also the main difficulties and constraints in its use, advantages, disadvantages, and potential of integrating ChatGPT into the teacher's work, as well as the implications for the teaching and learning process, and future prospects.

Various educational resources had been created by preservice teachers, from lesson plans, content for PowerPoint presentations, practical activities and games, a script for a video, a work, exercise, or debate script, formative or consolidation worksheets, to an assessment test corrected at the end by the pupils with the support of ChatGPT.

The main difficulties and constraints encountered were: difficulty due to unfamiliarity with the tool and how to ask the most appropriate questions for the objectives; the need to reformulate the prompt (input, stimulus or question) and add context; incomplete or even incorrect outputs; absence or errors in the references and sources of the information; limitation due to not providing images, graphics or videos; lack of creativity; obtaining results in Brazilian instead of Portuguese (although the translation done whenever requested); time limitation of the information provided by ChatGPT, particularly in terms of more up-to-date data statistics, especially as these preservice teachers are from the field of economics, which requires constant updating.

Regarding the perceived advantages, the respondents highlighted the usefulness of ChatGPT as a tool to help the teacher's work, referring to "the simplicity of the tool and the ease of use, considering that ChatGPT provides results immediately and access to personalised responses", including in the promotion of active teaching-learning strategies, preparation/ elaboration of teaching resources and support in carrying out more administrative tasks. It makes it possible to prepare "varied resources such as activities and assessments or reports capable of providing feedback on student progress". In addition, it allows "quick access to information and research", and consequently "freeing up teachers' time". It also makes it possible to "get a variety of different answers, emphasising that the AI tool itself has the option to regenerate response".

The main disadvantages pointed by respondents out were: the possibility of obtaining incomplete or incorrect information, with "possible errors and lack of context", so there will be a need to validate and verify the rigour of all the information obtained with a critical sense; "doubts about the ability to produce effectively correct, coherent and adapted scientific content"; outdatedness in certain types of questions; dependence on technology; "student distraction, plagiarism, and excessive reliance on the internet"; dependence on the quality and quantity of data" used; and "a gap in training in the area of Information and Communication Technologies".

However, the following potentialities were mentioned: the use of ChatGPT "for students' self-study" and "to help clarify doubts, contributing to the personalisation of teaching"; be a "tool to support teaching and learning", addressing this aspect directly with students; it can also "help teachers prepare their lessons and even carry out dynamic tasks in the classroom", namely as a "research assistant" in problem-based learning methodologies, formulating questions for project work or explaining a particular topic. It can also be used, for example to: "search for more complex information, get specific examples, ask for feedback, help with daily activities, lesson plans, think or exchange ideas/points of view, use chat as a discussion tool, ask for advice, search for thematic authors, ask for help to start something more complex (it can be a starting point for organising ideas), translation (...), ask for complex theories to be explained in a simplified way, get immediate answers to questions posed in class, generate games and activities, or find authors or studies on a theme".

Regarding the implications mentioned by respondents, it was considered that ChatGPT can "promote self-regulated learning processes by the student and create the stimulus for teachers to take a greater role in the development of procedural and metacognitive knowledge", and that "the use of these tools can be very effective if the teacher is able to monitor their use by the students, sensitising them to the importance of using them responsibly and ethically". "Teachers have to be vigilant and find ways to validate whether or not a student knows a certain piece of content", for example, with class presentations. Thus, "the biggest challenge is the authenticity of the work produced", so "we must warn students to be critical when using this tool". Our role as teachers is also to teach students how to search for and select relevant and scientifically correct information," explaining "what is right and what is wrong", warning about plagiarism and issues related to privacy and data security.

Finally, according to respondents' answers, it can be concluded that ChatGPT is a tool that will have "significant potential to transform education", "can innovate and create more attractive and differentiated teaching resources", and "offer personalisation in the teaching-learning process, additional support for the teacher, more comprehensive access to relevant content and even improvements in educational efficiency", both for the teacher and the students.

Nevertheless, it was felt that there is an urgent need for training and "the acquisition of computer skills relating to tools of this kind from the user's point of view", so that they can be used with awareness and a critical sense. An interesting conclusion of one of the respondents was that ChatGPT can threaten the banking teacher (Freire, 1987) "in his role as monopoliser of knowledge (factual and conceptual) but can help to achieve higher-order knowledge (procedural and metacognitive) through student-centred teaching and learning methodologies".

This data analysis of the answers obtained was carried out without using ChatGPT. The raw data was entered as inputs into ChatGPT and asked to be summarised, but it was considered not to be of sufficient quality to be used. Although the information was correct, it could not be presented in an equally rigorous way.

### 3.3 Discussion

In the results presented from experimenting with Gen-AI tools, we can see that although the information presented does not present any notable errors, its quality is not high in terms of writing and accuracy, and above all, with regard to the exact sources from which it was gathered. In the case of the Elicit tool, it is noteworthy that although the references are presented, the way in which they are selected is not mentioned, and we do not know how the quality of the articles considered is assessed.

In other words, we don't know how the information was generated, we don't have access to the selection criteria used to search for the articles used and we run the risk of there being some kind of distortion of knowledge, losing the reliability of the results obtained.

As the literature points out (e.g. Rawas, 2023; Dempere et al., 2023; Strzelecki, 2023a) support use of AI tools can serve as a support, but they do not replace a teacher or researcher, and there is a need to verify and validate the information obtained. Figueiredo (2023) notes that the outputs of large-scale language models require awareness of the principles and conditions of validity of the knowledge that can be obtained from them.

On the other hand, by experimenting with these tools, we have realised that it is important how the questions or prompts are asked (words, phrases or messages given in the conversation), the degree of knowledge on the subject and the depth and continuity of the conversation. The more detailed the information provided, the better the outputs generated.

Well-designed prompts have the potential to transform interactions with GenAI in teaching and learning in higher education, so improve the interaction with AI tools, it is important to develop prompt literacy as an academic skill. ChatGPT or any other chatbot can help the teacher's work, namely commenting on students' texts, evaluating them, and making suggestions for improvement, according to the prompt used (Moura & Carvalho, 2024). Or when asked to prepare a test, statement or script for an activity to be carried out by the students, the quantity and quality of details provided in the prompt will enable a product to be obtained that is more in line with what is required.

The literature corroborates that high-quality prompt engineering skills predict the quality of LLM results, suggesting that prompt engineering is indeed a necessary skill for using generative AI tools. Furthermore, certain aspects of AI literacy may play a role in high-quality prompt engineering and the targeted adaptation of LLMs in education (Knoth et al., 2024).

The results of the observation and narratives showed the potential of ChatGPT in terms of rapid access to substantial amounts of filtered information, as a research and support tool for teaching and learning. Whether for creating various educational resources, supporting administrative work, for students' self-study or clarifying doubts. In addition to the advantages, the tool has some significant limitations for the average user that need to be considered. These limitations are possible errors and omissions or gaps in outputs and ethical and security issues. In this way, the information has to be validated by the teacher or expert, and its quality is not guaranteed, especially when no sources are presented for verification. This requires critical thinking skills on the part of users and the need for specific training in digital literacy, as the literature has indicated.

Despite the potential benefits of using AI tools for personalised learning, feedback, and the provision of adapted educational resources, it is important to weigh up the challenges of loss of human interaction, prejudices, and ethical implications.

Therefore, in order to face these challenges, HEIs need support students in developing activities and tasks with these tools with a focus on improving student learning. On the other hand, they should invest in training their teaching staff to use and adapt to technology, as well as providing support for its effective and ethical use (Strzelecki, 2023b).

One knows most students consider that they check the reliability of online information, and teachers report that they have received training and feel prepared to teach responsible use of the Internet, according to the "Civic and Citizenship Education Study 2022 International Report" (Schulz et al., 2022). Although, new digital forms of communication and artificial intelligence tools seem to be increasing and have an ever-greater impact on generating more and less transparent information online. Hence the importance of training and educating citizens about the issues associated with digital technologies.

In today's society, we are obsessed with information and data. According to Han (2022), we understand the world through information and face-to-face experience is lost, and too much information can be counterproductive.

It will therefore be essential to train teachers and students in the advantages and limitations of using ChatGPT, whether in preparing lessons and assignments, or in relying on biased, limited, or even incorrect or false data. It is therefore crucial to raise students' awareness of academic integrity policies, to discuss the importance of academic honesty, and to teach students to use other reliable sources to verify, evaluate and corroborate the accuracy of the information provided by ChatGPT (Dempere et al., 2023).

Recognising the need to reflect on AI in instructional practices and teacher training programmes, Kelley and Wenzel (2025) suggest a multi-phase approach to integrating AI into higher education through individual exploration, partnerships with teachers, implementation of pilot studies and expanded partnerships, and professional development.

Therefore, ChatGPT represents an opportunity for HEIs to improve the quality and accessibility of education (Figueiredo, 2023). However, its implementation should be approached with caution and with a clear understanding of the opportunities and challenges involved. Insofar as these new technologies can contribute to increasing the noise and complexity of the educational process and can jeopardise equity, especially in less developed countries where access to technology is unequal or scarce.

In spite of the framework already put forward by the European Union, with the preparation of a Law and the "Ethical guidelines on the use of artificial intelligence (AI) and data in teaching and learning for Educators" (European Commission, 2022), or by the USA, with the "Blueprint for an AI Bill of Rights" (White House Office, 2022), and the report "Artificial Intelligence and Future of Teaching and Learning: Insights and Recommendations" (U.S. Department of Education, 2023), we still lack regulations that allow artificial intelligence to evolve ethically and safely. Following the U.S. Department of Education, Office of Educational Technology, policies are urgently needed to highlight the importance of using AI to enhance learning outcomes while ensuring data quality, promoting equity, and maintaining human oversight in educational decision-making.

In its report "AI and education: guidance for policy-makers", UNESCO (2021) made several policy recommendations too, of which we emphasise: define a system-wide vision of AI, strategic priorities, and education policies; adopt a humanistic approach as an overarching principle for AI and education policies; or build a trusted evidence base to support the use of AI in education. That said, it is clear that is critical to analyse the influence of AI on higher education, including in initial teacher education, so that it can be the subject of legislation and framed in educational policy.

Xiao et al. (2023) examined ChatGPT policies implemented at the top 500 universities according to the 2022 QS World University Rankings from around the world, including their existence, content, and issuance dates, concluding that there is significant variation in university policies. Less than a third of the universities included in this study implemented ChatGPT policies, and of the universities with ChatGPT policies, approximately 67% (more than double the number of universities that banned it) adopted ChatGPT in teaching and learning.

Also, An et al. (2025), in a study of 50 leading US universities on the use of generative AI in academic and administrative activities, concluded that although there is growing adoption of AI, there are still significant gaps in institutional policies, highlighting the need for clear and comprehensive regulation.

## 4. Conclusions

Literacy in generative AI will be indispensable for providing students with the skills they need to use AI systems critically, ensuring that they become active and discerning users. At the same time, prompt engineering makes it possible to improve the outputs generated in a more precise way and enables educators and students to maximize the usefulness of the educational resources created by AI, as concluded by several authors (e.g. Bozkurt, 2023 or Lee & Palmer, 2025).

This study corroborates that, for the development of AI literacy, it is important to acquire proficiency in understanding, interacting with and critically evaluating Gen-AI technologies, which is essential not only for the current digital age, but also to face the future. It is also important to understand the ethical considerations, prejudices, and limitations inherent in such systems, as well as to promote critical thinking and digital citizenship among students, teachers, and researchers.

It will therefore be relevant to integrate Gen-AI literacy into the curriculum to cultivate a new generation of informed and responsible users, and teachers will be able to adapt their teaching methods to incorporate AI, preparing students for a future where it is an integral part of their personal and professional lives.

The impact of AI on education and higher education cannot be ignored, and it is essential to integrate it into teacher education as well, according to this study and others reported in the literature (e.g. Kelley & Wenzel, 2025). It is therefore suggested to look for new learning outcomes, such as learning and teaching skills with GenAI, AI literacy, promote interdisciplinarity, new pedagogies, learning and assessment centred on more practical activities in the classroom as Chiu (2023) also mentioned. In particular, contextualised assessment activities.

Despite existing international frameworks from the European Union and the US, the lack of comprehensive regulations and the necessary discussion and analysis regarding the integration of AI into education systems makes it difficult to move forward ethically and safely. Educational policies are needed to strengthen competences and control the risk factors of Gen-AI in order to ensure its equitable, inclusive and ethical use.

Based on this study and literature, especially from UNESCO (2021, 2023), the recommendations include emphasizing humanistic approach, mobilizing interdisciplinary planning, empowering teachers, and enhancing trust and safety. From the latest update of the 2023 report, in 2025, highlight that the first step in regulating generative AI (GenAI) in education is to pass or develop national data protection laws with consistent implementation. Specific government strategies should be reviewed or adopted, integrating AI regulations and ensuring provisions for the ethical use of AI in various sectors, namely education, where AI should be used responsibly and transparently. Copyright laws need to be updated to consider AI-generated content, as current laws, such as those in the EU and the US, do not address the implications of GenAI results. It is also important to develop institutional capacity for the appropriate use of generic AI in education through training programmes and ongoing support for teachers and researchers. Public debates and policy discussions are also recommended to explore the long-term implications of generic AI for education, knowledge creation and research, ensuring the development of human-centred AI policies.

## Acknowledgements

This work was supported by National Funds through FCT-Portuguese Foundation for Science and Technology, I.P., under the scope of UIDEF - Unidade de Investigação e Desenvolvimento em Educação e Formação, UIDB/04107/2020, https://doi.org/10.54499/UIDB/04107/2020

## References

Amado, J., & Freire, I. (2014). Estudo de caso na Investigação em Educação. In J. Amado (Org.), *Manual de investigação qualitativa em educação [Handbook of qualitative research in education]* (2nd ed., pp.121-168). Imprensa da Universidade de Coimbra.

An, Y., Yu, J. H. & James, S. (2025). Investigating the higher education institutions' guidelines and policies regarding the use of generative AI in teaching, learning, research, and administration. *International Journal of Educational Technology in Higher Education, 22*(10). https://doi.org/10.1186/s41239-025-00507-3

Banihashem, S. K., Kerman, N. T., Noroozi, O. et al. (2024). Feedback sources in essay writing: peer-generated or AI-generated feedback? *International Journal of Educational Technology in Higher Education, 21*(23). https://doi.org/10.1186/s41239-024-00455-4

Bardin, L. (2013). *Análise de Conteúdo [Content Analysis].* Edições 70.

BERA (2011). *Ethical Guidelines for Educational Research*. https://eera-ecer.de/about-eera/ethical-guidelines

Bogdan, R., & Biklen, S. (1994). *Investigação Qualitativa em Educação. Uma introdução à teoria e aos métodos [Qualitative Research in Education. An introduction to theory and methods]*. Porto Editora.

Bolívar, A., Domingo, J., & Fernández, M. (1998). *La investigación biográfico–narrativa en educación. Guía para indagar en el campo [Biographical-narrative research in education. A guide to investigating the field].* Grupo FORCE, Universidad de Granada, y Grupo Editorial Universitario.

Bozkurt, A. (2023). Unleashing the Potential of Generative AI, Conversational Agents and Chatbots in Educational Praxis: A Systematic Review and Bibliometric Analysis of GenAI in Education. *OpenPraxis, 15*(4), 261–270. https://doi.org/10.55982/openpraxis.15.4.609

Chiu, T. K. F. (2023). Future research recommendations for transforming higher education with generative AI. *Computers and Education: Artificial Intelligence*, 100197. https://doi.org/10.1016/j.caeai.2023.100197

Chomsky, N. (2023, May 2). ChatGPT contra o pensamento crítico [ChatGPT against critical thinking]. *Outras Palavras Newspaper*. https://outraspalavras.net/tecnologiaemdisputa/chomsky-o-chatgpt-contra-o-pensamento-critico/

Damásio, A. (2024, February 23). Ciclo Futuros da Educação, Cátedra UNESCO. *Diário de Notícias Newspaper*. https://files.quickcom.pt/Files/Imprensa/2024/02-23/0/5_3332029_B32CE058F3214B9EB0FD5B8474DD604F.pdf

Denzin, N. K., & Lincoln, Y. S. (2000). Introduction: The Discipline and Practice of Qualitative Research. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research* (2nd ed., pp. 1-34). Sage Publications.

De Winter, J.C.F., Dodou, D., & Stienen, A.H.A. (2023). ChatGPT in Education: Empowering Educators through Methods for Recognition and Assessment. *Informatics, 10,* 87. https://doi.org/10.3390/ informatics10040087

Dempere, J., Modugu, K., Hesham, A., & Ramasamy, L.K. (2023). The impact of ChatGPT on higher education. *Frontiers in Education, 8,* 1206936. https://doi.org/10.3389/feduc.2023.1206936

Elicit (2023). *AI Research Assistant* (Dec 28th) [Large language model]. https://elicit.com

Elicit (2025). *AI Research Assistant* (Jul 29th) [Large language model]. https://elicit.com

BERA (2011). Ethical Guidelines for Educational Research. https://eera-ecer.de/about-eera/ethical-guidelines_European Commission (2022). *Ethical guidelines on the use of artificial intelligence (AI) and data in teaching and learning for educators*. Directorate-General for Education, Youth, Sport and Culture. Publications Office of the European Union. https://data.europa.eu/doi/10.2766/153756

Figueiredo, A. D. (2023, June 30). Inteligência Artificial Generativa e Construção de Conhecimento [Generative Artificial Intelligence and Knowledge Construction]. [Personal communication]. In *Processamento de Linguagem Natural: Tendências e Aplicações Práticas Conference.* Coimbra University, Portugal. https://doi.org/10.13140/RG.2.2.25801.52328

Freire, P. (1987). *Pedagogia do oprimido [Pedagogy of the Oppressed]* (17th ed.). Paz e Terra.

Fuchs, K. (2023). Exploring the opportunities and challenges of NLP models in higher education: is Chat GPT a blessing or a curse. *Frontiers in Education, 8*. https://doi.org/10.3389/feduc.2023.1166682

Ganuthula, V. R. (2025). The Solo Revolution: A Theory of AI-Enabled Individual Entrepreneurship, *Computers and Society*, https://doi.org/10.48550/arXiv.2502.00009

Han, B.C. (2022). *Não-Coisas. Transformações no mundo em que vivemos. [Non-Things. Transformations in the world we live in].* Relógio d´Água.

Heimans, S., Biesta, G., Takayama, K., & Kettle, M. (2023). ChatGPT, subjectification, and the purposes and politics of teacher education and its scholarship. *Asia-Pacific Journal of Teacher Education, 51*(2), 105-112. https://doi.org/10.1080/1359866X.2023.2189368

Hong, W.C.H. (2023). The impact of ChatGPT on foreign language teaching and learning: Opportunities in education and research. *Journal of Educational Technology and Innovation, 5*(1), 37-45. https://jeti.thewsu.org/index.php/cieti/article/view/103

Jardim, J. (2022). Competências Empreendedoras para Ser Bem-Sucedido no Mundo Global e Digital: proposta de um quadro de referência. [Entrepreneurial Skills for Success in the Global and Digital World: Proposal for a Reference Framework]. *Video Journal of Social and Human Research, 1*(2), 1-24. https://doi.org/10.18817/vjshr.v1i2.24

Jarvis, C., Gaggiotti, H., & Kars S. (2021). Is It All in the Mindset? Team Coaching, Psychological Capital, and the Collaborative Development of an Entrepreneurial Mindset. In E. Vettraino, & B. Urzelai (Eds.), *Team Academy: Leadership and Teams* (1st ed.). Routledge. https://doi.org/10.4324/9781003163121

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., Stadler, M., Weller, J., Kuhn, J., & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences, 103,* 102274. https://doi.org/10.1016/j.lindif.2023.102274

Kelley, M., & Wenzel, T. (2025). Advancing Artificial Intelligence Literacy in Teacher Education Through Professional Partnership Inquiry. *Education Sciences, 15*(6), 659. https://doi.org/10.3390/educsci15060659

Khalid, N., Kolivand, H., Balas, V.E., Paul, A, & Ramachandran, V. (2020).Artificial intelligence learning and entrepreneurial performance among university students: evidence from Malaysian higher educational institutions. *Journal of Intelligent & Fuzzy Systems, 39*(4), 5417-5435. https://doi.org/10.3233/JIFS-189026

Knoth, N., Tolzin, A., Janson, A., & Leimeister, J. M. (2024). AI literacy and its implications for prompt engineering strategies. *Computers and Education: Artificial Intelligence, 6*, 100225. https://doi.org/10.1016/j.caeai.2024.100225.

Lee, D., & Palmer, E. (2025). Prompt engineering in higher education: a systematic review to help inform curricula. *International Journal of Educational Technology in Higher Education, 22*(7). https://doi.org/10.1186/s41239-025-00503-7

Lo, C.K. (2023). What Is the Impact of ChatGPT on Education? A Rapid Review of the Literature. *Education Sciences*, *13*, 410. https://doi.org/10.3390/educsci13040410

Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification Strategies for Establishing Reliability and Validity in Qualitative Research. *International Journal of Qualitative Methods, 1*(2), 13-22. https://doi.org/10.1177/160940690200100202

Moura, A., & Carvalho, A. A. (2024). Literacia de Prompts para Potenciar o Uso da Inteligência Artificial na Educação. [Prompt Literacy to Enhance the Use of Artificial Intelligence in Education.]. *RE@D - Revista de Educação a Distância e Elearning, 6*(2), e202308. https://doi.org/10.34627/redvol6iss2e202308

Ng, D. T. K., Leung, J. K. L., Su, J., Ng, R. C. W., & Chu, S. K. W. (2023). Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. *Educational*

*Technology Research and Development*, *71*,137–161. https://doi.org/10.1007/s11423-023-10203-6

OpenAI. (2023). *ChatGPT* (Mar 14, 3.5 version) [Large language model]. https://chat.openai.com/chat

OpenAI. (2025). *ChatGPT* (Jul 29, 4 version). [Large language model]. https://chat.openai.com/chat

1. Park, J.-H., Kim, S.-J., & Lee, S.-T. (2025). AI and Creativity in Entrepreneurship Education: A Systematic Review of LLM Applications. *AI, 6*(5), 100. https://doi.org/10.3390/ai6050100

Rabelo, A. O. (2011). A importância da investigação narrativa na educação. [The importance of narrative research in education]. *Educação & Sociedade*, *32*(114), 171-188. https://doi.org/10.1590/S0101-73302011000100011

Ratten, V., & Jones, P. (2023). Generative artificial intelligence (ChatGPT): Implications for management educators. *The International Journal of Management Education, 21*(3), 100857. https://doi.org/10.1016/j.ijme.2023.100857

Rawas, S. (2023). ChatGPT: Empowering lifelong learning in the digital age of higher education. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-12114-8

Schulz, W., Ainley, J., Fraillon, J., Losito, B., Agrusti, G., Damiani, V., & Friedman, T. (2022). *Education for Citizenship in Times of Global Challenge*. IEA International Civic and Citizenship Education Study International Report. https://www.iea.nl/sites/default/files/2023-12/ICCS-2022-International-Report.pdf

Strzelecki, A. (2023a). To use or not to use ChatGPT in higher education? A study of students' acceptance and use of technology. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2023.2209881

Strzelecki, A. (2023b). Students' Acceptance of ChatGPT in Higher Education: An Extended Unified Theory of Acceptance and Use of Technology. *Innovative Higher Education*. https://doi.org/10.1007/s10755-023-09686-1

an den Berg, G., & du Plessis, E. (2023). ChatGPT and Generative AI: Possibilities for Its Contribution to Lesson Planning, Critical Thinking and Openness in Teacher Education. *Education Sciences, 13,* 998. https://doi.org/10.3390/educsci13100998UNESCO (2021). *AI and education: Guidance for policy-makers.* United Nations Educational, Scientific and Cultural Organization. https://doi.org/10.54675/PCSP7350

UNESCO (2023). *Guidance for generative AI in education and research*. United Nations Educational, Scientific and Cultural Organization. https://doi.org/10.54675/EWZM9535

U.S. Department of Education (2023). *Artificial Intelligence and Future of Teaching and Learning: Insights and Recommendations*. Office of Educational Technology, Washington, DC, US. https://tech.ed.gov

Usher, M. (2025). Generative AI vs. instructor vs. peer assessments: a comparison of grading and feedback in higher education. *Assessment & Evaluation in Higher Education*, 1-16. https://doi.org/10.1080/02602938.2025.2487495

UNESCO (2021). Van den Berg, G., & Du Plessis, E. (2023). ChatGPT and Generative AI: Possibilities for Its Contribution to Lesson Planning, Critical Thinking and Openness in Teacher Education. *Education Sciences, 13*, 998. https://doi.org/10.3390/educsci13100998

Wang, N. C. (2025). Scaffolding Creativity: Integrating Generative AI Tools and Real-world Experiences in Business Education. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25)*, April 26-May 01, Yokohama, Japan. ACM, New York, NY, USA (pp.1-9). https://doi.org/10.1145/3706599.372028

White House Office (2022). *Blueprint for an AI Bill of Rights*. White House Office of Science and Technology Policy. https://www.whitehouse.gov/wp-content/uploads/2022/10/Blueprint-for-an-AI-Bill-of-Rights.pdf

Xiao, P., Chen, Y, & Bao, W (2023). *Waiting, Banning, and Embracing: An Empirical Analysis of Adapting Policies for Generative AI in Higher Education*. http://dx.doi.org/10.2139/ssrn.4458269

Xie, Y., & Wang, S. (2025). Generative artificial intelligence in entrepreneurship education enhances entrepreneurial intention through self-efficacy and university support. *Scientific Reports, 15*, 24079. https://doi.org/10.1038/s41598-025-09545-3

Zemlyak, S., Naumenkov, A., & Khromenkova, G. (2022). Measuring the Entrepreneurial Mindset: The Motivations behind the Behavioral Intentions of Starting a Sustainable Business. *Sustainability, 14*(23), 15997. https://doi.org/10.3390/su142315997

Zhou, J., & Cen, W. (2023). Investigating the Effect of ChatGPT-like New Generation AI Technology on User Entrepreneurial Activities. *Innovation & Technology Advances, 2*(2), 1–20. https://doi.org/10.61187/ita.v2i2.124

# JOURNAL OF e-LEARNING AND KNOWLEDGE SOCIETY

*www.je-lks.org*

VOLUME 21 | ISSUE NO. 2 | AUGUST 2025

AN INTERNATIONAL AND OPEN ACCESS JOURNAL BY THE ITALIAN E-LEARNING ASSOCIATION (SIE-L)

*www.sie-l.it*

ISSN (online) 1971 - 8829 | ISSN (paper) 1826 - 6223