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AI Literacy, Digital Capabilities and Intellectual Property Awareness: Evidence for Preparing Future Professionals in the Digital Age

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ABSTRACT

The rapid expansion of artificial intelligence (AI), generative technologies, and digital platforms is transforming the ways knowledge is created, shared, and protected across educational and professional environments. As AI-driven tools become increasingly integrated into learning, research, and creative activities, intellectual property (IP) issues, including authorship, ownership, plagiarism, copyright protection, and the ethical use of digital content, have become more prominent. Despite growing attention to AI literacy, digital competencies, and IP governance, empirical evidence examining the relationship between digital capabilities and IP awareness in AI-driven environments is still limited. This study addresses this gap by examining the relationships between digital capabilities, AI-related environments, and IP awareness among individuals preparing to participate in increasingly digital and AI-enabled societies. It also investigates whether demographic characteristics are associated with perceptions of AI-related opportunities and risks associated with IP. By exploring these relationships, the study contributes to a better understanding of the factors that support responsible AI use, strengthen IP awareness, and promote the development of digital competencies. The findings provide practical implications for higher education institutions and policymakers seeking to foster ethical AI adoption and effective IP management in the digital era.

KEYWORDS AI literacy, digital capabilities, intellectual property, higher education, professional preparation

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Introduction

Public and private sector organizations and higher education institutions play a vital role in knowledge creation and development. They face challenges in managing and leveraging intellectual property (IP) in the context of rapid digital transformation (DT) [1], [2]. The utilization of digital technologies, such as digital platforms, e-commerce, social media and digital marketing, affects the valuation and protection of IP, including trademarks, patents, and

copyrights, demonstrated in several analyses and empirical studies [3], [4], [5], [6]. This research paper was developed within the project "Factors of Intellectual Property Management and Digital Transformation in Macedonia" (2025–2026), funded by the Ministry of Education and Science of the Republic of N. Macedonia, building on previous empirical research [7], [8], [9], and this study examines the relationship between DT, IP management, and AI literacy while taking gender-related differences into account. It is conceptually based on the resource-based view and dynamic capabilities theory, according to which AI-related environments and digital capabilities are regarded as strategic resources that enable organizations to create, manage, and protect IP in rapidly evolving environments.

Technological and Human Perspectives on Digital Transformation

DT encompasses more than the adoption of digital technologies; it involves the ability of organizations, and individuals to adapt to an increasingly digital environment. Previous research [10], [11] demonstrates that digital technologies contribute to higher productivity, greater competitiveness, and enhanced innovation, while also underscoring the critical role of human resources, AI literacy and digital competencies in achieving successful transformation.

Effective DT requires a strategic approach that aligns organizational goals with digital capabilities. Through process optimization, continuous improvement, and effective governance, organizations can enhance adaptability, sustain innovation, and achieve long-term resilience in a rapidly changing digital environment [12]. Okene et al. [13] highlights the challenges of balancing IP protection with public access in the digital environment, particularly regarding digital piracy, AI-generated content, and globally distributed works. Their study emphasizes differences among international legal frameworks and the need for harmonized approaches through legal adaptation, international cooperation, and public awareness to support innovation while ensuring fairness and accessibility.

The successful implementation of digital technologies depends largely on developing individuals' digital capabilities [14]. AI literacy, digital skills, and adaptability are essential for supporting DT, encouraging innovation, and enabling effective IP creation and protection. Similarly, Gyamerah et al. [15] highlights that AI literacy, and digital competencies are often overlooked in strategic planning, despite their significant impact on innovation and IP development. Their findings underline the importance of investing in formal and non-formal education to strengthen AI literacy, digital capabilities and improve the effective use of digital technologies.

As DT progresses, the development of digital capabilities becomes essential for effective technology adoption and process improvement. AI literacy and the ability to use digital tools, such as mobile applications and social media platforms, support organizational agility, innovation, and competitive advantage [16]. Strengthening these capabilities enables organizations to maximize the value of technological investments and achieve improved operational and strategic outcomes.

Digital Transformation and Its Implications for Intellectual Property

DT is transforming the IP landscape by enabling new forms of innovation, knowledge sharing, and value creation, while simultaneously increasing challenges related to piracy, misuse, and protection [17]. Emerging technologies, including AI, blockchain, and digital platforms, require adapted legal, institutional, and organizational frameworks to ensure effective IP governance and maintain a balance between innovation and protection [18].

DT has transformed the IP landscape by enabling innovation, value creation, and wider dissemination of intellectual assets, while also increasing risks related to digital reproduction, AI-generated content, and global distribution [19]. Zinych et al. [20] highlight persistent challenges in digital IP protection, including weak enforcement, inconsistent legal practices, and limited effectiveness of existing frameworks. They emphasize the need for stronger legislation, improved enforcement mechanisms, and institutional reforms to support innovation and digital development.

Sheikh [21] highlights the importance of IP rights in the digital economy, emphasizing challenges related to digital reproduction, ownership, licensing, and enforcement. The study suggests that stronger IP protection mechanisms are essential for supporting innovation and sustainable competitiveness. Hantoush [22] examines the integration of open access resources in academic libraries, emphasizing the need for effective licensing and management strategies to balance knowledge accessibility with IP governance. Similarly, Samoilenko, Bieliaieva, and Borodii [23] explore digital approaches for protecting authorship rights, highlighting the role of digital tools in verifying ownership, preventing plagiarism in AI-driven creative environments.

The Role of Artificial Intelligence and Digital Technologies in Intellectual Property Management

In the context of rapid technological development, advanced digital technologies, especially AI and digital tools, are becoming increasingly significant [24]. These technologies reshape IP practices by enabling more efficient processes for creation, management, monitoring, and protection of IP assets [25].

Kilimnik [26] examines the challenges of IP protection in the digital economy, highlighting the impact of AI, blockchain, and digital platforms on IP rights, governance, and regulatory frameworks. The study proposes an integrated legal and technological approach to strengthen IP protection in digital markets. Sanek et al. [27] examine the impact of digital assets, including cryptocurrencies, NFTs, and AI-generated works, on existing IP frameworks within the European Union context. The study identifies regulatory challenges related to ownership, attribution, and enforcement, emphasizing the need for harmonized legal frameworks and effective mechanisms for IP protection in the digital era. Finally, Rubio-Alfageme [28] argues that traditional copyright frameworks are insufficient for addressing digital piracy and rapidly evolving digital markets. The study emphasizes the

importance of adaptive business models, accessible digital services, and balanced AI-supported enforcement approaches that protect creators' rights while maintaining public access to digital content.

A conceptual distinction is made in this study between AI literacy and broader digital capabilities. AI literacy refers specifically to the ability to understand, critically evaluate, use, and interact responsibly with AI systems and AI generated outputs, including awareness of their limitations, risks, ethical implications, and potential consequences for intellectual property. Digital capabilities, in contrast, refer to broader competencies required to operate effectively in digitally mediated environments, including information search and evaluation, use of digital platforms and services, digital communication, security practices, and confidence in using digital technologies. Although these constructs are related and may mutually reinforce one another, they are not conceptually identical. This distinction is important because the present study examines their relationship with IP awareness while also recognizing that the available questionnaire data combines several AI-related and broader digital competency items into a composite measure. Accordingly, the empirical results should not be interpreted as demonstrating that AI literacy alone explains differences in IP awareness.

Background and related work

Research Question

Drawing on the theoretical foundations and empirical gaps identified in previous research and the existing literature, this study addresses the following research questions:

1. To what extent are AI literacy and digital capabilities associated with awareness of IP?

2. How do respondents perceive the positive and negative implications of digital transformation for intellectual property?

3. To what extent do AI literacy, digital capabilities, and awareness of IP differ across gender groups?

Research Hypotheses

Based on established theories and empirical gaps, this study tests hypotheses regarding AI literacy, digital transformation, and intellectual property:

H1 (Main hypothesis): AI literacy and digital capabilities are positively and significantly related to individuals' knowledge and awareness of IP.

H1a (Sub-hypothesis): There is a statistically significant difference in AI literacy and digital capabilities between respondents who correctly identify the types of IP and those who do not.

H1b (Sub-hypothesis): AI literacy and digital capabilities have a positive and statistically significant effect on awareness of IP.

H2 (Main hypothesis): Respondents perceive both positive and negative implications of DT for IP.

H2a (Sub-hypothesis): There is a statistically significant positive association between the positive and negative implications of DT on IP.

H3 (Main hypothesis): Statistically significant differences exist in AI literacy, digital capabilities, and awareness of IP between male and female respondents.

H3a (Sub-hypothesis): Gender significantly predicts AI literacy and digital capabilities.

H3b (Sub-hypothesis): Gender significantly predicts awareness of IP.

Variables

The AI Literacy and Digital Capabilities Index (AILI) was constructed from individual's overall score on the questionnaire items covering two related domains: (1) AI related competencies, including understanding and use of AI tools, evaluation of AI-generated outputs, recognition of AI limitations and risks, and responsible use of AI; and (2) broader digital capabilities, including information search and evaluation, use of digital services and platforms, digital security, and trust in digital systems. Items were measured on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The composite score was calculated as arithmetic means of valid item responses.

The Intellectual Property Awareness (IPA) refers to the level of an individual's knowledge and understanding of the concept of IP and their various key forms. The measure included multiple choice items and five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Where applicable, correct identification of IP types was analyzed separately as a knowledge indicator rather than being treated as equivalent to the broader IPA construct. Digital Transformation Impact (DTI) refers to respondents' perceptions of how AI and digital technologies influence the creation, dissemination, protection, and potential misuse of IP. The construct is conceptualized as comprising two core perceptual dimensions:

1. The positive dimension – Intellectual Property Positive Index (IPPI) reflects perceived enabling effects of DT on IP and constructed from Likert-scale items assessing perceived enabling effects of digital transformation on IP, including innovation, dissemination, accessibility, authorship verification, and modern licensing practices.

2. The negative dimension – Intellectual Property Negative Index (IPNI) captures perceived risks associated with DT, constructed from items assessing perceived risks, including piracy, unauthorized sharing, misuse of digital content, difficulties in enforcement, and trademark violations in online environments.

Gender is measured as a nominal variable with two categories (male, female).

Methods or analytical approach

Participants

The study sample consists of 102 respondents from the public sector in N. Macedonia. A convenience sampling

method was applied. The sample includes both male and female respondents, enabling comparative, correlational and regression analyses of AI literacy, digital capabilities and awareness of IP. Participation was voluntary and anonymous.

Questionnaire

The questionnaire included three main sections: demographic information, AI literacy and digital skills, and IP management. Responses were collected using multiple choice and yes/no questions, as well as a five-point Likert scale (1 = strongly disagree, 5 = strongly agree), with an additional option of "Don't know / No answer" for participants who were unsure or preferred not to answer.

Data Collection and Analysis Procedure

The study was conducted using an online questionnaire. Prior to participation, all respondents were informed about the purpose and duration of the study and were assured that their responses would be used exclusively for scientific purposes. Participants received clear instructions for completing the questionnaire. This method allows standardized, systematic data collection. The analysis includes descriptive statistics, correlation, t-tests for group comparisons, and regression analysis to examine relationships between DT, AI literacy and digital capabilities and IP variables. Responses coded as "Don't know / No answer" were treated as missing values. Therefore, the effective sample size varies across statistical tests depending on the availability of valid responses for the variables included in each analysis. Before conducting the inferential analyses, the relevant statistical assumptions were assessed, including the distributional characteristics of the variables and the assumptions relevant to correlation, group comparison, and regression analyses. Where the assumption of equal variances was not met, Welch's t-test was used as an alternative to the conventional independent samples T test. The results were interpreted with consideration of the relatively small effective sample sizes in some analyses.

Results and findings

Regarding the H1 (Main hypothesis): AI literacy and digital capabilities are positively and significantly related to individuals' knowledge and awareness of IP, the results supported the hypothesis, as the findings indicated a statistically significant positive correlation between the AILI and IPA, r (80) = 0.294, p = 0.007, indicating a weak-to moderate positive association between the two variables.

Regarding the H1a (Sub-hypothesis): There is a statistically significant difference in AI literacy and digital capabilities between respondents who correctly identify the types of IP and those who do not, the results supported the hypothesis, as the findings indicated a statistically significant difference in AILI scores between respondents with correct knowledge of types of IP and those with incorrect knowledge of types of IP, t (40.15) = 2.20, p = 0.034. The group with correct knowledge of types of IP had a higher AILI score (M = 4.37, SD = 0.42) than the group with incorrect knowledge of types of IP (M = 4.10, SD = 0.57).

Regarding the H1b (Sub-hypothesis): AI literacy and digital capabilities have a positive and statistically significant effect on awareness of IP, the results supported the hypothesis, as the findings indicated that the regression model was statistically significant, F (1,80) = 9.79, p = 0.002, explaining 10.9% of the variance in IPA (R^2 = 0.109). Furthermore, AILI emerged as a significant positive predictor of IPA (β = 0.33, p = 0.002). These findings indicate that respondents with higher levels of AILI tend to report higher levels of IPA. However, because the data are cross-sectional, the regression result should be interpreted as a statistical predictive association rather than evidence that AILI causes changes in IPA.

Regarding the H2 (Main hypothesis): Respondents perceive both positive and negative implications of DT for IP, the results supported the hypothesis, as the findings indicate a strong positive perceived impact of DT on IP, reflected in the Intellectual Property Positive Index (IPPI) (M = 4.21, SD = 0.61), as well as a notable negative perceived impact, reflected in the Intellectual Property Negative Index (IPNI) (M = 3.80, SD = 0.65), confirming the coexistence of both enabling and risk-related effects of DT on IP management. These findings indicate that respondents simultaneously recognized potential enabling effects and potential risks of DT for IP.

Regarding the H2a (Sub-hypothesis): There is a statistically significant positive association between the positive and negative implications of DT on IP, the results supported the sub-hypothesis, as the findings indicated a statistically significant moderate positive correlation was found between Intellectual Property Positive Index (IPPI) and Intellectual Property Negative Index (IPNI), r (33) = 0.412, p = 0.014. This finding indicates that respondents who reported stronger perceived benefits of DT also tended to report greater awareness of its potential risks. The result suggests that positive and negative perceptions of DT are not mutually exclusive.

Regarding the H3 (Main hypothesis): Statistically significant differences exist in AI literacy, digital capabilities, and awareness of IP between male and female respondents, the findings provided partial support for the hypothesis. First, as the findings indicated a statistically significant difference in AILI scores between male and female respondents, t (80) = 1.989, p = 0.050. Male respondents reported a higher mean AILI score (M = 4.40, SD = 0.58) compared with female respondents (M = 4.16, SD = 0.54), indicating higher levels of AI literacy among male participants. Second, no statistically significant difference was identified in IPA scores between male and female respondents, t (80) = 0.031, p = 0.975. The mean scores were identical for male (M = 3.83, SD = 1.21) and female respondents (M = 3.83, SD = 1.25), suggesting that gender does not significantly influence IPA.

Regarding the H3a (sub-hypothesis): Gender significantly predicts AI literacy and digital capabilities, the findings supported the hypothesis, as the regression model was marginally statistically significant, F (1,80) = 3.96, p = 0.050, explaining 4.7% of the variance in AILI scores (R^2 = 0.047). Gender was identified as a positive predictor of AILI (B = 0.245, β = 0.217, p = 0.050), indicating that male respondents reported slightly higher levels of AILI compared with female respondents. These findings suggest that gender contributes to differences in AILI, although the overall explanatory power of the model is limited.

Regarding the H3b (Sub-hypothesis): Gender significantly predicts awareness of IP, the results did not support the hypothesis, as the regression model was not statistically significant, F (1,80) = 0.001, p = 0.975, explaining virtually

none of the variance in IPA scores ($R^2 < 0.001$). Gender was not found to be a significant predictor of IPA (B = 0.008, β = 0.003, p = 0.975). The results show that male and female respondents reported almost identical levels of IPA.

Discussion

The discussion is structured around the three research questions. The first research question concerns the association between AI-related competencies, digital capabilities, and IPA; the second addresses respondents' perceptions of the positive and negative implications of DT for IP; and the third examines gender differences in these constructs. The interpretation below follows this structure to distinguish the empirical findings from their broader conceptual and educational implications.

The descriptive statistics provided an overview of respondents' self-reported proficiency in AI literacy and digital competence, their use of digital technologies, and their awareness of IP rights.

The findings reveal generally high levels of AI literacy and digital competence among the respondents, with all assessed dimensions recording mean values above the midpoint of 3. In contrast, comparatively lower scores were observed in relation to trust in digital systems and AI, as well as awareness of IP rights. This pattern indicates potential areas for further development, particularly in strengthening digital trust and improving understanding of IP protection within the increasingly digital environment.

The correlation analysis conducted to test Hypothesis H1 indicates a positive association between AI literacy, digital capabilities, and IPA. This relationship is particularly relevant in AI-driven environments, where a higher level of AI literacy may contribute to individuals' ability to recognize and address key IP-related issues, including authorship, ownership of AI-generated content, plagiarism, the ethical use of generated outputs, and the protection of IP. These findings further emphasize the growing importance of AI and digital competencies in supporting responsible and informed engagement with AI-generated content.

The significant association between AILI and IPA indicates that individuals with higher levels of AI literacy and digital competence tend to exhibit greater awareness of IP rights and the responsibilities associated with their use in digital environments. This finding contributes to existing literature and previous research by providing empirical evidence for the relationship between AI-related competencies and IP awareness in an increasingly AI driven context [14], [16]. However, the relatively modest strength of the correlation indicates that AI literacy and digital capability alone do not fully explain variations in IPA, suggesting that other individual, organizational, or contextual factors may also influence this relationship.

The findings for the H1a sub-hypothesis demonstrate a statistically significant difference in AILI scores between respondents who correctly and incorrectly identified the different types of IP. This result supports H1a and suggests that respondents with stronger knowledge of IP concepts tend to have higher levels of AILI. One possible explanation is that individuals with greater AI literacy and digital competence may be better positioned to acquire, understand, and retain knowledge related to IP. Conversely, greater awareness of IP rights may also promote more responsible, informed, and systematic engagement with digital technologies, particularly in AI-supported creative and content-generation processes.

The findings related to the H1b sub-hypothesis indicate that AI literacy and digital capability significantly contribute to the prediction of IPA. The positive association between AILI and IPA suggests that individuals with higher levels of AI literacy and stronger digital competencies are more likely to recognize and understand IP rights. Although the model explains a relatively modest proportion of the variance in IPA ($R^2 = 0.109$), the results nevertheless highlight the relevance of AI literacy and digital competence in shaping individuals' understanding of IPA. From a practical perspective, incorporating IP-related topics into digital literacy and competency development initiatives could help strengthen IPA and encourage more informed and responsible behavior in digital environments.

The findings of this study contribute to the growing body of research on the role of AI literacy in IP management by demonstrating that AI-related competencies and digital capabilities are positively associated with higher levels of IPA. Whereas previous research has predominantly viewed digital literacy as a fundamental prerequisite for technology adoption and innovation, the present study broadens this perspective by emphasizing the relevance of AI literacy for understanding and addressing IP-related challenges in AI enabled environments. As AI becomes increasingly embedded in content creation, knowledge production, and information processing, individuals need to develop not only technical competencies but also the capacity to recognize and appropriately address issues concerning authorship, ownership, originality, ethical use, and the protection of AI-assisted outputs. In this context, AI literacy can be regarded as an important complementary competence that supports responsible digital practices and more informed decision-making concerning IP rights. The findings therefore underscore the value of integrating AI literacy into IP education and broader digital competency development, particularly within higher education, where students are being prepared to operate in increasingly AI driven professional environments.

The findings related to the H2 hypothesis provide empirical evidence of the dual role of DT in the context of IP. Consistent with previous research, the results suggest that DT simultaneously creates opportunities for innovation and knowledge dissemination while also generating challenges related to accessibility, misuse, and IP protection [19], [20]. The relatively high IPPI score (M = 4.21, SD = 0.61) indicates that respondents perceive DT as an important enabler of innovation, knowledge sharing, and broader access to digital content. At the same time, the IPNI score (M = 3.80, SD = 0.65) reflects a considerable level of awareness regarding the risks associated with misuse, piracy, and the protection of IP in digital environments. Taken together, these findings highlight the complex and multidimensional role of DT in shaping contemporary IP practices.

Overall, the relatively high ratings across both the positive and negative dimensions suggest that respondents hold a balanced view of DT. While they recognize the potential of DT to facilitate innovation, knowledge sharing, and broader

access to information, they also acknowledge the challenges these technologies create for effective IP protection and governance. This balanced perception highlights the dual nature of DT and the need to maximize its benefits while addressing the associated risks to IP.

The findings for the H2a sub-hypothesis reveal a statistically significant, moderate positive association between respondents' positive and negative perceived impacts of DT on IP ($r = 0.412$, $p = 0.014$). This result suggests that respondents who perceive greater benefits of DT, including enhanced knowledge dissemination, innovation, and accessibility, also tend to demonstrate greater awareness of the associated risks, such as misuse and IP infringement. Rather than viewing the benefits and risks of DT as mutually exclusive, respondents appear to recognize both dimensions simultaneously. This pattern points to a relatively balanced perception of DT, in which greater recognition of its potential advantages is accompanied by increased awareness of its implications for IP protection.

The findings for H3, including the H3a and H3b sub hypotheses, suggest that gender has a relatively limited role in explaining differences in AI literacy and digital capabilities and does not have a significant effect on IPA. Although male respondents reported slightly higher AILI scores than female respondents, the observed difference appears to be modest, indicating that gender may account for only a small proportion of the variation in AI literacy and digital competence. This interpretation is further supported by the regression results, which show that gender explains only a small proportion of the variance in AILI. Consequently, other factors, including educational background, professional experience, access to digital training, and organizational context, may be more important in shaping individuals' AI literacy and digital capabilities.

In contrast, gender was not found to have a statistically significant effect on IPA, with male and female respondents reporting broadly comparable levels of IPA. This finding suggests that IPA may be more closely related to factors such as knowledge, prior experience, and exposure to digital environments than to demographic characteristics. Overall, the results indicate that gender represents a relatively weak predictor of both AILI and IPA when compared with broader individual, educational, and contextual factors.

These findings also carry important implications for higher education institutions. Integrating AI literacy, digital competencies, and IP education into academic curricula could help equip future professionals with the knowledge and skills necessary to navigate AI-enabled environments responsibly. Such an approach would support not only technological competence, but also greater awareness of ethical, legal, and IP-related considerations associated with the use of AI and digital technologies.

Conclusion

The empirical findings provide several important insights into the links between AI literacy, digital capabilities, awareness of IP, and the role of DT in IP management. However, limited empirical evidence exists on whether AI literacy and digital capabilities are associated with awareness of IP at the individual level. This study addresses this gap by providing empirical evidence on how AI literacy and digital capabilities relate to individuals' awareness of IP.

First, the findings show that AI literacy and digital capabilities are closely related to IPA. Respondents with higher AILI scores reported a better understanding of IP concepts, rights, and responsibilities. The regression results also show a positive relationship between AILI and IPA, indicating that individuals with stronger digital skills are more likely to recognize the importance of IP, understand its implications, and appreciate its value in digital environments.

The findings also point to a clear relationship between IP knowledge and AILI. Respondents who were able to correctly identify different types of IP tended to have higher levels of AILI, suggesting that AI literacy and knowledge of IP are closely connected. This finding underlines the need for educational approaches that develop technological skills alongside a basic understanding of IP principles and their application in digital environments.

Second, the findings show that DT has both positive and negative implications for IP management. Respondents recognize that digital technologies can create important opportunities by supporting innovation, improving access to information, facilitating the distribution of IP assets, and introducing new ways of verifying authorship, including blockchain-based solutions. At the same time, they are aware of the risks associated with piracy, unauthorized sharing, trademark misuse, and limitations in existing IP protection mechanisms. The recognition of both these opportunities and risks suggests that respondents have a relatively balanced understanding of the challenges and benefits that DT brings to IP management.

The results also indicate that individuals who perceive stronger positive effects of DT tend to be more aware of its potential risks. This suggests that responsible participation in digital environments depends not only on technological skills but also on an understanding of the legal and ethical issues associated with digital technologies.

Third, the findings related to demographic characteristics show only limited gender differences in AILI. Male respondents reported slightly higher levels of AILI, while gender did not have a significant effect on IPA, with male and female respondents showing nearly identical levels of IPA. These findings suggest that factors such as education, professional experience, exposure to digital technologies, organizational support, and access to AI and digital training may play a more important role in shaping AILI and IPA than gender alone.

A key contribution of this study is the identification of AI literacy as an emerging competence that can strengthen awareness of IP rights in digitally transformed environments. Compared with traditional digital skills, AI literacy also involves the ability to critically assess AI generated content, understand issues related to authorship, and recognize the ethical and IP implications of using AI technologies. The findings highlight the need to integrate AI literacy, digital capabilities, and IP education into higher education curricula and professional development programs. As future professionals are increasingly expected to work in AI-driven environments, developing AI literacy can contribute to a better understanding of IP rights, more responsible use of

technology, ethical content creation, and the protection of innovation. In this way, education can help students develop not only the technical skills needed to work with digital technologies, but also the critical, ethical, legal, and professional competencies required for responsible participation in AI-enabled workplaces and society. Although the findings may have implications for higher education, these implications should be understood as conceptual and practical proposals rather than direct empirical conclusions about students or academic institutions. The present sample consists of Macedonian public-sector respondents and does not include a dedicated student or higher-education population. Accordingly, the proposed integration of AI literacy, digital capabilities, and IP education into higher education curricula requires empirical validation in student and academic staff populations before broader conclusions can be drawn.

From this perspective, the digitalization of higher education can be understood through three closely related dimensions: digital infrastructure, AI and digital competence, and IP, ethics, and responsible AI use. The first dimension refers to the technological and organizational foundation needed to support digital education, including digital platforms and e-services, cloud-based and collaborative technologies, digital security, data protection, and access to emerging technologies. The second dimension focuses on the development of AI and digital skills, such as searching for and evaluating information, digital communication and collaboration, effective use of AI tools, critical assessment of AI-generated content, responsible use of generative AI, and the ability to continuously adapt to technological change. The third dimension addresses IP and ethical competencies, including knowledge of authorship, copyright, plagiarism, ownership, licensing, privacy, transparency, accountability, bias, and the responsible use of AI. Together, these dimensions provide a broader framework for supporting the responsible and effective DT of higher education.

Based on the empirical findings and theoretical discussion, the study proposes a conceptual educational framework that can be represented as: Student → Digitally Competent → AI-Literate → IP-Aware → Ethically Responsible → AI-Ready Professional.

This sequence should not be interpreted as an empirically established developmental pathway or as evidence that individuals necessarily progress through these stages in a fixed order. Rather, it represents a proposed conceptual framework illustrating how digital capabilities, AI literacy, IPA, and ethical responsibility may be integrated within broader professional preparation. The empirical results of the present study establish associations among selected constructs, but they do not demonstrate that these competencies develop sequentially or causally. Future longitudinal and multi-stage research is required to determine whether the proposed framework represents a developmental pathway, a set of mutually reinforcing competencies, or a broader model of professional readiness.

From a practical and institutional perspective, higher education institutions can apply this framework to assess their level of digital maturity, identify gaps in students' and staff competencies, redesign curricula, and establish measurable learning outcomes related to AI literacy. It can also support the integration of IP and AI ethics into teaching and learning, as well as the assessment of students' digital and AI readiness. In this context, AI literacy should be viewed as a transversal competence that is developed across study programs and linked to disciplinary knowledge, professional practice, ethical decision-making, and IPA.

Such integrated educational approaches can help students participate more responsibly in digital environments and become better prepared to respond to emerging technological challenges. In this regard, higher education institutions have an important role in developing not only students' technical AI skills, but also their ethical, legal, and IP knowledge. This broader approach can better prepare graduates to use AI responsibly and to respond effectively to the demands of AI-enabled workplaces and society.

From a policy and organizational perspective, the findings emphasize the need for evidence-based approaches to digital IP management. Policymakers, higher education institutions, and organizations should support training and development initiatives that bring together emerging technologies, AI-driven environments, digital competencies, and IP governance. In this context, strengthening AI literacy should be regarded as an important priority for higher education. Developing these competencies can encourage more responsible use of AI, increase awareness of IP rights, support ethical decision making, and better prepare graduates for the growing demands of an AI-enabled labor market.

The broader contribution of this approach lies in shifting the focus of DT from technology adoption towards competence development. The success of DT should therefore not be assessed only by the extent to which institutions adopt new technologies, but also by how effectively these technologies contribute to developing professionals who are digitally competent, able to think critically, aware of ethical responsibilities, and knowledgeable about IP. This perspective places human capabilities and responsible technology use at the center of DT in higher education.

This study has few limitations. The use of a convenience sample and a cross-sectional research design may limit the generalizability of the findings and does not allow for clear causal conclusions. Future research should therefore examine and further validate the proposed framework using larger and more diverse samples, including students and academic staff from different higher education institutions, sectors, and countries. Further studies could also consider additional individual and organizational factors that may influence AI literacy, digital capabilities, and the awareness of IP rights, such as organizational support, previous digital experience, and the intensity and frequency of AI use.

An additional consideration concerns the self-reported nature of AI literacy and digital capability measures. The study assesses respondents perceived competencies through questionnaire responses rather than through objective performance-based tasks. Consequently, the reported AILI scores may reflect respondents' perceptions of their abilities rather than their objectively demonstrated AI and digital skills. Future research could strengthen the measurement approach by combining self-report scales with performance-based assessments, scenario-based tasks, or validated AI literacy instruments.

In conclusion, the findings indicate that AI literacy, digital capabilities, and IPA are closely interconnected and should be viewed as important components of responsible DT. Effective DT should not be understood simply as the adoption of AI technologies. Rather, it is achieved when the use of these technologies contributes to the development of professionals who can apply AI critically, safely, ethically, and responsibly, while also understanding its implications for IP.

Declarations

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