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Heutagogy Meets Generative AI in Teacher Education: Examining an Evolving Synergy

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Abstract

As generative AI (GAI) tools become increasingly embedded in educational contexts, understanding their intersection with learner autonomy is critical—particularly in teacher education. This study explores the evolving synergy between pre-service teachers' (PSTs) use of GAI tools and their heutagogical orientations, with attention to disciplinary differences. A quantitative analysis was conducted with 181 PSTs (103 from Humanities and 78 from Math and Science), who completed a validated questionnaire based on Blaschke's four core principles of heutagogy. Results indicate a positive relationship between GAI usage and heutagogical orientation, with Humanities PSTs reporting significantly higher levels of self-regulated and reflective learning principles. While the overall frequency of GAI use did not differ by discipline, its pedagogical implications did: linguistic applications (e.g., writing assistance, translation) were more strongly associated with reflection and metacognition among Humanities students, whereas multimedia-based GAI usage correlated with enhanced problem-solving confidence, reflecting the self-efficacy principle, across both groups. Notably, the cybergogy principle—autonomous learning in digital environments—emerged as most closely linked to GAI engagement, particularly among Humanities participants. Age and program track also influenced outcomes, with younger and secondary-track PSTs demonstrating greater adaptability to digital learning. These findings suggest that while GAI tools are broadly accessible, their transformative potential in teacher education depends on aligning technological integration with disciplinary cultures and learner agency. Fostering this synergy requires teacher education programs to support not only digital fluency but also reflective, self-determined learning across diverse educational contexts.

Keywords: Heutagogy, Generative Artificial Intelligence, Pre-Service Teachers, Disciplinary Differences, Self-Directed Learning, Cybergogy, Teacher Education.

Introduction

In 2024, the European Commission introduced an add-on to the DigCompEdu framework (Bekiaridis, 2024), which, beyond emphasizing digital literacy, incorporates competencies and skills specifically related to artificial intelligence (AI). The primary aim of this extension is to equip teachers with the capacity to use AI technologies effectively and responsibly, while also addressing the associated ethical and social implications (Miao et al., 2021; Floridi et al., 2018). The add-on enhances the existing framework by integrating AI-related proficiency levels into DigCompEdu's six core areas: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. It also examines the multifaceted challenges of AI integration in education—both as a pedagogical tool and as a subject of study—while offering assessment metrics and exemplar learning activities to support teacher development.

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Concurrently, heutagogy—a learner-centered educational approach that emphasizes autonomy, self-direction, and reflective practice—has gained prominence as a pedagogical framework, well-suited to the affordances of the digital age (Blaschke, 2021). In contrast to pedagogy, which is teacher-directed, and andragogy, which emphasizes facilitation in adult learning, heutagogy positions learners as the central agents in constructing and managing their own learning processes (Khattak et al., 2021). The growing integration of generative AI (GAI) tools into educational contexts raises critical questions regarding the extent to which these technologies support or potentially challenge heutagogical principles.

Pre-service teachers (PSTs) constitute a particularly relevant population for examining the intersection of GAI and heutagogy. As learners themselves, PSTs not only adopt emerging technologies to support their academic development but also develop pedagogical beliefs and practices that will influence their future classrooms. Furthermore, GAI usage is likely to vary across disciplinary domains. For instance, students preparing to teach in the Humanities and those training to teach Science and Mathematics (hereafter referred to as S&M) often encounter different types of content, problem-solving practices, epistemological orientations, and disciplinary hierarchies. These differences may shape both their engagement with GAI tools and their attitudes toward self-directed learning (Authors, 2024).

This study aims to explore the usage profiles of GAI among PSTs training to become Humanities teachers and those preparing to teach in S&M fields, and how this usage correlates with attitudes toward key dimensions of heutagogy. Specifically, it investigates whether and how the frequency and nature of GAI use are associated with four principles of heutagogical learning: self-directed learning, reflection and metacognition, problem-solving self-efficacy, and cybergogical engagement (Blaschke, 2021). Moreover, the study examines the moderating role of disciplinary background in shaping these associations. By employing a quantitative research design, this study seeks to offer a generalizable perspective on the relationship between GAI use and heutagogical orientations among PSTs.

Literature Review

Heutagogy in Education

Heutagogy can be seen as building on a long-standing tradition of learner-centered education, with intellectual roots traceable to thinkers such as Rousseau and John Dewey. Rousseau's emphasis on natural development and intrinsic motivation, and Dewey's advocacy for experiential learning and democratic education, both foregrounded the learner as an active participant in the educational process. These foundational ideas resonate with heutagogy's emphasis on self-determined learning and the cultivation of autonomy. While heutagogy has also been associated with critical pedagogical aims—such as challenging hierarchical structures in education—recent studies emphasize its practical, context-sensitive implementation. For example, Marin (2022) and Authors (2023) explores heutagogical course design in blended learning during the COVID-19 pandemic, while Blaschke (2012, 2019) conceptualizes the Pedagogy–Andragogy–Heutagogy (PAH) continuum as a developmental trajectory toward learner independence. In this spirit, the present study examines heutagogy as a flexible, situational instructional approach that enables diverse forms of learning in contemporary educational contexts.

The concept of heutagogy, and the term itself, were first coined and introduced by Hase and Kenyon (2000), addressing a learner-centered framework grounded in the principle of self-determined learning. It positions learners as active agents in determining the content, methods, pace, and goals of their educational experiences. In contrast to pedagogy and andragogy—both of which emphasize teacher-led or facilitator-guided instruction—heutagogy promotes autonomy, flexibility, and the cultivation of capacities such as adaptability, critical thinking, and resilience in dynamic and complex contexts (Blaschke, 2019; McAuliffe et al., 2009). The theoretical underpinnings of heutagogy are informed by constructivist and connectivist learning theories. Constructivism emphasizes the active construction of knowledge through experience and reflection, while connectivism underscores the significance of networks—both human and technological—in knowledge formation and dissemination (Siemens, 2005). These foundations support heutagogy's emphasis on flexible, personalized, and technology-enhanced learning environments that are increasingly relevant in today's digital landscape. Moreover, heutagogy aligns with emerging models of digital-age education, such as cybergogy, which integrates cognitive, emotional, and social dimensions of learning in online environments. Collectively, these frameworks stress the importance of equipping learners not only with content knowledge but also with the skills, dispositions, and digital literacies required for sustained, self-directed learning in complex, technology-rich settings.

Drawing on the work of Sala et al. (2020), Redecker (2017), and Ehlers and Kellermann (2019), Blaschka (2021) argues that heutagogy comprises four core principles aligned with lifelong learning skills: (a) learner agency, which involves granting learners the autonomy to make decisions about their learning paths; (b) self-efficacy and capability, which entails providing opportunities for experimentation, allowing learners to make mistakes and learn from them; (c) reflection and metacognition, whereby learners reflect on what they have learned, how they learned it, and how they can improve; and (d) nonlinear learning, in which learners define the learning outcomes and determine how these will be achieved (Blaschka, 2021, pp. 4–5). The current study adopts Blaschka's four principles to examine PSTs' attitudes toward heutagogy.

The Role of Generative AI in Supporting Heutagogical Learning

The integration of generative AI (GAI) tools into education is reshaping self-directed learning in ways that align with heutagogical principles. Blaschke and Hase (2019) note that digital media offer environments where learners can choose their paths, access diverse resources, and engage informally—key conditions for heutagogy. Blaschke (2021) further emphasizes that technology fosters learner agency through flexible and personalized experiences.

As 21st-century demands evolve, emphasis on core competencies—critical thinking, creativity, collaboration, and communication (the 4C's)—has intensified. These skills, rooted in constructivist traditions (e.g., Dewey, Vygotsky), are increasingly crucial as AI automates routine tasks, highlighting the value of uniquely human capabilities (Perkins et al., 2024; Moore, 2020; Luckin et al., 2016). Fawns (2019) suggests that in the postdigital age, technologies like GAI are not external tools but embedded in the learning environment, shaping how knowledge is constructed. This reinforces the need to design educational experiences that integrate AI meaningfully and ethically.

GAI tools can support metacognitive development by helping students brainstorm, refine ideas, and reflect on their learning (Zawacki-Richter et al., 2023). Students also report tangible benefits in writing and multimedia tasks, citing improvements in organization, fluency, and creative expression (Chan & Hu, 2023). These tools may enhance problem-solving self-efficacy, a key

element in lifelong learning. When learners use AI to tackle challenges independently, their confidence and autonomy grow—both central to heutagogy. Some scholars describe AI as a “distributed mentor” that supports but does not replace learner agency (Luckin et al., 2016). However, this role requires ethical safeguards. Holmes, Bialik, and Fadel (2019) warn that AI’s integration must be guided by pedagogical intent and ethical reflection to ensure it augments, rather than undermines, human judgment and creativity.

Finally, the interaction with GAI tools supports cybergogical learning, blending cognitive, emotional, and social engagement (Pangrazio & Selwyn, 2019; Wang & Kang, 2006). In AI-rich learning environments, such holistic engagement is increasingly essential.

Heutagogy in the Context of Mathematics and the Humanities

While heutagogical approaches have been widely explored in higher education (Canning, 2010), their increasing adoption in vocational and workplace learning underscores their potential for fostering professional capability development (Stoten, 2024). Importantly, heutagogy does not operate in isolation but often intersects with other digital-age pedagogical models, notably cybergogy—an approach that emphasizes learning in online, networked, and immersive environments (Wang & Kang, 2006). Cybergogy integrates cognitive, emotional, and social engagement and is especially relevant in digital education that incorporates AI, simulations, and virtual collaboration. In the field of mathematics, the application of AI tools has shifted the learning experience from repetitive problem-solving toward conceptual understanding and experimentation. Platforms incorporating generative AI can now suggest solutions, visualize data, generate alternative methods of problem-solving, and adapt feedback based on learner input. Such environments align well with heutagogical principles, as they enable students to identify gaps in understanding, explore personalized strategies, and manage their learning pace (Holstein et al., 2020). However, the challenge in mathematics is balancing the mechanistic affordances of AI with deeper mathematical thinking. Heutagogy encourages reflection and capability development—traits that AI tools can support if they are used critically and intentionally, not simply as answer-generators.

In humanities disciplines such as literature, history, and philosophy, generative AI tools present distinctive opportunities for creative and critical engagement. Students can co-author narratives with AI, perform textual analyses, generate summaries of complex readings, or simulate historical debates, all of which support personalized learning pathways and foster interdisciplinary connections (Lu et al., 2023; Risam, 2018). For instance, a student exploring postcolonial theory might use AI to generate interpretations of a literary text from different cultural perspectives and then critically analyze these outputs. The iterative process of curating, evaluating, and refining AI-generated content fosters critical thinking and metacognitive awareness—skills central to heutagogical learning, which emphasizes learner agency and self-directed inquiry (Blaschke, 2021; Blaschke & Hase, 2019). At the same time, the integration of AI into the humanities requires careful ethical and epistemological consideration. Heutagogy in this context encourages learners to question the authority of machine-generated content, reflect on the biases inherent in algorithms, and examine the broader implications of delegating interpretive and meaning-making processes to non-human agents (Knox, 2020; Risam, 2018). Such engagement not only enhances digital literacy but also aligns with the core aims of heutagogical pedagogy in cultivating autonomous, reflective, and critically conscious learners.

In sum, the convergence of heutagogy, cybergogy, and generative AI marks a significant shift toward a more learner-empowered, technology-enhanced educational paradigm. While notable

challenges remain—such as ensuring digital equity, fostering critical AI literacy, and maintaining academic integrity—the potential for transformational learning is substantial. Emerging instructional models are beginning to position AI-informed heutagogy as a foundational framework, emphasizing co-agency between human learners and artificial intelligence. In these models, learners pursue goals aligned with their own values and interests, while AI tools support their navigation through complex and evolving knowledge ecosystems. Further research is needed to explore how this co-agency is enacted in practice, how it is experienced by students and educators, and what implications it may hold for curriculum development and educational policy.

The present study investigates how generative AI (GAI) usage profiles relate to heutagogical learner orientations among pre-service teachers from different disciplinary backgrounds. Given the increasing integration of GAI tools in educational settings, the study aims to examine whether—and in what ways—the frequency and type of GAI use are associated with core dimensions of heutagogy, including self-directed learning, reflection and metacognition, problem-solving self-efficacy, and cybergogical engagement. Additionally, the study considers whether these relationships vary between students specializing in the Humanities and those in Science and Mathematics (S&M).

Research Questions

1. To what extent do GAI usage profiles uniquely explain variance in different aspects of heutagogical orientation beyond background characteristics?
2. Are there significant differences in heutagogical learner orientation and GAI usage profiles between disciplinary specialization groups (Humanities vs. S&M)?
3. What are the associations between GAI usage profiles and the dimensions of heutagogical learner orientation within each disciplinary group?

Methodology

Participants

The study sample comprised 181 pre-service teachers (33 males and 148 females). Participants were categorized into two disciplinary specialization groups: Humanities (n = 103) and Science & Mathematics (S&M; n = 78). PSTs were asked to provide background information, including their gender, teacher training program, the academic discipline they intend to teach, and their age. Table 1 presents participants' background characteristics by disciplinary specialization group.

		Humanities Specialization	S&M		χ^2	p
		(n = 103)	Specialization (n = 78)			
Gender	Male	16 (15.5%)	17 (21.8%)			
	Female	87 (84.5%)	61 (78.2%)		1.17	0.28

Training program	Early childhood education	16 (15.5%)	6 (7.7%)		2.56	0.11
	Elementary education	42 (40.8%)	40 (51.3%)		1.98	0.16
	Secondary education	45 (43.7%)	32 (41.0%)		0.13	0.72
Academic degree	First degree	68 (66.0%)	44 (56.4%)		1.74	0.187
	Second degree	23 (22.3%)	14 (17.9%)		0.52	0.469
	Alternative teacher certification program	12 (11.7%)	20 (25.6%)		5.97*	0.015
Age	Mean (SD)	31.81 (10.29)	33.50 (12.38)		t(179) = .98, p = .329	

Table 1: Participant's Background Characteristics by Disciplinary Specialization Group

*p < .05

As shown in Table 1, chi-square analyses indicated that the two groups were comparable in terms of gender distribution [$\chi^2(1) = 1.17, p = .280$], and in the proportions of individuals enrolled in early childhood, elementary, or secondary education training programs [$\chi^2(1) = 2.56, p = .110$; $\chi^2(1) = 1.98, p = .160$; and $\chi^2(1) = 0.13, p = .720$, respectively]. No significant differences were found between the groups regarding the proportions of participants holding a first or second academic degree [$\chi^2(1) = 1.74, p = .187$; and $\chi^2(1) = 0.52, p = .469$, respectively]. However, a significantly greater proportion of participants in the S&M group had completed an alternative teacher certification program compared to their Humanities counterparts [$\chi^2(1) = 5.97, p = .015$]. Finally, an independent samples t-test indicated no significant difference in age between the two groups [$t(179) = 0.98, p = .329$].

Materials

GAI Usage Profile questionnaire: To assess the ways in which pre-service teachers utilize generative artificial intelligence (GAI) tools, participants completed the GAI Usage Profile questionnaire. This instrument was developed specifically for the current study and consists of items measuring different types of usage behaviors. Respondents rated the extent to which they engage in various GAI-related activities on a Likert scale ranging from 1 (never) to 5 (very frequently). The items were designed to capture both academic and creative uses of GAI technologies.

To evaluate the construct validity of the questionnaire and to identify the underlying dimensions of GAI use, an exploratory factor analysis (EFA) was conducted using principal component extraction with Varimax rotation. Factors were retained based on the eigenvalues > 1 criterion. Table 2 presents the results of the EFA analysis.

	Factors	
Item	Linguistic	Multimedia Usage
	Usage	
Clarify reading materials	0.892	
Get a summary of reading material	0.871	
Improve writing quality	0.836	
Information search	0.775	
Translate reading materials	0.728	
Check linguistic accuracy / Check grammar	0.668	
Create videos		0.91
Create music		0.871
Create images		0.764
Eigenvalues	4.49	1.83
% of variance	43.18%	27.06%
Cronbach's alpha	0.9	0.83

Table 2: Exploratory Factor Analysis (EFA) of the GAI Usage Profile Questionnaire

As shown in Table 2, the analysis yielded a clear two-factor solution, explaining a combined 70.24% of the total variance. As shown in Table 2, the first factor, labeled Linguistic Usage, accounted for 43.18% of the variance and included six items related to language-based academic support (e.g., summarizing, translating, grammar checking, and improving writing). The second factor, labeled Multimedia Usage, accounted for 27.06% of the variance and included three items reflecting creative GAI applications such as generating videos, music, or images.

All items demonstrated strong factor loadings above .66, supporting the coherence of each factor. Reliability analyses indicated high internal consistency for both factors, with Cronbach's alpha coefficients of .90 for Linguistic Usage and .83 for Multimedia Usage. These psychometric results suggest that the GAI Usage Profile questionnaire is a valid and reliable instrument for capturing distinct patterns of GAI use among pre-service teachers.

Heutagogy questionnaire: To explore heutagogical dispositions among pre-service teachers, participants completed the Heutagogy Questionnaire, which was developed to capture key aspects of four heutagogical principles framed by the works of Agonács & Matos (2019) and Blaschke (2021) in digital and contemporary educational environments. The questionnaire included 15 items rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), addressing four dimensions of heutagogical learning which are: reflection and meta-cognition, problem-solving self-efficacy, cybergogy, and self-directed learning. An exploratory factor analysis (EFA) was conducted using principal component extraction with Varimax rotation to identify the underlying dimensions of the questionnaire. Factors were retained based on the eigenvalues > 1 criterion. Table 3 presents the results of the EFA analysis.

Item	Factors			
	Reflection and meta-cognition	Problem-solving self-efficacy	Cybergogy	Self-directed learning
I dedicate time to reflecting on new learning topics to assess my understanding of them.	0.907			
I analyze the information I receive to determine its reliability and accuracy.	0.896			
I do not take information from various sources for granted and examine it before using it for learning.	0.855			
I delve into the subjects I study and strive to understand their background and deeper meaning.	0.649			
When I encounter a problem, I usually consider multiple ways to approach it.		0.796		
I feel confident in dealing with learning challenges that arise during the learning process.		0.729		
I am not afraid to make mistakes.		0.726		

I apply what I learn in new contexts.		0.685		
I learn new things spontaneously while "wandering" through digital spaces such as the internet and digital libraries			0.837	
Social networks are part of my knowledge sources.			0.799	
I use computer technologies for learning on a daily basis			0.701	
I feel comfortable with technological innovations in learning.			0.583	
I can manage my learning without direct guidance from a lecturer or instructor.				0.786
I can evaluate the quality of my learning.				0.698
I plan my own study time and how to distribute my tasks over time.				0.698
Eigenvalues	5.56	2.04	1.59	1.09
% of variance	20.79%	17.75%	15.50%	14.45%
Cronbach's alpha	0.81	0.76	0.88	0.67

Table 3: Exploratory Factor Analysis (EFA) of the Heutagogy Questionnaire

As shown in Table 3, The EFA yielded a four-factor solution, which together explained 68.49% of the total variance. As shown in Table 3, the first factor, Reflection and Meta-Cognition, included items related to critical thinking and evaluation of learning content and accounted for 20.79% of the variance ($\alpha = .81$). The second factor, Problem-Solving Self-Efficacy, reflected confidence in managing learning-related challenges and contributed 17.75% of the variance ($\alpha = .76$). The third factor, Cybergogy, captured digital and spontaneous learning behaviors (e.g., learning via digital platforms and social networks), explaining 15.50% of the variance ($\alpha = .88$). The fourth factor, Self-Directed Learning, included items measuring learners' ability to regulate their own learning processes without external supervision, accounting for 14.45% of the variance ($\alpha = .67$).

All factor loadings were above .58, indicating strong associations between items and their respective underlying dimensions. The internal consistency of the subscales was generally acceptable to high, supporting the reliability of the instrument. This multidimensional structure

aligns with contemporary models of heutagogy, emphasizing learner autonomy, digital engagement, and metacognitive regulation.

Procedure

Prior to data collection, the study received ethical approval from the Ethics Committee of the sampled college. Participants were informed about the purpose of the study, assured of the confidentiality and anonymity of their responses, and provided informed consent before participating. Data was collected using an online questionnaire administered via Google Forms. The link to the survey was distributed through institutional mailing lists and educational networks targeting PSTs enrolled in teacher training programs. Participation was voluntary, and no incentives were offered. The questionnaire took approximately 10 minutes to complete and was accessible via computer or mobile device. Participants were instructed to respond individually.

Data Analysis

Data were analyzed using SPSS Statistics (Version 29). Prior to the main analyses, tests of normality using the Shapiro-Wilk test indicated significant deviations from normality. Given this, both independent samples t-tests (parametric) and Mann–Whitney U tests (non-parametric) were conducted to compare Humanities and S&M groups on heutagogical learner orientation and GAI usage profiles. The results from both tests were consistent; therefore, the parametric results (t-tests) are reported.

To assess the associations between heutagogical orientation and GAI usage profiles within each disciplinary group, Pearson correlation coefficients were computed. Fisher’s r-to-z transformations were used to test for significant differences in correlation coefficients between groups. Finally, hierarchical multiple regression analyses were conducted to examine the unique contribution of GAI usage profiles in explaining variance in heutagogical principles beyond background variables. In each model, only statistically significant background characteristics were entered in the first block using a stepwise method, followed by GAI usage profile variables in the second block.

Results

Differences in Heutagogical learner orientation and GAI usage profiles between disciplinary specialization groups

To examine group differences in Heutagogical learner orientation and GAI usage profiles between disciplinary specialization groups (Humanities vs. S&M), independent samples t-tests were conducted for each of the main variables and subscales. Table 4 presents the means, standard deviations, t-values, p-values, and Cohen’s d effect sizes for each comparison.

	Humanities Specialization (n = 103)		S&M Specialization (n = 78)		t-values		
	M	SD	M	SD	t	p	d
Heutagogical learner orientation							

Heutagogy - Total	3.82	0.56		3.65	0.6	2.03*	0.044	0.31
Reflection and meta-cognition	3.72	0.91		3.58	0.74	1.1	0.272	0.16
Problem-solving self-efficacy	3.83	0.73		3.83	0.83	0.01	0.989	0
Cybergogy	3.78	0.87		3.56	0.85	1.71	0.09	0.26
Self-directed learning	3.96	0.72		3.62	0.72	3.19**	0.002	0.48
GAI usage profile								
Linguistic usage	3.29	1.13		3.17	1.16	0.71	0.478	0.11
Multimedia usage	2.29	1.15		2.24	1.25	0.28	0.777	0.04
GAI tools quantity	2.26	1.22		2.1	1.1	0.91	0.365	0.14

Table 4: Mean, SD And T-Values for Aspects of Heutagogy and GAI Usage Profile By Disciplinary Specialization Group

* $p < .05$, ** $p < .01$

As shown in Table 4, a significant difference was found in the overall Heutagogical learner orientation, with participants from the Humanities group reporting higher scores ($M = 3.82$, $SD = 0.56$) compared to those in the S&M group ($M = 3.65$, $SD = 0.60$), $t(179) = 2.03$, $p = .044$, $d = 0.31$, indicating a small to moderate effect size. When analyzing specific dimensions of heutagogy, a significant difference emerged in Self-directed learning, with Humanities participants scoring higher ($M = 3.96$, $SD = 0.72$) than their S&M counterparts ($M = 3.62$, $SD = 0.72$), $t(179) = 3.19$, $p = .002$, $d = 0.48$, representing a moderate effect. No significant differences were found between the groups in Reflection and meta-cognition, $t(179) = 1.10$, $p = .272$, Problem-solving self-efficacy, $t(179) = 0.01$, $p = .989$, or Cybergogy, $t(179) = 1.71$, $p = .090$.

Regarding the GAI usage profile, no significant differences were observed between Humanities and S&M participants in Linguistic usage, $t(179) = 0.71$, $p = .478$, Multimedia usage, $t(179) = 0.28$, $p = .777$, or in the quantity of GAI tools used, $t(179) = 0.91$, $p = .365$. Effect sizes for these comparisons were small ($ds < 0.15$), indicating minimal practical differences.

The Associations between Heutagogical Learner Orientation and GAI Usage Profiles

To explore the associations between heutagogical learner orientation and GAI usage profiles, Pearson correlation coefficients were conducted separately within each disciplinary specialization group (Humanities and S&M). Additionally, Fisher r -to- z transformations were conducted to assess whether the strength of the correlations differed significantly between the two groups. The results are presented in Table 5.

	GAI usage profile						
	Linguistic usage		Multimedia usage			GAI tools quantity	
	r	Z	r	z		r	z
Heutagogy - Total	.37*** / .30**	0.5	.20* / .22*	0.14		.15 / .19	0.27
Reflection and meta-cognition	.11 / .24*	0.88	.10 / .19	0.6		- 0.1176	1.25
Problem-solving self-efficacy	.23* / .24*	0.07	.22* / .28*	0.42		.09 / .15	0.4
Cybergogy	.56*** / .30**	2.12*	.37*** / .25*	0.87		.31*** / .23*	0.57
Self-directed learning	.09 / .12	0.2	1.875	0.46		.02 / - .01	0.2

Table 5: Pearson Correlation Coefficients Between Aspects of Heutagogy and GAI Usage Profile Among the Entire Sample (N=181) And Within Each Disciplinary Specialization Group Separately.

* $p < .05$, ** $p < .01$, *** $p < .001$; r = the correlation coefficients of Humanities/ S&M Specialization; Z = Fisher r -to- z transformation

As shown in Table 5, when comparing disciplinary groups, the correlation between total heutagogy and linguistic usage was significant in both groups, though stronger in the Humanities group [$r(101) = .37, p < .001$] than in the S&M group [$r(76) = .30, p < .01$]; however, the difference was not statistically significant based on Fisher's z transformation ($z = 0.50$). Similarly, the correlations between total heutagogy and multimedia usage were modest [Humanities: $r(101) = .20, p < .05$; S&M: $r(76) = .22, p < .05$] and comparable across groups ($z = 0.14$).

The correlations between the problem-solving self-efficacy component of heutagogy and both linguistic usage [Humanities: $r(101) = .23, p < .05$; S&M: $r(76) = .24, p < .05$] and multimedia usage [Humanities: $r(101) = .22, p < .05$; S&M: $r(76) = .28, p < .05$] were modest and comparable across groups ($z = 0.07$ and $z = 0.42$, respectively).

Cybergogy was moderately to strongly correlated with linguistic usage in the Humanities group [$r(101) = .56, p < .001$], but only moderately so in the S&M group [$r(76) = .30, p < .01$], with this difference reaching statistical significance ($z = 2.12, p < .05$). This suggests that for Humanities PSTs, engagement with digital and spontaneous learning (cybergogy) is more strongly associated with GAI tool use in linguistic contexts than for their S&M counterparts. In addition, the correlation between the cybergogy component and both multimedia usage and the quantity of GAI tools used was significant in both groups, though stronger in the Humanities group [$r(101) = .37, p < .001$; $r(101) = .31, p < .001$, respectively] than in the S&M group [$r(76) = .25, p < .05$; $r(76) = .23, p < .05$, respectively]; however, these differences were not statistically significant based on Fisher's z transformation ($z = 0.87$ and $z = 0.57$, respectively).

Finally, the Reflection and meta-cognition component of heutagogy was modestly and positively correlated with linguistic usage in the S&M group [$r(76) = .24, p < .05$], but not in the

Humanities group [$r(101) = .11, p = .268$]; however, the difference was not statistically significant based on Fisher's z transformation ($z = 0.88$).

Overall, the results highlight significant associations between heutagogical dispositions (particularly cybergogy) and patterns of GAI tool usage. The findings also suggest some variation in these associations by disciplinary specialization, specifically in the association between cybergogy and linguistic tool use.

The Unique Contribution of GAI Usage Profiles in Explaining Heutagogy

Aspects

Hierarchical regression analyses were conducted to examine the extent to which participants' background characteristics and GAI usage profiles explained different aspects of heutagogical orientation. In each model, only significant background variables were entered in the first block using a stepwise method, followed by GAI usage profile measures in the second block. Table 6 presents the unstandardized coefficients (B), standard errors (SE), standardized coefficients (β), F statistics, R^2 values, and changes in R^2 for each model.

Steps	Explanatory variables	B	SE.B	β	F	R^2	ΔR^2
Heutagogy - Total							
1	Disciplinary specialization ¹	-0.18	0.09	-.15*	4.12*	.022*	----
2	Disciplinary specialization ¹	-0.15	0.08	-0.13			
	Linguistic usage	0.17	0.04	.33***	13.74***	.134***	.111***
Reflection and meta-cognition							
1	----	----	----	----	----	----	----
2	Linguistic usage	0.12	0.05	.16*	4.93*	.027*	----
Problem-solving self-efficacy							
1	----	----	----	----	----	----	----
2	Multimedia usage	0.16	0.05	.25***	11.73***	.062***	----
	Multimedia usage	0.12	0.05	.19*			

	Linguistic usage	0.11	0.05	.17*	8.42***	.086***	.025*
Cybergogy							
1	Students' age	-0.01	0.01	-.17*	5.11*	.028*	----
	Students' age	-0.02	0.01	-.22**			
	Secondary education ²	0.28	0.14	.16*	4.68**	.050**	.022*
2	Students' age	-0.01	0.01	-.19**			
	Secondary education ²	0.11	0.13	0.06			
	Linguistic usage	0.34	0.05	.44***	18.14***	.235***	.185***
	Students' age	-0.01	0.01	-.18**			
	Secondary education ²	0.09	0.12	0.05			
	Linguistic usage	0.29	0.05	.38***			
	Multimedia usage	0.12	0.05	.17*	15.38***	.259***	.024*
Self-directed learning							
1	Teaching specialization ¹	-0.35	0.11	-.23**	10.17**	.054**	----

Table 6: Hierarchical Regression Results for Heutagogy Aspects Based on Participants' Background Characteristics and Their Frequency of GAI Use (N = 181)

* $p < .05$, ** $p < .01$, *** $p < .001$; Disciplinary specialization: 0 = Humanities, 1 = S&M; ²Secondary education: 0 = No, 1 = Yes

Total Heutagogical Orientation: Disciplinary specialization significantly explained total heutagogical orientation, $\beta = -.15$, $p < .05$, accounting for 2.2% of the variance, $F(1, 179) = 4.12$, $p < .05$. The negative β coefficient indicates that participants from the Science & Mathematics (S&M) group reported lower levels of heutagogical orientation compared to their Humanities counterparts. When GAI usage profiles were entered in the second block, linguistic usage was positively associated with total heutagogical orientation ($\beta = .33$, $p < .001$), indicating that a higher frequency of linguistic GAI tool use was related to stronger heutagogical orientation. This addition accounted for an additional 11.1% of the variance, with the overall model explaining 13.4% of the variance, $F(2, 178) = 13.74$, $p < .001$.

Reflection and Meta-Cognition: No background characteristics significantly explained variance in reflection and meta-cognition in the first block. When GAI usage profiles were entered in the second block, linguistic usage was positively associated with reflection and meta-cognition ($\beta = .16, p < .05$), suggesting that more frequent use of linguistic GAI tools was related to higher levels of reflective and metacognitive learning. This model explained 2.7% of the variance, $F(1, 179) = 4.93, p < .05$.

Problem-Solving Self-Efficacy: No background characteristics significantly explained variance in problem-solving self-efficacy in the first block. In the second block, both multimedia and linguistic usage significantly explained variance in problem-solving self-efficacy ($\beta = .19, p < .05$; $\beta = .17, p < .05$, respectively), indicating that both forms of GAI usage contributed to greater problem-solving self-efficacy. This model accounted for 8.6% of the variance, $F(2, 178) = 8.42, p < .001$.

Cybergogy: In the first block, students' age significantly explained cybergogy ($\beta = -.17, p < .05$), accounting for 2.8% of the variance, $F(1, 179) = 5.11, p < .05$. The negative β coefficient indicates that younger participants reported higher levels of cybergogy compared to older ones. Additionally, the contribution of teaching specialization in secondary education ($\beta = .16, p < .05$) was significant, with those in secondary education programs reporting higher levels of cybergogy. This model explained 5.0% of the variance, $F(2, 178) = 4.68, p < .01$. In the second block, both linguistic ($\beta = .38, p < .001$) and multimedia usage ($\beta = .17, p < .05$) were positively associated with cybergogy, suggesting that higher frequency of both types of GAI usage contributed to a stronger digital learning orientation. The final model explained 25.9% of the variance, $F(4, 176) = 15.38, p < .001$.

Self-Directed Learning: Teaching specialization significantly explained self-directed learning ($\beta = -.23, p < .01$), accounting for 5.4% of the variance, $F(1, 179) = 10.17, p < .01$. Consistent with earlier findings, the negative β coefficient indicates that participants from the S&M group reported lower levels of self-directed learning compared to their Humanities counterparts. In the second block, none of the GAI usage profiles made a unique contribution beyond the effects explained in the first block.

In summary, Humanities PSTs showed stronger overall heutagogical orientations—especially in self-directed learning—than their S&M peers. While GAI usage levels did not differ significantly between groups, only cybergogy showed a notable link to GAI use, particularly linguistic tools among Humanities PSTs. This underscores the role of digital learning ecologies in heutagogical development, with background factors playing a minor role.

Discussion

This study explored the relationship between PSTs' generative AI (GAI) usage and their heutagogical orientations, with attention to disciplinary variation between Humanities and S&M students. The findings may contribute to a growing body of research that highlights how digital technologies—particularly GAI tools—can support learner agency, reflection, and capability development in teacher education (Blaschke & Hase, 2019; Blaschke, 2021).

Disciplinary Differences in Heutagogical Orientation

Humanities PSTs reported significantly higher levels of heutagogical orientation, especially in self-directed learning, compared to their S&M peers. These differences may align with

disciplinary pedagogical and epistemological cultures: the Humanities often prioritize open-ended inquiry, interpretation, and autonomy, whereas S&M disciplines typically emphasize procedural accuracy and problem-solving within predefined frameworks (Becher & Trowler, 2001; Authors, 2024)). This may support the argument that heutagogical dispositions are influenced not only by individual learning characteristics but also by the epistemological and pedagogical cultures of academic disciplines in which the learning occurs (Canning, 2010).

In this regard, an interesting conclusion of this research is that educational strategies aimed at fostering heutagogical learning must be sensitive to disciplinary contexts. This is especially important given heutagogy's emphasis on capability development over mere competency (Stoten, 2024), requiring educators to foster critical reflection and adaptability within their specific content domains.

GAI Usage and Heutagogical principles

Although no significant differences were observed in the frequency or type of GAI usage between the examined disciplines, the way in which GAI usage predicted heutagogical orientations varied. Linguistic GAI usage—writing assistance, summarization, and translation—was positively associated with reflection, metacognition, and cybergogy principles of heutagogy. These findings resonate with Zawacki-Richter et al. (2023), who demonstrated that GAI tools can foster iterative and reflective learning processes, encouraging learners to monitor and regulate their thinking. This use of GAI as a scaffold for metacognitive development aligns with Blaschke's (2021) argument that technology, when applied meaningfully, can support personalized, flexible learning that fosters learner autonomy. By assisting students in refining their ideas and language, GAI serves as a metacognitive aid rather than a mere content generator—facilitating deeper engagement with the learning process. Similarly, multimedia GAI use was associated with increased problem-solving self-efficacy and cybergogical engagement. These outcomes reflect the broader shift in education from static content consumption to active, constructivist learning—where learners experiment with ideas, co-construct knowledge, and adapt solutions to new challenges (Holstein et al., 2020). In this light, GAI tools can act as "distributed mentors" (Luckin et al., 2016), augmenting learners' capabilities while preserving their agency. Finally, according to the EFA that validated Blaschke's (2021) four heutagogical principles, the self-directed learning factor was found to contribute the least to the overall heutagogical structure, while reflection and metacognition contributed the most.

Cybergogy and Disciplinary Patterns

Cybergogy, which integrates cognitive, emotional, and social dimensions of online learning (Wang & Kang, 2006), emerged as the most consistently GAI-associated heutagogical dimension. Humanities students exhibited stronger links between cybergogical engagement and GAI usage—particularly in linguistic contexts—suggesting that they may be more comfortable using these tools for exploratory and generative purposes. This is consistent with previous findings that AI supports creative and critical engagement in the Humanities, from co-authoring texts to simulating historical debates (Lu et al., 2023; Risam, 2018). For S&M students, while GAI tools were used at similar rates, their application appeared more instrumental. This highlights the need for pedagogical interventions that encourage S&M learners to move beyond procedural uses and engage AI tools for conceptual exploration and reflective practice—an essential shift if GAI is to support deeper mathematical thinking rather than simply providing answers (Holstein et al., 2020).

Background Characteristics and Digital Dispositions

Although background variables such as disciplinary specialization, age, and teacher training track accounted for only modest variation, some patterns emerged. Younger students and those enrolled in secondary education tracks reported higher cybergogy scores—possibly reflecting greater digital fluency or exposure to AI-enhanced learning environments. Nonetheless, the relatively limited explanatory power of these variables suggests that heutagogical development is more strongly influenced by pedagogical design and institutional culture than by demographic factors alone.

Theoretical and Practical Implications: Responding to the Call for Educational Transformation

This study contributes an additional theoretical layer to ongoing scholarly discourse on heutagogy as a pedagogical framework, particularly in the context of generative AI (GAI) integration in teacher education. Based on our findings, we cautiously propose that the relative salience of heutagogical principles may vary according to contextual factors, including digital learning environments, disciplinary cultures, and specific educational objectives. Notably, in the current study, the foundational principle of self-directed learning appeared less influential in predicting GAI usage patterns compared to the principle of cybergogy. Contrary to prevalent assumptions that associate AI-facilitated tools with enhanced learner autonomy, we found no significant relationship between self-directed learning and participants' GAI usage profiles.

One possible interpretation is that while GAI—such as chatbots—is often perceived as fostering independence, it may primarily support surface-level autonomy, such as task efficiency and cognitive offloading, rather than deeper forms of self-regulation and reflective learning. Pre-service teachers (PSTs), for instance, may utilize GAI to expedite task completion or manage workload pressures, rather than to actively shape and take ownership of their learning trajectories. The immediacy and convenience afforded by such tools might, paradoxically, inhibit the development of core components of self-directed learning, such as critical inquiry, goal-setting, and sustained engagement. An alternative explanation may lie in the nature of the self-directed learning items used in the study, which emphasize internal regulation and intrinsic motivation. PSTs scoring high on this dimension may prefer to rely on their own evaluative judgment and cognitive resources, thus perceiving GAI as a potentially intrusive or unnecessary aid. Conversely, students who frequently engage with GAI may do so for pragmatic or instrumental reasons, such as time management or assignment completion, rather than as a reflection of autonomous learning orientation.

From a practical standpoint, the findings carry significant implications for the redesign of teacher education in response to the demands of 21st-century learning. The strategic integration of GAI aligns with the foundational tenets of heutagogy and supports the cultivation of the 4Cs—critical thinking, creativity, collaboration, and communication—as essential competencies in AI-mediated educational environments (Moore, 2020; Luckin et al., 2016). As routine tasks are increasingly delegated to AI systems, the pedagogical focus must shift toward uniquely human capacities, such as ethical judgment, reflective practice, and complex problem-solving.

Rooted in constructivist traditions (e.g., Dewey, Vygotsky, Bloom), heutagogy foregrounds learner agency, social interaction, and experiential engagement—dimensions that can be meaningfully enhanced through GAI tools. When embedded within a critical and intentional pedagogical framework, GAI can support learners in co-constructing knowledge, interrogating

content, and engaging with diverse perspectives. Importantly, GAI-enabled learning exemplifies the transition toward cybergeological learning environments, where cognitive, emotional, and social domains intersect (Wang & Kang, 2006). Across disciplines—including both the Humanities and Science and Mathematics (S&M)—GAI tools, when used reflectively, can assist learners in identifying conceptual gaps, generating novel ideas, and building confidence in their academic agency.

However, realizing this transformative potential demands ongoing attention to ethical, epistemological, and pedagogical concerns. Scholars such as Knox (2020) and Risam (2018) emphasize the need for critical engagement with AI systems, particularly in relation to algorithmic bias, transparency, and the preservation of human judgment. Accordingly, teacher education must incorporate AI literacy as an integral component of pedagogical innovation, preparing future educators to navigate AI-enhanced learning environments in ways that are inclusive, equitable, and ethically grounded.

In sum, the study suggests that GAI tools can serve as catalysts for heutagogical learning by fostering autonomy, metacognition, creativity, and digital engagement. These findings respond directly to the call for a shift from transmissive models of instruction to constructivist, learner-centered paradigms. By embracing the affordances of AI while maintaining a critical and reflective stance, teacher education programs can prepare a new generation of educators who are adaptive, capable, and ethically attuned to the complexities of teaching and learning in an AI-mediated world.

Limitations and Future Directions

Several limitations should be acknowledged. First, the study relied on self-report measures, which may be subject to social desirability bias and limitations in participants' self-awareness or recall. Second, although the employed instruments demonstrated robust psychometric properties, the cross-sectional design constrains causal inferences. Future research should consider longitudinal or mixed-methods approaches to capture dynamic changes in GAI usage and heutagogical orientations over time and in authentic learning contexts. Third, while the study distinguished between the Humanities and S&M fields, further granularity is warranted. Future investigations could explore disciplinary subfields (e.g., natural sciences vs. mathematics; literature vs. history) to examine how specific epistemological orientations and academic cultures shape GAI engagement and heutagogical practice.

Finally, as GAI technologies continue to evolve—including the emergence of multimodal AI, personalized AI tutors, and emotionally responsive systems—ongoing research is needed to investigate their implications for teacher professional identity, pedagogical agency, and learner autonomy. These future inquiries will be critical in informing both theoretical advancements and the design of responsive, forward-looking teacher education curricula.

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References

- Agonács, N., & Matos, J. (2019). Heutagogy and self-determined learning: a review of the published literature on the application and implementation of the theory. *Open Learning: The Journal of Open, Distance and e-Learning*, 34, 223 - 240. <https://doi.org/10.1080/02680513.2018.1562329>.

- Bekiaridis, G. (2024). Supplement to the DigCompEDU framework: Outlining the skills and competences of educators related to AI in education. *AI Pioneers*. https://aipioneers.org/wp-content/uploads/2024/01/WP3_Supplement_to_the_DigCompEDU_English.pdf
- Blaschke, L. M. (2021). The lifelong learning mindset: A heutagogical approach using learning technologies. *British Journal of Educational Technology*, 52(4), 1629–1645. <https://doi.org/10.1111/bjet.13116>
- Blaschke, L. M., & Hase, S. (2019). Heutagogy and digital media networks: Setting students on the path to lifelong learning. *Pacific Journal of Technology Enhanced Learning*, 1(1), 1-14. <https://doi.org/10.24135/pjtel.v1i1.1>
- Blaschke, L. M. (2012). Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. *The International Review of Research in Open and Distributed Learning*, 13(1), 56–71. <https://doi.org/10.19173/irrodl.v13i1.1076>
- Canning, N. (2010). Playing with heutagogy: Exploring strategies to empower mature learners in higher education. *Journal of Further and Higher Education*, 34(1), 59–71. <https://doi.org/10.1080/03098770903477102>
- Chan, C.K.Y., Hu, W. Students' voices on generative AI: perceptions, benefits, and challenges in higher education. *Int J Educ Technol High Educ* 20, 43 (2023). <https://doi.org/10.1186/s41239-023-00411-8>
- Ehlers, U.-D., & Kellermann, S. A. (2019). Future skills: The future of learning and higher education. Baden-Württemberg Cooperative State University. <https://nextskills.org/wp-content/uploads/2019/05/Future-Skills-Report-2019.pdf>
- Floridi, L., Cowlis, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., ... & Schafer, B. (2018). AI4People—An ethical framework for a good AI society: Opportunities, risks, principles, and recommendations. *Minds and Machines*, 28(4), 689–707. <https://doi.org/10.1007/s11023-018-9482-5>
- Fawns, T. (2019). Postdigital education in design and practice. *Postdigital Science and Education*, 1(1), 132–145. <https://doi.org/10.1007/s42438-018-0021-8>
- Hase, S., & Kenyon, C. (2000). From andragogy to heutagogy. *ULT Base Articles*. <https://www.doit.com.au/heutagogy/from-andragogy-to-heutagogy>
- Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Center for Curriculum Redesign.
- Holstein, K., McLaren, B. M., & Aleven, V. (2020). The classroom as a dashboard: Co-designing wearable cognitive augmentation for K–12 teachers. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1–15). Association for Computing Machinery. <https://doi.org/10.1145/3313831.3376720>
- Knox, J. (2020). Artificial intelligence and education in China. *Learning, Media and Technology*, 45(3), 298–311. <https://doi.org/10.1080/17439884.2020.1754236>
- Lu, Y., Tang, T., & Chen, X. (2023). Integrating generative AI in higher education: Opportunities and challenges. *Journal of Educational Technology Development and Exchange*, 16(1), 45–62.
- Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). Intelligence unleashed: An argument for AI in education. Pearson. <https://www.pearson.com/content/dam/one-dot-com/one-dot-com/global/Files/about-pearson/innovation/open-ideas/Intelligence-Unleashed-Publication.pdf>
- Marin, V. I. (2022). Student-centered learning in higher education in times of COVID-19: A critical analysis. *Studies in Technology Enhanced Learning*. <https://doi.org/10.21428/8c225f6e.be17c279>
- McAuliffe, M., Hargreaves, D., Winter, A., & Chadwick, G. (2009). Does pedagogy still rule? *Australasian Journal of Engineering Education*, 15(1), 13–18. <https://doi.org/10.1080/22054952.2009.11464073>
- Miao, F., Holmes, W., Huang, R., & Zhang, H. (2021). AI and education: Guidance for policy-makers.

- UNESCO. <https://unesdoc.unesco.org/ark:/48223/pf0000376709>
- Moore, R. (2020). Developing lifelong learning with heutagogy: contexts, critiques, and challenges. *Distance Education*, 41, 381 - 401. <https://doi.org/10.1080/01587919.2020.1766949>
- Nisar Khattak, M., Muhammad, N., & Robinson, D. (2021). Understanding the interplay between support agencies and small and medium-sized enterprises in a conflict environment from an institutional theory perspective. *Asia-Pacific Journal of Business Administration*, 13(2), 256-271.
- Pangrazio, L., & Selwyn, N. (2019). 'Personal data literacies': A critical literacies approach to enhancing understandings of personal digital data. *New Media & Society*, 21(2), 419-437. <https://doi.org/10.1177/1461444818799523>
- Perkins, M., Furze, L., Roe, J., & MacVaugh, J. (2024). The Artificial Intelligence Assessment Scale (AIAS): A framework for ethical integration of generative AI in educational assessment. *Journal of University Teaching and Learning Practice*, 21(6), 49-66.
- Redecker, C. (2017). European framework for the digital competence of educators: DigCompEdu. Publications Office of the European Union. <https://doi.org/10.2760/159770>
- Risam, R. (2018). *New digital worlds: Postcolonial digital humanities in theory, praxis, and pedagogy*. Northwestern University Press.
- Sala, A., Punie, Y., Garkov, V., & Cabrera Giraldez, M. (2020). *LifeComp: The European framework for personal, social and learning to learn key competence*. Publications Office of the European Union. <https://doi.org/10.2760/302967>
- Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 397-417). Cambridge University Press.
- Siemens, G. (2005). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning*, 2(1). http://www.itdl.org/Journal/Jan_05/article01.htm
- Stoten, D. (2024). Developing individual capability in organizations through the promotion of heutagogy. *On the Horizon: The International Journal of Learning Futures*. <https://doi.org/10.1108/oth-04-2024-0016>.
- Wang, M., & Kang, M. (2006). Cybergogy for engaged learning: A framework for creating learner engagement through information and communication technology. In D. Hung & M. S. Khine (Eds.), *Engaged learning with emerging technologies* (pp. 225-253). Springer. https://doi.org/10.1007/1-4020-3669-8_11
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2023). Systematic review of research on artificial intelligence applications in higher education: Where are the educators? *International Journal of Educational Technology in Higher Education*, 20(1), 1-28. <https://doi.org/10.1186/s41239-023-00393-7>.