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Digital natives in the scientific literature: A topic modeling approach

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ABSTRACT

The term "digital natives" was introduced in 2001 to describe a generation that has grown up surrounded by technology and the internet. The accompanying claims of a new way of thinking among digital natives were influential in shaping educational policy. Still, they were challenged by research that found no evidence of generation-wide cognitive changes in learners. Yet, the digital natives narrative persists in popular media and the education discourse. This study set out to investigate the reasons for the persistence of the digital native myth. It analyzed the metadata from 1886 articles related to the term between 2001 and 2022 using bibliometric methods and structural topic modeling. The results show that the concept of "digital native" is still both warmly embraced and fiercely criticized by scholars mostly from western and high income countries, and the volume of research on the topic is growing. However, the results suggest that what appears as the persistence of the idea is actually evolution and complete reinvention: The way the "digital native" concept is operationalized has shifted over time through a series of (metaphorical) mutations. The concept of digital native is one (albeit a highly successful) mutation of the generational gap discourse dating back to the early 1900s. While the initial digital native literature relied on Prensky's unvalidated claims and waned upon facing empirical challenges, subsequent versions have sought more nuanced interpretations. Notably, a burgeoning third mutation now co-opts the "digital native" terminology for diverse purposes, often completely decoupled from the foundational literature and its critiques. This study explains the concept's persistence as dynamic evolution of the digital native discourse in contemporary academic and public spheres.

1. Introduction

The generation(s) born in the so-called digital era are known by many names including the net generation (Oblinger & James, 2005), Homo zappiens (Veen, 2007), iGeneration (Rosen, 2010), and iGen (Twenge, 2017). But the best-known and widest applied label is *digital natives* introduced by Marc Prensky in his 2001 opinion piece *Digital Natives – Digital Immigrants*. Prensky argued that due to digitalization the younger generations have become "native speakers" of the digital language of computers, video games, and the Internet, and as a result, they "think and process information fundamentally differently from their predecessors" (2001, 1). Digital natives, wrote Prensky,

"… are used to receiving information really fast. They like to parallel process and multi-task. They prefer their graphics *before* their text

rather than the opposite. They prefer random access (like hypertext). They function best when networked. They thrive on instant gratification and frequent rewards. They prefer games to "serious" work." (2001, 2 [italics original])

Digital immigrants, in turn, were described to

learn – like all immigrants, some better than others – to adapt to their environment, they always retain, to some degree, their "accent," that is, their foot in the past. The "digital immigrant accent" can be seen in such things as turning to the Internet for information second rather than first, or in reading the manual for a program rather than assuming that the program itself will teach us to use it. Today"s older folk were "socialized" differently from their kids, and are now in the process of learning a new language. And a language learned later in

life, scientists tell us, goes into a different part of the brain (Prensky, 2001, p. 2).

Due to these fundamental differences, Prensky called for a major reformation of formal education because our "Digital Immigrant instructors, who speak an outdated language (that of the pre-digital age), are struggling to teach a population that speaks an entirely new language" (2001, 2). While Prensky's claims were not based on empirical evidence (e.g., Kirschner & De Bruyckere, 2017), they have been notably influential (Eynon, 2020). In educational policy, for example, one major theme in the history of digital re-schooling discourses (Selwyn, 2015) has been that digitalization builds bridges between formal education and student life outside the school (e.g., Mertala, 2020; Palmgren-Neuvonen, Jaakkola, & Korkeamäki, 2015; Roberts-Holmes, 2014). That narrative has been adopted by educators, policymakers, and parents in many countries (e.g., Evans & Robertson, 2020).

Policymakers, educational administrators, parents, teachers, and popular media were not the only ones enticed by the phrase: researchers found it attractive as well (Evans & Robertson, 2020). Many scholars did not only embrace the concept but the whole argument behind digital natives. Zevenbergen and Logan (2008, 37–38), for instance, stated that societies should be "rethinking practice as digital natives come to preschool". Because they contended "that young children coming into early childhood settings may be different from other generations because of the social and technological conditions within which they are developing." Notice the resemblance with Prensky's original thoughts.

Soon after the phrase caught on, empirically oriented researchers started to check on the grand claims associated with the "digital natives" phrase (Bennett, Maton, & Kervin, 2008). Especially suspect was the egregious idea that tech-savviness is an inborn trait of one whole generation. That idea was, rightly or wrongly, associated with Prensky's (2001) original "digital natives" thesis. Indeed, the very word "native" stems from old French and old Latin words for innate, or produced by birth. Soon after, researchers collected and presented evidence against the sweeping statements in popular media about a technologically superior new generation of learners, but in vain (see Judd, 2018). They showed that there is no monolithic "new generation" entering tertiary education, and no simple way to capture the processes of change at play (see Jones & Shao, 2011). They found no evidence of generation-wide changes that would necessitate pedagogical changes in higher education (see Jones & Shao, 2011). Yet, despite the accumulating evidence to the contrary, several especially persistent ideas became established in the digital native discourses (e.g., De Bruyckere, Kirschner, and Hulshof 2015). Smith, 2012 analyzed those discourses and identified eight dominant claims according to which digital natives …

- possess new ways of knowing and being
- drive a digital revolution transforming society
- are innately tech-savvy
- are multi-taskers, team-oriented, and collaborative
- natively speak the language of technologies
- embrace gaming, interaction, and simulation
- demand immediate gratification, and
- reflect and respond to the knowledge economy.

Come 2022, some of those discourses are as popular as ever, either in their original form or under new phrases, such as "iGen", "millennials", and "Generation Z" (e.g., Judd, 2018), under more nuanced conceptualizations, such as the "Digital Native Assessment Scale" DNAS (e.g., Wilson, Hall, & Mulder, 2022), or under ever new technological descriptors, such as savvy users of TikTok, WhatsApp, virtual/extended/augmented reality, and Instagram. The latest addition to the concept pool is "AI natives" (e.g., Eliot, 2022; Parmenter, 2019), which is unambiguously grounded on Prensky's ideas. Many new labels that have appeared since 2017, wrote Evans and Robertson (2020), reconceptualized the original concept to some degree, yet repeated much of

the crisis narrative that characterized the early 2000s digital natives' "moral panic". At the same time, also the digital natives vs. digital immigrants distinction is well alive (e.g., Agárdi & Mónika, 2022; Noronha-Sousa, Costa, Mateus, Noronha, & Vasquez-Justo, 2022).

1.1. Purpose of the study

The concept of digital natives has seen a number of literature reviews. Influential reviews include, for instance, Selwyn's (2009) oft-cited review that challenged the exaggeration and inconsistency involved in the "myth of the digital native" that was quickly gaining traction; and Kirschner and De Bruyckere's (2017) popular review that repeated the points there is no such thing as an information-savvy digital native, and that learners cannot multitask. These reviews, however, are narrative by nature and, thus, include a relatively small sample of articles (e.g., Bennett et al., 2008; Evans & Robertson, 2020; Judd, 2018; (Reid, Button, & Brommeyer, 2023); Selwyn, 2009). Reviews have also often focused on a certain (sub)discipline, like learning-sciences (Vitvitskaya, Josefina Amanda, Meneses-La-Riva, & Hugo Fernández-Bedoya, 2022) or specific domain, like higher education (Smith, 2012).

Given the high number of citations that Prensky's original article (and its successors) has received—and continues to receive—it is important to broaden the perspective in order to gain a better understanding of the distribution and effects of the concept in the scholarly domain. As of late 2023, Prensky's 2001 paper has garnered more than 40,000 citations in Google Scholar, 14,000 of which are from 2020 to 2022 (see Evans & Robertson, 2020). As Lim, Kumar, and Ali (2022, 487) argue: "as independent studies, literature reviews are relevant when they take stock of either an emerging or a mature field that continues to be widely practiced". The numbers mentioned above imply that, despite claims to the contrary (see Evans & Robertson, 2020), research on digital natives is by no means obsolete. This study set out to investigate why the "digital native myth" (Selwyn, 2009) has persisted even after it has been repeatedly debunked and denounced. In order to do that, the study posed three research questions.

- RQ1. How have the main themes of research on digital natives changed over the years?
- RQ2. Who are the key knowledge producers of the digital natives literature?
- RQ3. What are the main venues of dissemination of digital natives research?

In order to conduct a large-scale review we opted for conducting a structural topic modeling (STM) based bibliometric analysis. Bibliometric analysis is a rigorous method for exploring and analyzing large volumes of bibliometric data (e.g., number of citations and publications, occurrences of keywords and topics). Bibliometric studies are particularly useful when analyzing a large corpus of research, allowing researchers to find trends and hidden patterns that are otherwise unobserved (Donthu, Kumar, Mukherjee, Pandey, & Weng, 2021; Kraus et al., 2022). STMis a relatively new research method that offers a "semi-automated" analysis of large text corpora. STM provides a more nuanced approach for the thematic understanding of research and overcomes the limitations of the traditional keyword analysis that are limited by space (usually 3–5 keywords) and context (authors often choose from existing limited options). To date, only one bibliometric analysis on digital native research has been conducted (Dastane & Haba, 2023). Due to the differences in search strategies (see Section 2) the present paper includes twice as many articles (1886 vs, 983) making it the most comprehensive analysis so far –in terms of the included literature.

Furthermore, no topic modeling analyses have been done on the digital native literature. There is especially a need to overcome the limitations of the metadata-only approach that is limited to keyword analysis by using text mining methods to extend the analysis to rich

content of textual data in article abstracts. That would add much-needed depth that enhances the bibliometric analysis, as bibliometrics often trades depth of synthesis for breadth of coverage. This article takes advantage of recent advances in bibliometric methods, network science, as well as STM to offer a large-scale analysis of all the literature that refers to the concept of "digital natives" to understand the diverse research strands, the disciplinary traditions, as well as the temporal trends and inter-relationships across and within disciplines.

The results of the STM-based bibliometric analysis (see Section 3) were further interpreted by applying a sensemaking approach. This approach "enables researchers to move beyond the mere description of data and develop interpretations that offer deeper insights into the data's patterns, trends, and implications." It also "requires a comprehensive understanding of the literature and the broader contextual factors that influence bibliometric results" (Lim & Kumar, 2024, pp. 3, 5). Consequently, we argue that the concept of the "digital native" represents not only a highly successful mutation of a traditional generational gap/dichotomy discourse (as discussed in Section 4) but also functions as an "empty signifier" into which users can project their ambitions (as explored in Section 5).

2. Methods

2.1. Search

Since digital natives is a rather specific concept, with no synonyms or alternative phrasings or spellings, the Scopus database was searched for the phrase "digital native*" in article titles, abstracts, and keywords. Scopus was selected due to its large coverage of venues relevant to the topic, rigorous quality assurance procedure, and clear inclusion criteria (Baas, Schotten, Plume, Grégoire, & Karimi, 2020; Singh, Singh, Karmakar, Leta, & Mayr, 2021). The search, which was performed on May 28th, 2022, returned 2091 articles, spanning the years 2001–2022. Articles in languages other than English were excluded, leading to a total of 1886 articles included in the analysis.

2.2. Data processing

The metadata for all the included articles were processed using the *bibliometrix* R library (Aria & Cuccurullo, 2017). Bibliometrix enables complex scientometric analyses and is compatible with major scientific databases. Bibliometrix uses publication metadata to create a bibliographic data frame where each row represents a single document and each column is mapped to a bibliographic field provided by the database (e.g., DOI, title, keywords, publication year, etc.). Although bibliometrics can perform basic cleaning of article metadata, some inconsistencies typically remain. Based on the guidelines by López-Pernas, Saqr, and Apiola (2023), we took further steps to clean our data. We disambiguated author names that have different spellings, which are mapped to the same author ID in Scopus. We made sure that each author had a single name, corresponding to the most recent spelling found. We also cleaned the author keywords, as the same keyword can be written in many ways (e.g., singular and plural forms, acronyms, and synonyms). This step was performed using OpenRefine, a tool that provides several algorithms to detect and combine similar text data.

2.3. Data analysis

Two categories of bibliometrics are generally recognized: a performance analysis that focuses on the productivity, metrics and impact and another category that focuses on mapping the literature content (Donthu et al., 2021; Kraus et al., 2022). Our article focuses mostly on the latter and uses some performance measures to answer our research questions. To prepare the data for analysis, we used the *bibliometrix* R library to process the relevant bibliographic fields. Performance analysis included most productive countries, the most prolific authors, and the scientific

venues in which authors most frequently published their work related to digital natives (Donthu et al., 2021; Kraus et al., 2022).

The mapping of the digital native literature included: content analysis through extraction of the key terms mentioned in the abstract and keywords to gain insights into the common keywords that were commonly used along with "digital natives''. To identify distinct themes of research within the digital native literature, we used structural topic modeling (STM). STM can help summarize the research themes and it makes use of all textual data. Grouping the keywords using STM overcomes the fragmentation of author keywords as it groups close articles together. STM is an unsupervised machine learning method, which requires no manual training. We followed an approach similar to Group concept mapping methodology (Rosas, 2017). In that, we used the *stm* package for R (Roberts, Stewart, and Tingley 2019).

The STM input consisted of the article titles, abstracts, and keywords. The *stm* package uses an implementation of Latent Dirichlet Allocation (LDA) and a variational Expectation-Maximization algorithm to estimate the topic models. Similar to other unsupervised clustering and mixture models, the optimal number of topics is not known apriori. Researchers have to rely on other methods to identify the number of topics, such as fit indices and human judgment. This study followed the latest guidelines that combine human judgment (consensus among researchers) with fit indices, namely semantic coherence and exclusivity. Semantic coherence is highest when the most probable keywords exist together and has a high correlation with human judgment. Yet, a shortcoming often noticed with semantic coherence is that it is dominated by frequent and common keywords. Exclusivity reflects how exclusive a word is to a given topic (Roberts & Tingley, 2017). A combination of both indices (semantic coherence and exclusivity) helps narrow down the number of topics. Yet, no statistic guarantees to identify the correct or the "true" number of topics (Donthu et al., 2021; Roberts, Stewart, and Tingley 2019).

Using STM, we estimated 21 models, each with a different number of topics (ranging from 5 to 25). To select the most fitting model, the semantic coherence and exclusivity were plotted and several models were found to be candidates for further examination by researchers. Those models corresponded to 14, 15, 16, 19, 23, and 25 topics. Two researchers manually inspected the topics in each model and rated the models according to 1) how homogeneous and meaningful the topics are within a single theme, 2) the low overlap between topics, and 3) low dissonance or remarkable differences among the topic keywords. The model with the best score was the one including 16 different topics. The extracted topics were sorted, and each topic was assigned a label based on the most salient features of the included keywords (Rosas, 2017). We examined the 16 topics in the selected model, both from a relational and a temporal perspective. First, we studied the co-occurrence of topics within the same article by constructing a network where two topics are considered connected if they existed in the same document. The topic co-occurrence network was plotted using Gephi. Modularity detection was used to identify topics that co-occur frequently and therefore, represent a common theme. We then analyzed how the different research themes have evolved throughout the years since the term "digital native" appeared. We built a trend line for each topic, representing the number of articles published each year, weighted by the probability that each article belongs to the topic in question, i.e., if an article is clearly covering the topic, its weight would be close to 1, whereas if an article is unrelated to the topic, its weight would be close to 0.

3. Results

3.1. The main themes of research on digital natives

3.1.1. Topic identification

The digital native terminology played a central role in the articles. The term "digital native" was used as an author keyword in roughly one

in four articles in the dataset, and it appeared in most abstracts in the dataset. Its sister term, "digital immigrant" featured in 91 author keywords and 502 abstracts. The list of most used author keywords and bigrams (adjacent pairs of words) found in abstracts reveals a significant focus on, firstly, social media-related concepts (social media, social networking, web 2.0), and secondly, education as a context (higher education, e-learning, education, digital literacy, learning environment, language learners). Table 1 presents the most used author keywords and abstract bigrams.

Table 2 presents 16 topics identified through STM. In the body of literature that employs the phrase "digital native", learning-oriented topics included game-based learning and gamification, technology-enhanced learning, technology-enhanced language learning and teaching, and online learning. These topics, as the word "learning" suggests, were centered around the role of technology in the learning of "digital natives" either at the general level (e.g,. Adams, Sumintono, Ahmed, & Nur Syafika, 2018) or specified to certain contents (language learning: e. g., Hubbard, 2013), methods (game-based learning: e.g., Miglino, Di Ferdinando, Di Fuccio, Rega, & Ricci, 2014) or contexts (online learning: e.g., Comer, Lenaghan, and Sengupta 2015) sometimes in an overlapping manner (game-based methods for language learning: e.g., Flores, 2015; Berns, Isla-Montes, Palomo-Duarte, & Juan-Manuel, 2016).

Outside learning, "online" defined the context in three other topics: online behavior, online political participation and citizenship, and social media. Online behavior and social media were thematically heterogeneous categories including a variety of themes including "the role of social media platforms […] among younger consumers ("digital natives") in their interactions with brands" (Rohm, Kaltcheva Velitchka, and Milne George 2013), user characteristics on online trust (Hoffmann, Lutz, & Meckel, 2014), and "digital natives' intention to use permission-based location-aware mobile advertising" (Richard & Meuli, 2013) to provide a few examples. Online political behavior and citizenship, in turn, was a more homogenous topic, an illustrative example of which is Ohme, 2019b study about the relationship between increased use of digital media and changing patterns of political participation.

The topic "transformation of work" included papers that discussed new forms of labor like digital nomadic work from an individual's point of view (Nash, Hossein Jarrahi, Sutherland, & Phillips, 2018) as well as papers that discuss how companies should react to digital natives because the "[d]igital native generation […] has altered our perception about how employees need to be engaged and challenged at their workplace" (Depura & Garg, 2012). A similar trend was identifiable from the topic "information system," which was often about how libraries (and other traditional information hubs) should rethink their practices to meet the needs and preferences of digital natives (e.g., Robinson, 2008). The topic "health and medical" included articles that pondered on the question of what it means for the health industry that an increasing number of professionals and patients are digital natives (Sadiku et al., 2022). With regard to the latter group, patients, articles on this topic also discussed the mental and physical health effects of increasing digital (screen) media use (Rich, 2014).

Table 1
Top 10 most used author keywords and abstract bigrams.

Author Keywords	N	Abstract Bigrams	N
digital native	513	digital native	2149
social media	107	social media	502
digital immigrant	91	digital immigrant	294
ict	72	social networking	260
technology	67	digital technology	215
higher education	66	communication technology	137
e-learning	65	learning environment	136
education	53	digital literacy	132
web 2 0	53	language learners	122
digital literacy	47	information systems	121

Table 2
Topics identified through STM and the terms related to each topic.

Topic	Terms
Game-based learning and gamification	Games, Learning, Game, Children, Design, Educational, Computer, Gamification, Serious, School
Generational differences/ dichotomies	Generation, Information, Young, Communication, People, ICT, Internet, Technologies, Immigrants, Generational
Health and medical	Health, Medical, Information, Care, Scale, Assessment, Students, Video, Quality, Data
Information systems	Information, Systems, Design, Social, Management, Service, Software, Cloud, Computing, Business
Literacy skills	Literacy, Skills, Students, Information, Thinking, Design, Education, Critical, Knowledge, Development
Mobile devices	Mobile, Devices, Internet, Students, Gender, Technology, Differences, Age, Multitasking, Years
New generation	New, Generation, Millennials, Technology, Work, World, Changes, Society, Future, Age
News & journalism	News, Journalism, System, Analysis, Content, Data, Memory, Control, Algorithm, Journalistic
Online behavior	Behavior, Online, Model, Technology, Factors, Acceptance, Mobile, Perceived, Intention, Data
Online learning	Learning, Students, Online, Course, Teaching, E-Learning, Environment, Classroom, Blended, Courses
Online political participation and citizenship	Online, Political, Internet, Information, Web, Communication, Data, Citizenship, Participation, Mobile
Social media	Social, Media, Online, Facebook, Networking, Networks, Marketing, Communication, New, Sites
Technology enhanced language learning and teaching	Teachers, Technology, Language, Learning, Learners, Teacher, English, Classroom, Teaching, School
Technology enhanced learning	Education, Students, Technology, Technologies, Learning, Higher, University, Educational, Teaching, Student
Transformation of work	Work, Innovation, New, Business, Design, Practices, Management, Case, Spaces, Organizations
Virtual reality	Virtual, Reality, New, Design, World, Training, Application, Tools, Methods, Content

The topic "literacy skills" was typical of digital literacy (Porat, Blau, & Barak, 2018; Ting, 2015), but sometimes included also traditional (i.e. print) literacies by using the framework of multimodal literacy/literacies (Mills, 2010). News and journalism included studies that explored digital natives as consumers (Batsell, 2012) or producers (Cozma & Tom, 2019) of traditional or digital news media. We also noticed that under this topic the term "digital native" was sometimes used to describe news media outlets that have started online (no history as a broadcast or paper media) with no actual connection to Prensky's writings (e.g., Kopalle, Kumar, and Subramaniam 2020; Tandoc & Maitra, 2018).

The topic of "mobile devices" mainly consisted of studies in which mobile devices were either a central theme or one observed device among others. Examples of the first branch include studies about teachers' perceptions of using mobile phones in schools (O'Bannon & Kevin, 2014) and students' multitasking with mobile phones (Ames, 2013). The latter branch, in turn, included studies that mapped the broader technology use of different groups (i.e. young children; see Bittman, Rutherford, Brown, & Unsworth, 2011). Last, "virtual reality" (VR) was about the educational use of VR (Alkhattabi, 2017; Burch & Smith, 2019; Kiryakova, Angelova, & Yordanova, 2018), virtual visits to real environments (i.e. virtual home visits in intervention programs; Olsen, Fiechtl, & Rule, 2012) and corporations move in virtual realities to attract digital native customers (Wyld, 2010) to provide some examples.

3.1.2. Topic co-occurrence

As shown in Fig. 1, technology-enhanced learning formed a kind of nexus with strong connections to several other topics including the ones it was clustered with (technology-enhanced language learning and game-based learning) as well as topics from other clusters (e.g., online learning and generation themed topics, dark green cluster). A major body of research on digital natives and learning appears to be about the question of how formal education should adapt to the situation where "a new generation of students —digital natives— armed with a dizzying array of gadgets and gizmos roam the hallways of academic institutions struggling to keep pace with speed of the digital world" (Madhavan & Lindsay, 2014) (see also Harvey & Kotting, 2011, p. 633). Empirical research on younger generations' learning and technology, however, suggests that such statements are heavily inflated: in numerous studies, the younger cohorts of students showed no significant difference (Waycott, Bennett, Kennedy, Dalgarno, & Gray, 2010) with regard to learning preferences (Margaryan, Littlejohn, & Vojt, 2011), technology use (Waycott et al., 2010), technology skills (Porat et al., 2018), and attitudes towards technology (Salajan, Schönwetter, & Cleghorn, 2010).

In the "mobile devices, online behavior, and health and medical" cluster (orange), health was treated either as content or context. Studies that approached health as content were interested in how people seek and evaluate online health information (Haluza, Naszay, Andreas Stockinger, & Jungwirth, 2017; Keil & Kominsky, 2013; McGloin, Richards, & Embacher, 2016; Tao, LeRouge, Smith, & De Leo, 2017) or use digital health apps (Naszay, Andreas Stockinger, Jungwirth, & Haluza, 2018). Typically, these studies compared different age groups to test the digital native–digital immigrant hypothesis but found no statistically significant differences (e.g., Haluza et al., 2017; Keil & Kominsky, 2013). One exception to this "rule" was a study by Naszay et al. (2018) who found that age played a statistically significant role in whether the respondents used mobile health apps or not in favor of the younger participants. Health as a context can be further divided into two sub-categories. The first was about the use of mobile technologies either in medical/nursing training or practice (e.g., Coovert, Howard, Coovert, & Nelson, 2015; van Houwelingen, Roelof, Helianthe, & Olle ten, 2017). The second was about the use of mobile-based/online (mental) health interventions and services (often) in higher education (e.g., Colasante, Lin, De France, & Tom, 2022; Herrero et al., 2019; Montagni, Cariou, Feuillet, Langlois, & Tzourio, 2018). In both cases, the rationale was that the younger generations of students and professionals would embrace the use of mobile devices and online services because "university students are digital natives having easy access to the internet and new technologies" (Montagni et al., 2018). These claims were not always supported by empirical evidence as students often had negative or mixed views regarding intensifying use of technology in health and medical services (e.g., Coovert et al., 2015; Montagni et al., 2018; van Houwelingen et al., 2017).

The light green cluster (social media, political participation, and information systems) included studies that observed adolescents' use of social media as means of organizing and facilitating political actions like street protests (Hsiao, 2018), as well as papers that problematized the assumption that younger generations would, by default, prefer digital media for politics and civic action (Banaji, 2011). While some studies —like the ones cited above— had an inclusive take on social media, others focused on individual media texts like memes (Kulkarni, 2017). The purple cluster (transformation of work, virtual reality, literacy skills, and news and journalism) was the most scattered one. It included, for example, publications that discussed what the use of virtual office environments (which were argued to be preferred by the new tech-savvy generation of the workforce) implies for workplace security policies and procedures (Nezami, Bakker, & Tinga, 2021).
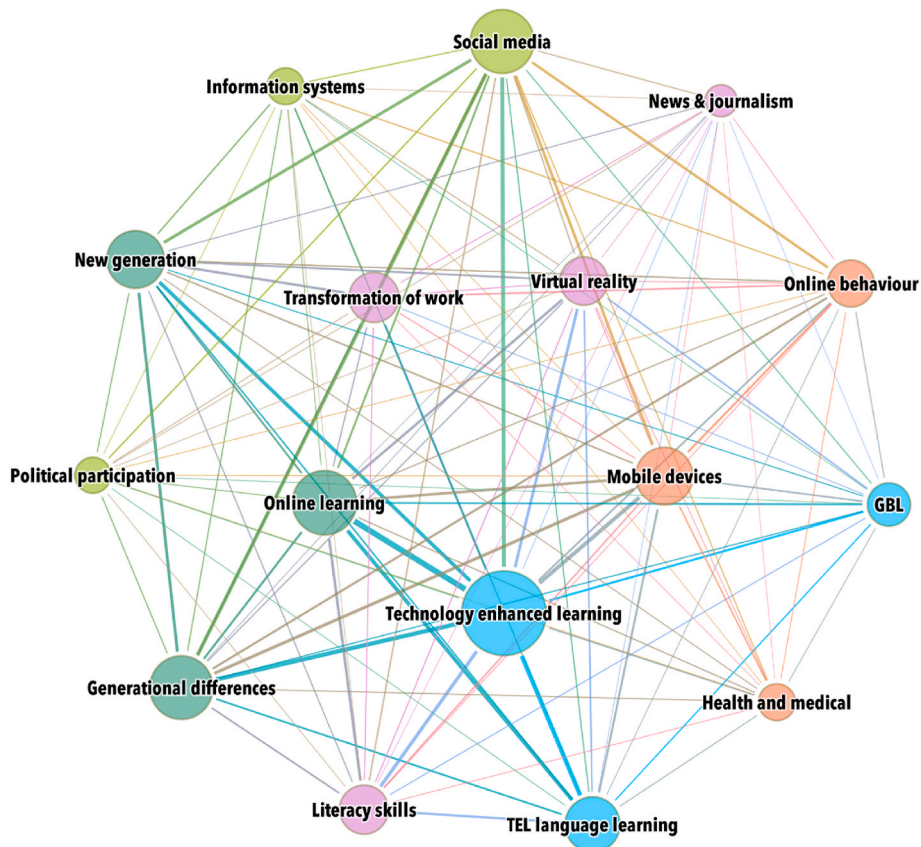

Fig. 1. Network of topic co-occurrence.

3.1.3. Temporal evolution of the topics

Some differences can be noted in how the 16 topics evolved over time (Fig. 2). A number of topics peaked in 2010–2012 and remained stable since. One topic, information systems, saw around 2012–2013 a promising peak that never materialized as a sustained focus of research after which the interest waned. However, most topics have seen a steadily increasing frequency of publications since the year 2005, most prominently technology-enhanced learning (TEL), technology-enhanced language learning and teaching, virtual reality, and "new generation." One factor fueling this trend might be the introduction of tablet computers in the early 2010s, which led to an extensive scholarly debate about their role and (often inflated) potential in education (see Mertala, 2021).

Lastly, the growth of the topics "online behavior", "online political participation and citizenship", and "social media" (to a lesser extent) follow roughly the schedule of the US presidential elections (2012, 2016, 2020), which since 2012 have heavily relied on online (social media) platforms for data collection and targeted advertisement (O'Neil, 2016). While the geographical contexts of such research were not limited to the US only (see for example Ohme, 2019a), the US was the country that produced the most digital native articles—a topic to be discussed in more detail in the following section.

3.2. The knowledge producers of research on digital natives

3.2.1. Geographical distribution

As illustrated in Table 3 and Fig. 3, research contributions on digital natives originated mostly in western and high-income countries with an additional notable presence of some emerging economies, including Malaysia, Indonesia, India, and South Africa. The three most productive countries were the USA, UK, and Australia, which are English-speaking countries and where around 37.5% of all articles were produced. With about 5% of all articles, China came fifth. As country productivity is a reflection of authors' affiliations and interests, this section offers an author analysis.

3.2.2. Most prolific authors

The most productive authors of articles in the current set of publications are far from being a group of enthusiastic evangelists of the digital native account. The list of 20 most productive authors on the topic (Fig. 4) contains six people from a team of researchers whose series of research studies from 2006 to 2010 scrutinized and criticized the original digital native concept from a number of angles (e.g., Kennedy et al., 2006, 2007, p. 517; Kennedy, Dalgarno, et al., 2008; Kennedy, Judd, Anna, Gray, & Krause, 2008; Kennedy, Judd, Dalgarno, & Waycott, 2010; Waycott et al., 2010). They investigated how active users of Web 2.0 technologies digital natives are (they are not particularly active) (Kennedy et al., 2007, p. 517). They conducted empirical research on students' and staff's technology use (Corrin, Lockyer, & Bennett, 2010; Kennedy, Dalgarno, et al., 2008), on their perceptions of ICT (Waycott et al., 2010), and on pre-service teachers' preparedness for educational technology (Gill & Dalgarno, 2010).

The team wanted to set the original digital native story straight. They wrote a scathing critique saying that many grand claims related to digital natives were never based on empirical facts, but rather "an academic form of a 'moral panic'" (Sue Bennett et al., 2008). While some in the team continued their own investigations later too, their work culminated in a 2011 book "Deconstructing Digital Natives" (Thomas, 2011). Some other very productive authors in Fig. 4 were critical, too. For example, Jones (e.g., Jones, 2010) published a flurry of critical contributions in 2010–2011 but never returned back to the topic.

Most other prominent authors in Fig. 4 presented new "digital natives" -related work after the original wave of criticism. Many of them used the digital native terminology to frame their research and to provide a rationale for their own educational technology or pedagogical initiatives, such as virtual programming lab (Mozelius & Olsson, 2015),

self-destructing content (Sixto-García & Duarte-Melo, 2020), edutainment software (Guran, Cojocar, and Dioşan 2020), or game-based learning (Mozelius, 2014). Others employed the concept to study differences between digital immigrants and digital natives in a variety of contexts, such as dimensions of literacy (Nikou, Brännback, & Widén, 2020), leadership potential (Braccini, 2013), and team behavior (Braccini & Francesca Marzo, 2016). The application areas were diverse. Sundaram and Myers re-framed ubiquitous information systems research in terms of digital natives and proposed a research agendum for studying digital natives in that context (e.g., Vodanovich, Sundaram, & Myers, 2010). Mayer et al., 2012 looked at the impact of digital natives—as "new-generation managers"—on management. In the field of economics, Mäntymäki et al. (e.g., Mäntymäki & Riemer, 2014) studied gratifications, consumption values, and purchasing behavior of digital natives in virtual worlds.

Some on the list of most productive authors adopted the digital native concept as a central or fundamental concept in their research but acknowledged that the original conception is too limited and aimed to refine the concept. Nikou, Cavalheiro, and Widén (2020) used Teo's (2013) Digital Native Assessment Scale (DNAS) to promote a "digital native" division not based on birth year but a range of other constructs. Huang and Yang (2014) noted the growing body of evidence against the notion of "digital native" and the "net generation" gap, but continued to work on a revised framework and better understanding of a new generation of "digital native" learners (e.g., Yang, Ahmed, Huang, Zhuang, & Kumar Bhagat, 2021).

3.3. Dissemination venues of research on digital natives

The dissemination of research about digital natives is widespread and fragmented between fields and journals. Around 70.3% of venues (journals or conferences) have only published a single manuscript that refers to digital natives, and just 4.4% of venues have published more than five manuscripts. On the list of top journals (Table 4) only four have published ten or more articles that mention digital natives. The top ten conferences have published between 9 and 18 papers that refer to digital natives. *Computers and Education* tops the journals list with 21 articles (1.1% of all the dataset) with a remarkably high average citations per article (118.3). For example, the *Computers and Education* article that validated the Digital Natives Assessment Scale (Teo, 2013), has gathered a respectable number of citations. *Computers In Human Behavior* had 13 articles (0.7%) of all articles with 86.6 citations per article. The other journals on the list come from diverse areas including education, technology, media and library sciences—however, with relatively lower citation counts. The top conferences were even more diverse, had far lower citations per manuscript, and included mostly educational conferences (eight out of ten), the two others being *Human Computer Interaction International* (top conference in count) and *Pacific Asia Conference On Information Systems* (top conference in citations) (see Table 5).

4. Discussion

To synthesize our main findings, the concept of the digital native is characterized by self-contradictory features. First, the concept is both warmly embraced and fiercely criticized by scholars (Section 3.2.2). Second, digital natives are simultaneously ubiquitous and restricted: they are studied across various research topics and disciplines (Section 3.1) and disseminated through numerous outlets (Section 3.3) by various authors (Section 3.2.2). However, at the same time, research on digital natives is geographically dominated by Western and high-income countries (Section 3.2.1), raising doubts about the inclusivity of the claims associated with the concept. This "chameleon-like" essence could be one factor behind the success of the concept. By success, we mean that despite serious and sustained critique of the conceptual and empirical foundations of the "digital native" idea, the phrase continues to persist in established and new forms and forums. The number of
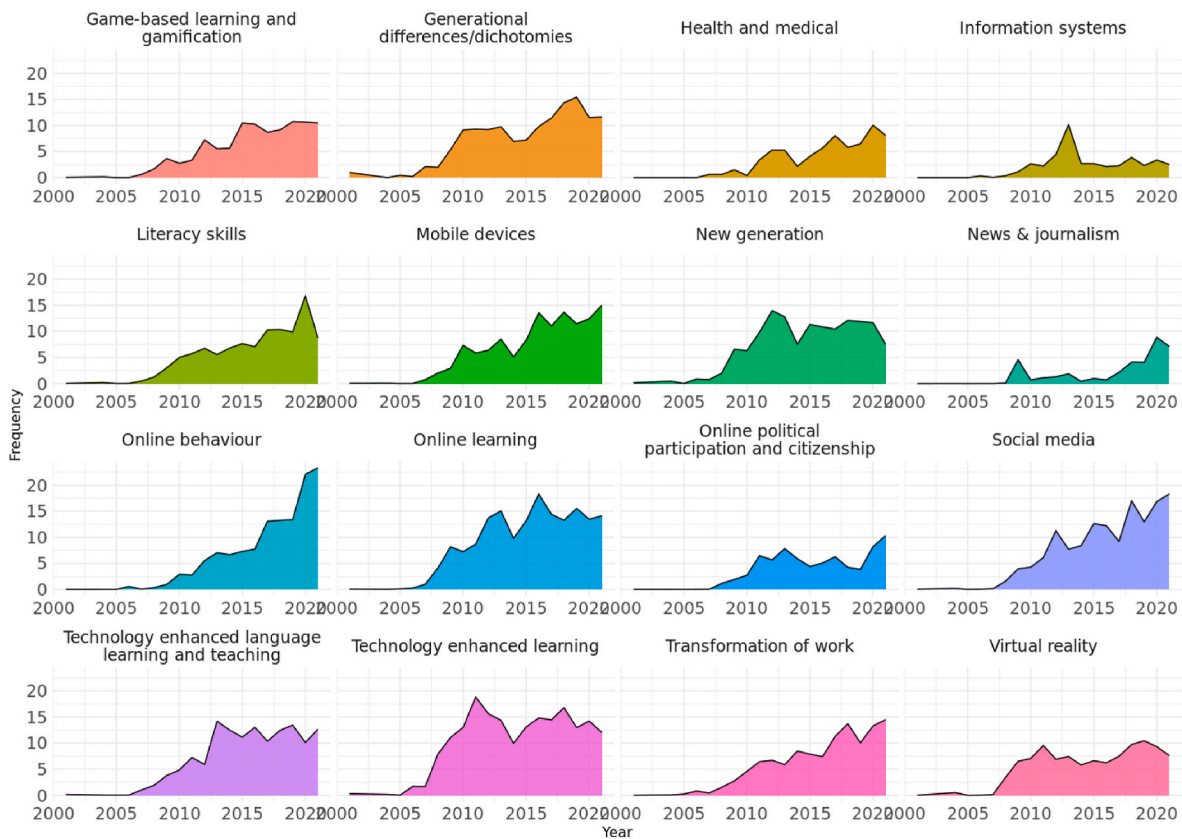
Fig. 2. Temporal evolution of the topics. The x-axis represents the year. The y-axis represents the number of articles with each topic weighted by the probability the topic appears in the article.

Table 3

Number of publications per country. A country is only counted once per publication, regardless of the number of authors.

Country	N	Mean Cit.	Tota Cit.	SCP	MCP
United States	424	29.941	12,695	371	53
United Kingdom	159	22.138	3520	128	31
Australia	124	39.016	4838	96	28
Spain	108	11.028	1191	82	26
China	94	7.734	727	65	29
Italy	92	7.815	719	69	23
Germany	87	7.540	656	64	23
Malaysia	57	4.140	236	48	9
India	52	3.308	172	47	5
Canada	51	7.941	405	37	14
Turkey	46	7.435	342	41	5
Indonesia	42	2.262	95	40	2
Finland	33	18.606	614	21	12
France	33	9.121	301	22	11
Switzerland	32	12.500	400	17	15
Portugal	31	3.419	106	19	12
South Africa	31	23.161	718	26	5
Austria	30	5.033	151	20	10
Romania	29	4.241	123	23	6
Netherlands	23	55.565	1278	14	9

publications that use the phrase is not only constantly growing, but the ways in which they use it have also evolved over the years. Next, we will examine these changes by using the concept of "mutation" as a metaphor. The utility of the mutation metaphor, as opposed to that of a phase or a wave (see Evans & Robertson, 2020), lies in its ability to accommodate the simultaneous existence of different versions of the digital native concept.

4.1. The initial mutation

First, it needs to be acknowledged that the concept of digital native is not an origo in itself. Instead, statements about "generation gaps" challenging education date back to the 1960's, at least (e.g., Mead, 1969), and their initial forms are quite identical to the "moral panic" discourse typical for digital native discourse. As Bengtson (1970, p. 7)) argues "[i]ndeed, all too often the discussions of such issues [generational differences] has been impressionistic speculative and even apocalyptic –not only in the popular press, but also in the pages of scholarly books and journals"– a statement that could just as well be from the 2000s. The concept of digital native is just one (if a highly successful) mutation of the generational gap discourse that, for reasons to be discussed in section 5, found its audience and proponents in early 2000's. In fact, in 1999 Don Tapscott (2008) introduced the concept of net generation, which despite similarities with digital native never reached a similar status.[1]

The original digital native idea, relied on Prensky's initial works and how they resonated with everyday intuition. Prensky's opinions caught the public eye, which, in the words of Evans and Robertson (2020), "helped this professional public speaker to start a cottage industry around his invented term."In the academic world, the reception was much less welcoming. As research studies by a growing number of researchers countered Prensky's untested, sensationalistic claims about a new breed of learners whose cognitive processes fundamentally differ from earlier generations, the original wave started to lose its appeal. It

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[1] Tapscott re-introduced the term in his book "Grown Up Digital: How the Net Generation is Changing Your World" (2008), which with more than 6000 citations in Google Scholar popularized the concept more successfully than the original paper.
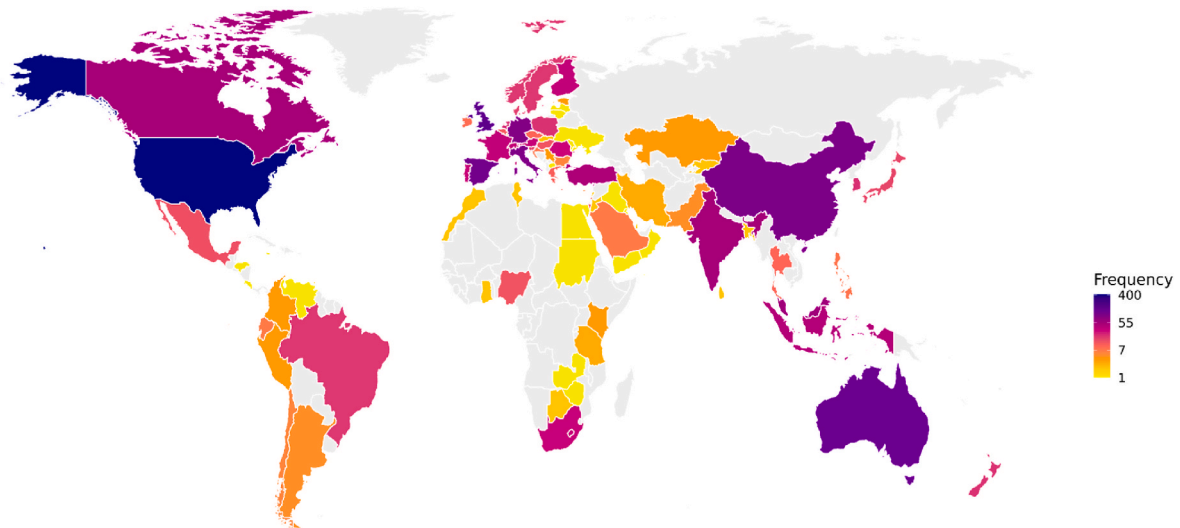
Fig. 3. World map of country production. Color represents the number of publications per country. A country is only counted once per publication.
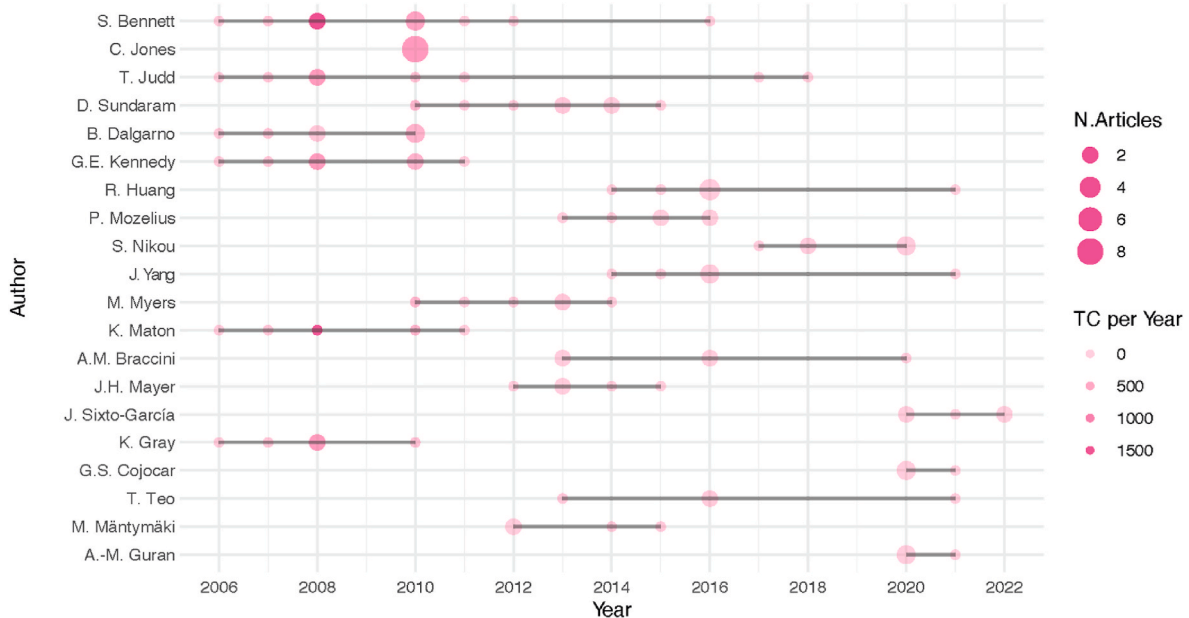

Fig. 4. Authors with most articles in the current dataset. Circle size represents the number of articles in a specific year. Circle opacity represents the number of yearly citations.

turned out that "digital natives" needed to learn the skills and tools for the datafied society like everyone else does (e.g., Selwyn, 2009; Judd, 2018; Bennett & Maton, 2010). It turned out there is much more to understanding the roles technology plays in learning than simple dichotomies like "natives and immigrants" (Bennett & Maton, 2010). What is more, Prensky's digital native concept was often associated with another "urban myth" about education: learning styles (De Bruyckere, Kirschner, and Hulshof 2015, pp. 20–27).

4.2. The nuanced mutation

As the initial concept was losing momentum, a new form of digital native literature was on the rise. This so-called nuanced mutation acknowledged the shortcomings and empirical refutations of the original idea and proposed much more nuanced, redesigned versions of the digital native concept. Most notably, Teo's (2013) oft-cited Digital Natives Assessment Scale (DNAS), for instance, introduced a 21-item

instrument for measuring learners' perceptions of themselves as digital natives. It included factors such as growing up with technology, being comfortable with multitasking, relying on graphics for communication, and thriving on instant gratification and rewards. The new, more nuanced version of digital nativeness faced issues similar to the initial one. Generations are heterogeneous in terms of their technological practices, preferred modalities of learning, and comfort with technology (Thompson, 2015). Learners do not possess unique cognitive abilities, such as multitasking (Kirschner & De Bruyckere, 2017). Instead of "native" (natural, inborn) inclinations, technology adoption could be better described through concepts that individuals can learn, such as digital literacy or fluency with technology (Wilson, Hall, and Mulder 2022).

4.3. The decoupled mutation

At the same time, overlapping with the second one, a third but very

Table 4
Top 10 journals with the highest number of publications, including the first and last year in which research about digital natives was published, the mean number of citations (in Scopus) per article, the total number of articles published, and the percentage they represent from all the publications in our dataset. (Includes journal articles, reviews, and editorials.)

Top journals	First	Last	Avg. Cit.	Articles	Pctg
Computers and Education	2010	2021	118.29	21	1.11%
Computers in Human Behavior	2010	2021	86.54	13	0.69%
Turkish Online Journal of Educational Technology	2013	2017	1.69	13	0.69%
Media and Communication	2020	2020	7.00	12	0.64%
International Journal of Emerging Technologies in Learning	2011	2020	12.56	9	0.48%
Electronic Journal of E-Learning	2012	2022	13.25	8	0.42%
Information Communication and Society	2011	2021	31.13	8	0.42%
Library Philosophy and Practice	2019	2021	0.63	8	0.42%
Sustainability	2017	2021	7.50	8	0.42%
Interactive Learning Environments	2016	2022	11.29	7	0.37%

Table 5
Top 10 conferences with the highest number of publications in the dataset.

Top conferences	First	Last	Avg. Cit.	Articles	Pctg
Human Computer Interaction (HCI) International	2011	2021	4.00	18	0.95%
Annual Conference Of The Australasian Society For Computers In Learning In Tertiary Education (ASCILITE)	2006	2017	20.59	17	0.90%
European Conference On E-Learning (ECEL)	2007	2020	2.00	15	0.80%
Asee Annual Conference And Exposition	2008	2021	1.02	11	0.58%
International Conference On Advanced Learning Technologies (ITCAL)	2011	2018	2.63	11	0.58%
Pacific Asia Conference On Information Systems (PACIS)	2011	2018	3.35	11	0.58%
European Conference on Game Based Learning (ECGBL)	2009	2021	1.20	10	0.53%
European Conference On Information Systems (ECIS)	2012	2020	17.10	10	0.53%
International Conference On Computers In Education (ICCE)	2009	2019	3.44	9	0.48%
International Conference On E-Learning (ICEL)	2007	2015	1.44	9	0.48%

different mutation of digital native was emerging. An increasing number of studies appropriated the digital native terminology for their own purposes, without a reference to the original body of digital native literature or its critique. Examples of appropriation include research on indigenous people and big data (Radin, 2017), on innately digital media formats (Vázquez-Herrero, Sabela, & López-García, 2019), and on firms that were born in the digital ecosystems (such as Google, Netflix, and Uber) (Kopalle, Kumar, and Subramaniam 2020). The third wave brings both an extended life to the phrase "digital native" but also a detachment from its established meaning.

5. Conclusion

5.1. Digital native as an empty signifier?

The primary theoretical contribution of the present study is its illumination of the multifaceted factors contributing to the persistence of digital native research and discourse. In conclusion, it appears that the endurance of the pro-digital native discourse can be attributed, at least in part, to two intertwined factors: 1) its reliance on an established narrative (the generational gap) and 2) the continual emergence of opportunities for the generational dichotomy discourse due to the introduction of novel technologies. A pertinent example is artificial intelligence (AI), as discussions about the existence of an "AI generation" (Chan & Lee, 2023) and "AI natives" (e.g., Eliot, 2022; Parmenter, 2019) are prevalent in academic and public discourse. On the other hand, since critical perspectives on digital natives also appear to be equally common (as seen in Section 3.2), it suggests that the concept may be useful for critics as well (assuming that not all critical articles are mere responses to pro-digital native ones). One possible explanation is that some critical authors employ the concept as a well-known example of an "evocative—but false—rhetoric that has had notable effects on teachers' beliefs about students and digital technologies" (Mertala, Moens, & Teräs, 2022, p. 11).

On the other hand, the term "digital native" itself appears to possess rhetorical qualities that have helped it endure for more than 20 years. One supporting example of this is its popularity when compared to concepts like the net generation (Tapscott, 1999), Homo zappiens (Veen, 2007), and iGeneration (Rosen, 2010), which, despite sharing many substantive commonalities, have not achieved similar attention or longevity. Arguably, "digital" is a more inclusive term than "net" or "i," which references Apple's product line (e.g., iPad, iPhone, iTunes), and "digital native" is a more understandable wordplay than "homo zappiens." Another supporting example is the notion that scholars from various disciplinary fields have independently coined the term without being aware of its origin. In other words, it seems that the combination of the concepts "digital" and "native" enables authors to effectively communicate their ideas to others. Consequently, we argue that, in the scholarly field, the concept of the digital native, in a sense, functions as an "empty signifier" that users can employ for various purposes. Gandini (2021) has made a similar observation regarding the concept of "digital labor." In fact, the last sentence from the quote would serve as a suitable conclusion for the present paper with only one word changed.

> Over the years, however, this expression has evolved into an umbrella term, used to describe a variety of practices and instances concerning the broader relationship between labour and digital technology – including paid work – often with little or no relation to the original theory. Reflecting on this evolution, this article argues that 'digital labour' has become a kind of empty signifier, unable to serve a clearly distinguishable critical or analytical purpose (Gandini, 2021, p. 369).

5.2. Limitations and implications for future research

As is the case with any literature synthesis, there is a trade-off between the scope of coverage, depth of analysis, and breadth of inclusion of articles. Bibliometrics studies cover a large number of studies and therefore, they are not expected to retain the accuracy of literature reviews. Nonetheless, our study offers a different perspective through an overarching bird-eye view of the extant literature. Topic modeling has a summarizing power, yet, as the literature emphasizes, it should not be confused with a true and accurate representation of the included articles. Another limitation of our study is that the literature was identified by searching a database. It is understandable that no search can retrieve all articles published about the matter, especially when the authors do not include the term "digital natives". However, the large number of retrieved articles from a well-maintained database constitute a representative sample that fully depicts the status of digital native research.

Additionally, the utility of the mutation metaphor introduced in the present paper could be tested and developed by future research. The concepts like phases (Evans & Robertson, 2020) and stages (Laru, Naykki, & Jarvela, 2015) are commonly used in research literature exploring the conceptual or thematic changes in a given field. The

problem with such terms are that, unlike the mutation-metaphor, they suggest the existence of (more or less clear-cut) temporal transitions (we have moved from a certain phase or stage to another), which our findings do not support: while the original digital native conceptualization was stripped from its initial popularity due to the harsh criticism it was never fully abandoned and still used alongside the nuanced and decoupled mutations.

Additionally, the utility of the mutation metaphor introduced in the present paper could be tested and developed by future research. Concepts like "phases" (Evans & Robertson, 2020) and "stages" (Laru et al., 2015) are commonly used in research literature exploring conceptual or thematic changes in a given field. The problem with such terms is that, unlike the mutation metaphor, they suggest the existence of (more or less clear-cut) temporal transitions, which our findings do not support. While the original digital native conceptualization was stripped of its initial popularity due to harsh criticism, it was never fully abandoned and is still used alongside nuanced and decoupled mutations.

5.3. Societal implications

From a societal point of view, it is important to distinguish the digital native rhetoric from other techno-enthusiastic attitudes. Changes in many societies' sociotechnical environments do enable new pedagogical and technological learning designs that may turn out to be beneficial for learning if and when used in ways amenable to learning. Technology-diffused and datafied environments do require new sets of skills to be taught which may require changes in education systems. Those statements are, however, very different from the digital native assumption that learners would, by virtue of their life-long exposure to technology, have different cognitive architecture, epistemic propensities, preferences in learning, or drive for economic or societal transformation (e.g., E. Smith, 2012).

The digital native rhetoric also relates to the questions of equity, especially in terms of the support children receive from their parents and educators (Eynon, 2020). While the digital native discourse celebrates all children as innately or inherently tech-savvy (Smith, 2012), not all children are equally able to safely navigate the digital environment or safely benefit from the existing opportunities (Eynon, 2020; Livingstone, Stoilova, & Nandagiri, 2019). For example, previous research has revealed substantial differences both among children's online activities as well as in the support children receive from adults concerning their online privacy and security (Stoilova, Livingstone, & Nandagiri, 2020). This raises pressing questions of how the persistence of pro-digital native discourse fuels inequality and makes some children more vulnerable than others. Given the power of the digital native discourse, it is also important to think about who benefits from this continued promotion, as Eynon (2020) has asked. Although there may be many beneficiaries, the digital native rhetoric is also fueling discourses and imaginaries that legitimate use of technologies as well as datafication of children's lives and education. As Williamson (2021) has pointed out, various multinational technology companies are creating digital markets for their services and the realization of it necessitates the creation of visions and conditions that create gaps for particular products to fill. Therefore, it's crucial that research avoids unintentionally legitimizing catchy discourses that can influence not only public acceptance and uptake of new technologies, but also the ways that these systems are designed and regulated (Eynon, 2020).

CRediT authorship contribution statement

Pekka Mertala: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Sonsoles López-Pernas:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Henriikka Vartiainen:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Mohammed Saqr:** Conceptualization, Methodology, Formal analysis,

Writing - original draft, Writing - review & editing. **Matti Tedre:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors report no conflict of interests.

Data availability

The data consits of research articles and their metadata

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2023.108076.

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