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Using AI for developing personalized learning paths

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Abstract

This research aims to examine how artificial intelligence (AI) can be used within the educational framework for developing personalized learning paths. In order to achieve this goal, an etic approach is employed, and a qualitative-quantitative perspective is adopted. Thus, following the PRISMA guidelines, 71 articles published on Web od Science, during January 2014 – June 2024, are selected and analysed using cluster and density analysis. The results bring forward that the peak of the scientific production was reached in 2022 and that the topic is more appealing to the scholars from the information technology field than to the ones from the educational area. Furthermore, two lines of research can be identified; one that is technology-driven and another one that is learner/human-driven. Further research is required in providing a nexus between the two of them since, in the context of Industry 5.0 and Society 5.0, AI could act as a bridge. This research has several implications. On the one hand, it emphasizes the topics that captured scholars' attention and also various research gaps that should be addressed. On the other hand, it extends the research from the educational management area by highlighting how AI could facilitate the transition towards the implementation of the connectivism learning theories.

Keywords: Artificial intelligence, Personalized learning path, Industry 5.0

1. Introduction

Learning pathways are essential for lifelong learning especially in the context of Industry 5.0 when companies claim that they cannot find employees with the necessary skills to meet market's demands. This situation occurs due to the speed at which new technologies are advancing [1].

To enable workers at all levels to acquire the required competencies for ensuring company's competitiveness in the Industry 5.0 context, it is necessary to develop appropriate learning pathways. These must be adapted to companies' needs and, at the same time, they must be customized, considering employees' current competencies and learning style [2].

Artificial intelligence (AI) can greatly help define personalized learning paths since it is capable to adapt in a faster pace to users' requirements [3]. Taking these into account, the current article aims to analyse how AI can be used within the educational framework to develop personalized learning paths.

To do this, an extensive literature search has been carried out, selecting a set of articles that address this topic, analysing their content and carrying out a co-occurrence analysis

and clustering (section 2). The main findings have been developed in section 3. Finally, the article's conclusions are presented in section 4.

2. Research methodology

This research aims to examine how AI can be used within the educational framework for developing personalized learning paths. In order to achieve this goal, an etic approach is employed which encompasses an external view on meaning associations and real-world events. Unlike the emic approach, the etic perspective generates "descriptions and analyses expressed in terms of the conceptual schemes and categories regarded as meaningful and appropriate by the community of scientific observers" [4, p.130]. Hence, a documentary study is used which consists of a review of articles and studies from the educational management journals. The research adopts a qualitative-quantitative perspective and the whole multi-stage process is dominated by an inductive approach.

On a first stage, PRISMA guidelines are used for identifying the most relevant articles published on Web od Science database. Thus, the articles published during January 2014 – June 2024 which include in title, abstract or keywords the phrases "artificial intelligence", "AI", and "learning", "learning path", "personalized learning" are selected. A total of 390 articles are found; 300 are published in the international journals while 90 are included in proceedings volumes. Each article is analysed in order to determine its relevance for the research problem. As suggested by [5], those which fall out of scope are removed from the final database. As a result, 71 articles are selected since they focus exclusively on the use of AI within the educational framework and not on developing AI-based technologies. 53 of them are included in international journals while 18 in conference proceedings.

On the second stage, for the selected articles a content analysis is employed. This research method is used due to the fact that (i) it is has an analytical flexibility; (ii) it is nonintrusive; and (iii) it entails the specification of category criteria for reliability and validity tests [6]. The main categories in which the analysis focused are: (i) the type of article; (ii) the approach; and (iii) the main topic.

On the third stage, the previously selected articles become subject of co-occurrence and cluster analysis which are performed using VOSViewer 1.16.17 and the steps indicated by [7]. Thus, the similarity matrix is constructed, taking into account the co-occurrence principles, according to which:

$$s_{ij} = \frac{c_{ij}}{w_i * w_j} \quad (1)$$

where s_{ij} is the similarity between item i and j;

c_{ij} is the number of co-occurrences of item i and j;

w_i is the number of occurrences of item i;

w_j is the number of occurrences of item j.

The results of the similarity matrix are further used within the mapping technique in order to obtain a visual representation of the causal linkages established among concepts. The mapping technique is based on the following relationship:

$$V(x_1, \dots, x_n) = \sum_{i<j} s_{ij} \left\| x_i - x_j \right\|^2 \quad (2)$$

where $x_i=(x_{i1}, x_{i2})$ reflects where item i is located;

$\|\blacksquare\|$ is the Euclidean norm.

Last but not least, a cluster density analysis is performed in order to emphasize the hot topics that are drawing academics attention. This involves:

$$D_p(x) = \sum_{i=1}^{n} I_P(i) w_i K\left(\left\|x - x_i\right\| \Big/ (\bar{d}h)\right) \quad (3)$$

where $D_P(x)$ is cluster's density;

$I_P(i)$ is a function that equals 1 when the item i belongs to cluster p and 0 otherwise;

K is the Gaussian kernel function;

h is kernel width;

$\bar{d}$ is the average distance between items, and it is calculated with the help of the following equation:

$$\bar{d} = \frac{2}{n(n-1)} \sum_{i<j} \left\|x_i - x_j\right\| \quad (4)$$

Using an inductive and interdisciplinary approach, the current research provides an external view on a real-world phenomenon like the use of AI within the educational framework for providing personalized learning paths. The inductive character comes from analysing previously researched phenomenon from different perspectives while the interdisciplinary character is generated by integrating, interacting, and linking theories from the information technology management area with educational management.

3. Main findings

3.1. Descriptive statistics

From a total of 390 articles published in Web of Science during January 2014 – June 2020, only 71 focus on the educational framework and have a look on how AI could be used for developing personalized learning paths. As reflected in Figure 1, the interest in using AI within the educational framework appeared in 2015 and increased slowly by 2019. However, after the COVID period, there is a boom in the scientific production, and the number of articles increased by 77%. Nevertheless, it must be mentioned that the focus of this article is on the general approach of AI and not on specific technologies developed within this area. Different results may have been obtained if ChatCPT would have been included as component of the research context.

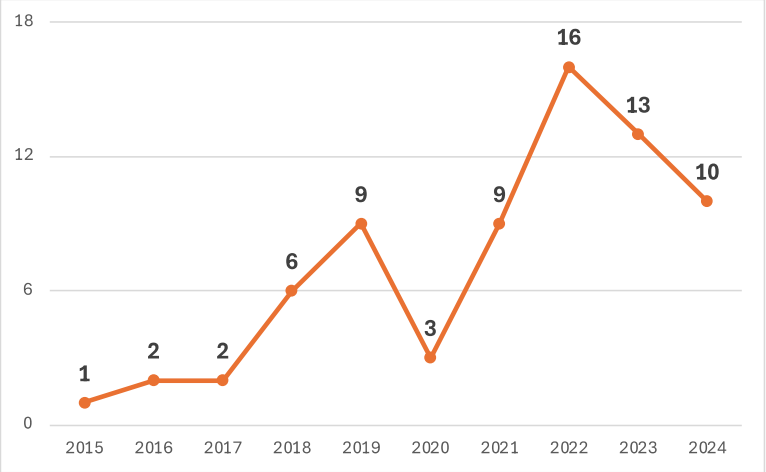

Figure 1. Literature trends: Number of papers published since 2015

Almost 41.5% of the scientific production regarding the use of AI for developing personalized learning paths is concentrated in 10 journals (Table 1). As it can be noticed, only 3 of them belong to the educational field while all the other ones come from the information technology (IT) area. Thus, it can be claimed that the topics related to using AI for developing personalized learning paths are more appealing for the IT researchers than for the educational scholars. The former adopt a wider view and highlight how AI and Internet of Everything can change the educational process and practices while the latter remain focused on the constructivism learning theories and neglect how AI could facilitate the transition towards the implementation of the connectivism learning theories.

Table 1. Articles distribution based on the journals in which they were published

Name of the journal	**Share of published articles**
Sustainability	5,66%
Education and Information Technologies	5,66%
Journal of Intelligent & Fuzzy Systems	3,77%
Soft Computing	3,77%
Scientific Programming	3,77%
International Journal of Emerging Technologies in Learning	3,77%
Artificial Intelligence in Education	3,77%
Mobile Information Systems	3,77%
IEEE Access	3,77%
Knowledge-Based Systems	3,77%

3.2. Cluster and density analysis

Analysing the studies developed so far, two lines of research can be identified (Figure 2). The first one is technology-driven and concentrates on developing a model based on artificial intelligence that can be used within the teaching process for fostering adaptive learning. The focus is on using data, in general, and big data, specifically, for addressing the challenges that come from the external environment. The second one concentrates on learners' needs and characteristics and how these could be addressed by establishing personalized learning paths. Against this backdrop, the blended learning approach is considered, and the classical resources and courses are combined with e-learning, genetic algorithms and platforms like MOOC. Furthermore, the studies included on this category are treated as experiments, using a trial and error approach for showing how AI and intelligent tutoring systems could be used for addressing students' needs and interests.

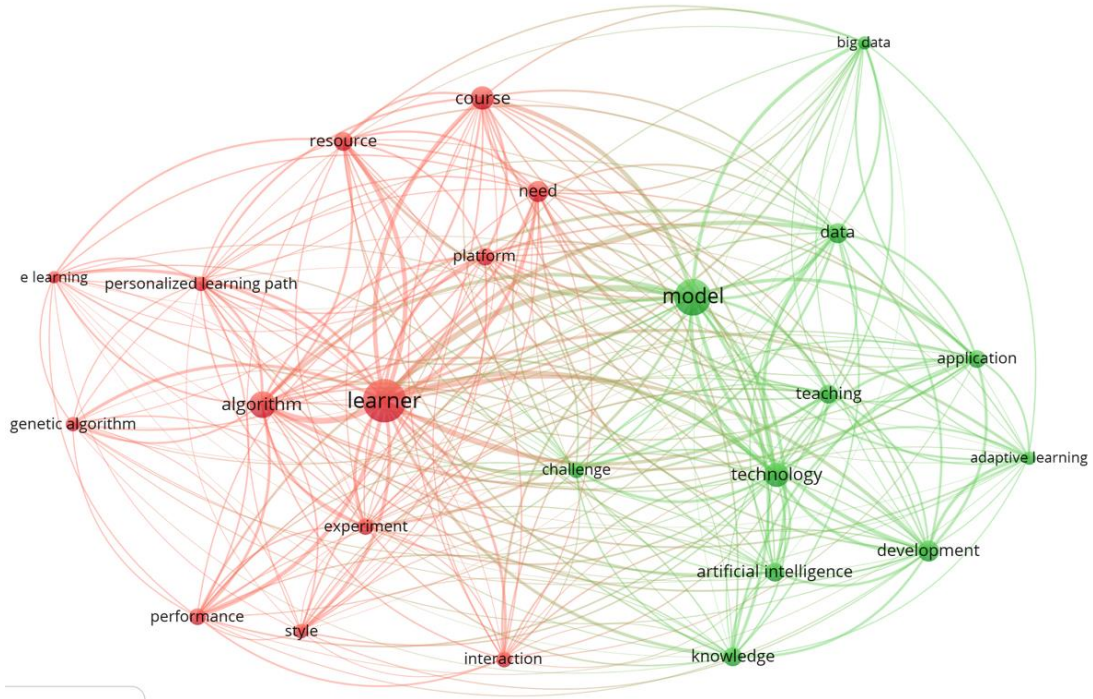

Figure 2. The clusters defining the research regarding the use of AI for developing personalized learning paths

For the cluster density analysis, a red-green-blue colour scheme is used where red highlights the topics that mainly capture academics' attention and blue emphasises the less addressed topics. As reflected in Figure 3, academics focus on addressing learners' needs by providing personalized learning paths based on e-learning and genetic algorithm. On the other hand, further research is required on developing systems-based on artificial intelligence that could support teaching, in terms of content delivery, assessment, and interaction while considering students' learning style.

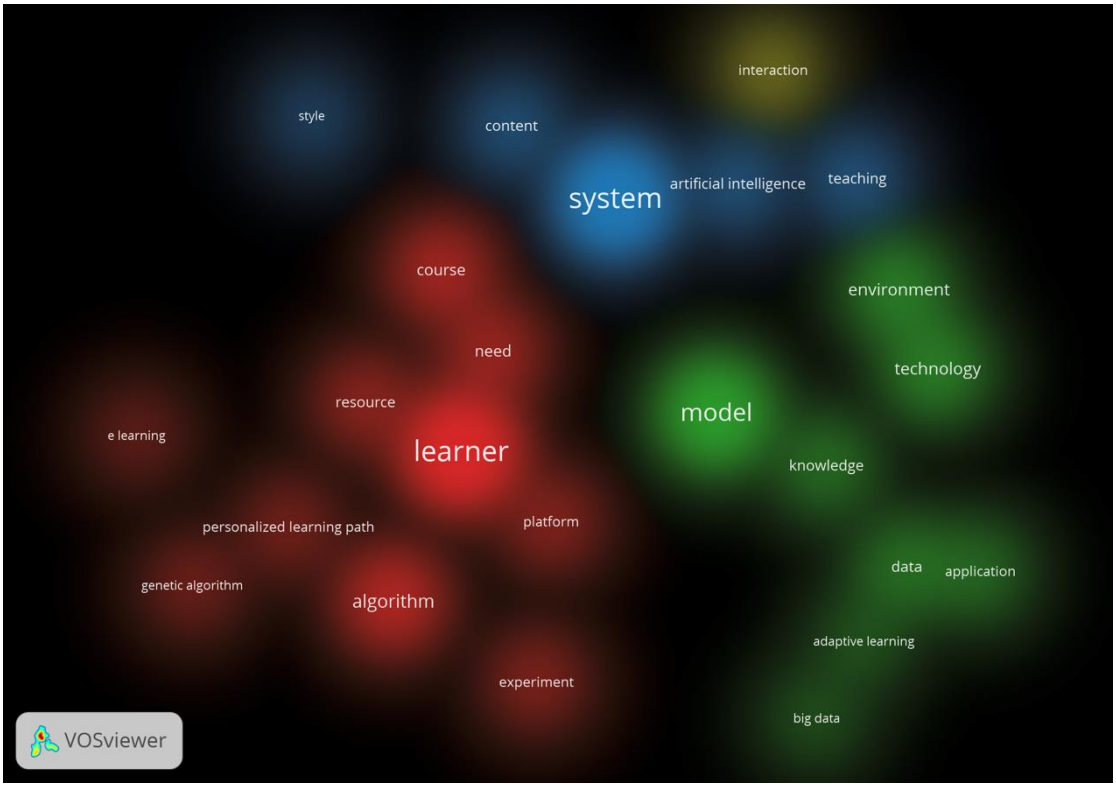

Figure 3. Results of the cluster density analysis

4. Conclusions

Using an inductive and interdisciplinary approach, the current research provides an external view on a real-world phenomenon, like using AI within the educational framework to provide personalized learning paths. Thus, 71 articles published in international journals indexed on Web of Science were selected and analysed since they focused exclusively on the use of AI within the educational framework. The results of the similarity matrix and the mapping technique brought forward a visual representation of the causal linkages established among concepts, while the cluster density analysis emphasized the hot topics that are drawing academics' attention.

One of the paper's main conclusions is that the topics related to using AI for developing personalized learning paths are more appealing to IT researchers than educational scholars. Besides, two lines of research have been identified by analysing the studies developed so far. The first one is technology-driven and concentrates on developing a model based on artificial intelligence that can be used in the teaching process to foster adaptive learning. The focus is on using data, in general, and big data, specifically, to address the challenges of the external environment. The second one concentrates on learners' needs and characteristics and how these could be addressed by establishing personalized learning paths based on e-learning and genetic algorithms.

Despite these insights, the research is limited by its structural characteristics. It adopted AI from a general approach without considering the use of specific AI tools like ChatGPT and it focused exclusively on the articles indexed on Web of Science. Different results may have been obtained if different concepts have been included in the search process and if databases like Scopus, Sage or Emerald would have been considered. Hence, further research is required to develop AI-based systems that could

support teaching in terms of content delivery, assessment, and interaction while considering students' learning styles.

Acknowledgment

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