UNIVERSITAS RIVISTA

VOL. 1 - No. 1
December 2025

Digitalization, Data, Interoperability and Digital Tools (AI included) in Higher Education

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https://doi.org/10.65158/SKBX7449

Abstract

In the face of rapid technological transformations, particularly driven by Industry 4.0, artificial intelligence (AI) and digitalization, higher education institutions should radically rethink how academic programmes are designed, updated, and aligned with labour market dynamics. This article explores how data-driven approaches, advanced analytics, and AI - both traditional and generative - can be integrated into the design and strategic evolution of academic courses. It focuses on actionable datasets, organizational constraints, and the contributions of multiple stakeholders beyond the well-discussed customers (students and families) and higher education providers such as career services, credential evaluators, alumni associations, policy makers, and companies. Our contribution ends the critical literature review with a forward-looking framework for enhancing higher education course design through intelligent data integration. The goal is to move from reactive and ideologically polarized practices toward strategic, evidence-informed, and continuously adaptive educational ecosystems.

Keywords: Higher education, Academic course design, Artificial intelligence, Data-driven decision-making, Labour market alignment

1. *The Higher Education Ecosystem*

The higher education (HE) system develops and evolves thanks to the interaction of various actors, operating within a constantly changing national and supranational framework. This framework is influenced by geopolitical developments, new technologies, regulatory aspects, as well as new environmental, ethical, and social sensitivities. At the same time, society itself is changing its customs, references, and development prospects.

Figure 1 represents the higher education (HE) system at the centre, surrounded by actors who interact directly with it. Further outward, the data generated and exchanged during these interactions are shown, while the outermost layer contains the forces that, while external to the system, influence its behaviour and guide its evolution.

Starting from the centre, the first-layer actors – capable of influencing both the content and dynamics of the system – are students and faculty, but also labour marker (companies and public organizations), policy makers, credential evaluation offices (essential for international mobility), alumni (former students who become professionals and maintain ties with their home institution), and career offices, which play a crucial role in connecting with the labour market and university programmes. On the data level, each actor produces or manages specific information sources. Faculty members manage degree programmes, individual courses, handouts, and training materials; they exchange grades (from faculty to student) and teaching evaluations (from students to faculty) with students; they interact in the classroom, in professional courses, in continuing education activities (including lifelong learning, first- and second-level master's degrees), and in the relevant professional registers.

Figure 1. The Higher Education ecosystem: driving forces, data and actors

Students, in turn, interact with career offices by answering questionnaires, submitting resumes, participating in career days and meetings with companies, and updating their employment and salary information. This relationship changes over time, with students forming alumni associations that maintain ongoing interaction with the university to strengthen their network and promote "giving back" initiatives.

Career offices also interact with companies and the labour market, seeking to facilitate the matching of supply and demand and, in the most effective cases, reporting to the degree programmes any mismatches found between the required skills and those actually provided.

International student mobility is achieved through admission procedures and the recognition of training completed abroad. This activity is made possible by credential offices, which verify the validity of certifications, arrange for their translation, and manage the processing of applications, which are then forwarded to the degree programme chairs.

Companies recruit new resources not only through career offices, but primarily through advertisements, referrals, direct contacts, and informal or non-digitalized channels. While online job offers, posted on company websites or matchmaking platforms, can be collected and monitored, tracking hires made through personal relationships or informal networks is much more difficult. This data, while valuable, largely escapes datafication processes.

Policymakers, observatories, and national and supranational institutions analyse the available data, which is often fragmented across different ministries and replicated at the national level, in the absence of a coordinating supranational body. Overlaps between offices and directorates are not uncommon. The data, managed in silos, fuels interesting reporting but is rarely integrated with other sources, thus limiting the possibility of developing more comprehensive explanations.

Based on stakeholder interests, international trends, and national or supranational contingencies, policymakers define new or updated policies, laws, and standards to guide the evolution of higher education and generate added value for businesses and society as a whole.

The current landscape reveals a growing misalignment between academic offerings and professional demands. Enterprises increasingly require adaptive, often hybrid professional profiles, but tend to avoid investing in long-term relationships with academic institutions. As a result, Career Services operate under reactive modes, focusing primarily on immediate placement tasks while lacking the analytical tools, time, and strategic mandate to inform curricular changes. The limited reuse of structured and unstructured data from these offices represents a critical missed opportunity for universities.

Credential Evaluators (e.g., those in the ENIC-NARIC[1] networks), historically tasked with recognition and comparison of qualifications, now face new challenges such as generative AI-enabled credential fraud. Although they possess large-scale knowledge on international mobility and education comparability,

[1] The ENIC (European Network of Information Centres)-NARIC (National Academic Recognition Information Centres in the European Union) Networks, is an initiative to coordinate national information centres on academic recognition of qualifications of 56 countries, operating under the principles of the Lisbon Recognition Convention (1997).

their insights are not yet systematically embedded into institutional planning and curriculum design processes. Moreover, internal fragmentation within universities – across offices, programmes, and levels – hinders interoperability and limits the potential for integrated analysis of credential data[2].

Alumni associations also represent a largely untapped resource. While they often focus on networking and identity-building, their potential to contribute longitudinal data on career development remains underexploited. If coordinated with Career Services, these data could be used to build predictive models to evaluate course efficacy over time.

Even richer data is available for individual degree programmes and courses. Indeed, interactions between instructors and students could reveal important suggestions for improving teaching. Instructors evaluate students' acquired knowledge and skills based on tests and exams, while students evaluate teaching in terms of quality and quantity. This can allow us to correlate final results with different pedagogical approaches to teaching, assuming the incoming student population does not change. This assumption is somewhat tentative, but if the population were to change, it would be possible to measure it by analysing the entrance tests required in some faculties (e.g., medicine, engineering) to assess entry skills and formalize learning gaps. If we then delve deeper into each course, the quantity and richness of data become even greater. The syllabus for each course, which often identifies the content of a single lesson, as well as lecture recordings, slides, handouts, and reference texts, are a vast treasure trove of information. The complexity of the analysis has often prevented analytical use of these data, let alone prospective use.

The authors argue that a digital and data-centric approach is essential to overcome this fragmented ecosystem. Therefore, the aim of the article is to review the various sources of data that Higher Education Institutions (HEIs) can (potentially) use to better inform curricula development, and the means available to merge and synthesize these data. It looks at both demand requirements (labour market) and supply-side ones, including the use of new types of education and training delivery (including both platforms and gamification approaches).

The integration of multiple datasets – ranging from Credential Evaluator repositories, labour market intelligence, and online job ads (Filippo Chiarello, Gualtiero Fantoni & Terence Hogarth, 2021[3]; Silvia Fareri, Nicola Melluso, Filippo Chiarello & Gualtiero Fantoni, 2020[4]) to internal data sources like course syllabi, teaching evaluations, and career outcomes – enables a more evidence-based, agile approach to curriculum development.

The article is structured as follows: it starts with the analysis of the current landscape through the driving forces that shape Higher Education, as illustrated in Fig. 1. It then investigates individual data sources, exploring their analytical and prospective uses, and various approaches for their analysis. The

[2] Debowski, S., *Shifting sands: Navigating being academic in an evolving sector*, "Higher Education Research & Development", Vol. 41, no.1, 2022, pp.7-20. Le Deist, F. D., Winterton, J., What is competence?, "Human Resource Development International", Vol. 8, no.1, 2005, pp. 27-46.
[3] Chiarello, F., Fantoni, G., Hogarth, T., et al. Towards ESCO 4.0: *Is the European classification of skills in line with Industry 4.0?*, "Technological Forecasting and Social Change", Vol. 173, no. 121177, 2021. https://doi.org/10.1016/j.techfore.2021.121177.
[4] Fareri, S., Melluso, N., Chiarello, F., Fantoni, G. *SkillNER: Mining and mapping soft skills from any text*, "Expert Systems with Applications", Vol. 184, no.115544, 2021. https://doi.org/10.1016/j.eswa.2021.115544.

article critically presents potential uses of the sources highlighting areas for interoperability. It concludes by outlining the advantages and outcomes of systematically analysing data sources. Furthermore, given the rise and widespread application of new AI technologies, including generative AI. The paper concludes with an illustrative case study where different sources and tools are used to design a novel course.

2. *The present scenario*

The digital transformation of HE is deeply influenced by multiple external forces – political, economic, social, technological, environmental, legal, and ethical. A STEEPLE analysis helps to systematically map these factors, highlighting both opportunities and risks that universities must address when redesigning courses with AI, data, and interoperable systems at the core.

Table 1 - STEEPLE Analysis

DRIVING FORCE	KEY ISSUES FOR HIGHER EDUCATION DIGITALIZATION
Political	EU and national policies on digital skills and AI adoption; funding programmes (Horizon Europe, Erasmus+); tensions in international geopolitics affecting tech dependencies (US software, Chinese/Taiwanese hardware).
Economic	Labour market mismatches and STEM skills shortage; pressure to align courses with employability; cost-saving potential of online/hybrid education; impact of edtech startups aiming to become "Netflix of education".
Social	Changing student profiles, shorter attention spans (microlearning trends); demand for motivation and guidance beyond content; alumni networks as underused resources for career tracking and feedback loops.
Technological	Machine-to-Machine and IoT; Industry 4.0; Industry 5.0; AI, Deep Learning and generative AI development; interoperability challenges across university systems; opportunities in predictive analytics (job ads, skill mining); risks of overreliance on generative AI and cognitive skill losses.
Environmental	Push for green and sustainable transitions (ESCO[5] integration of green skills); digital education can reduce commuting emissions but increases energy demand for IT infrastructure.
Legal	Credential evaluation and recognition (ENIC-NARIC, ESCO updates); risks of credential fraud with generative AI; data privacy and GDPR compliance in student monitoring and learning analytics.
Ethical	Risk of exacerbating inequalities (access to AI tools, digital divide); bias in AI-driven recommendations; role of teachers as motivational and ethical guides; need to balance gamification/addiction with genuine learning motivation.

[5] European Skills, Competences, Qualifications and Occupations.

The STEEPLE analysis shows that technological and economic drivers are currently the most pressing: universities are under pressure by the rapid evolution of technologies (IoT, blockchain; DeepLearning, etc..) and models (digital twining; Industry 4.0 and 5.0) to adopt. The availability of data increased as the complexity to homogenize, clean and correlate them, tools for data analytics are more available than those for data integration that still require IT proficiency. New competences on AI to stay aligned with labour market dynamics face both infrastructure and capability gaps not often the HEIs can assure.

The speed at which technologies and business needs evolve is significantly higher than the reactivity of universities, which are hindered not so much by willingness (though this also warrants discussion) but primarily by the technical time required to update courses and curricula. Indeed, even for a single course that undergoes substantial revision or update, the minimum time we can expect between identifying a need and launching a new course is about one year, not to mention the revision of an entire degree program, which takes at least three years. The solution adopted by many instructors is to progressively introduce new content that doesn't drastically alter the course's overall structure but provides new elements as technology improves. This is a palliative compared to the significant need for revision of many university courses that were designed when artificial intelligence and generative artificial intelligence did not exist, were not known, and were not inexpensive or free as they are today. Political and legal factors provide both constraints and opportunities, with EU policies pushing for interoperability, green/digital skills, and international recognition systems (ESCO), but also imposing compliance requirements (e.g., GDPR).

Microcredentials, recently introduced by the Commission, offer a clever solution to the rapid evolution of the market and its new demands. While microcredentials have existed in various forms within vocational training, the European Commission has recently sought to standardize them to ensure quality and portability across the EU ecosystem[6]. Although the concept is well-conceived and structured, the systematic adoption of micro-credentials varies significantly across national contexts and educational sectors. While they are increasingly common in Vocational Education and Training (VET), their integration within HEIs remains uneven – often confined to lifelong learning or executive training portfolios rather than being fully embedded into standard degree curricula. It is currently unclear whether this resistance stems from a need for further experimentation with microcredentials or from ideological biases against this new approach.

On the social side, students' evolving profiles and expectations require universities to rethink pedagogy – moving from knowledge delivery to motivation, guidance, and skills for uncertainty. The abrupt emergence of Generative Artificial Intelligence (GenAI) has necessitated a shift in perspective and a thorough re-evaluation of potential ethical challenges. Universities, it seems, were unprepared for its arrival. Without careful management, the adoption of AI risks exacerbating inequalities, encouraging dependency, and diminishing crucial cognitive abilities.

In this complex scenario, HEIs continue to find answers to questions such as: What are the most sought-after professional profiles in the market? How can we adapt our educational offerings to market needs?

[6] European Centre for the Development of Vocational Training, *Microcredentials for labour market education and training*, CEDEFOP, n.d. https://www.cedefop.europa.eu/en/projects/microcredentials-labour-market-education-and-training. [Last accessed 15 Settembre 2025].

What new skills are needed for professional growth? Are there differences in the jobs and salaries students can expect if they graduate from different universities with the same degree program?

While many of these questions were once answered through logical considerations and deductive reasoning based on limited data or by observing macroscopic trends in enrolment at individual universities or degree programmes, now, thanks to abundant and diverse data, we can answer them much more accurately and likely even predictively, ignoring events that introduce difficult-to-predict nonlinearities (COVID-19, wars, etc.).

Unfortunately, data are often hidden in siloes, heterogeneous in format, with restricted access and disconnected, although sometimes gathered within the same institution. But, although available, too often such data are not used for analysis and for redesign content courses and pedagogical approaches. The following section details the data sources and methodologies employed to analyse historical trends and forecast future outcomes.

3. *Data sources and interoperability*

This section examines data sources and their interoperability, considering the content embedded within each source and the stakeholders involved in their production, aggregation, or management.

Information regarding lectures, courses, and studies offers valuable insights into content relationships, course structuring, dependencies, interconnections, and potential redundancies. Information types range from textual data, which is impactful yet challenging to analyze, to details regarding duration, organization, keywords, and topics.

3.1 *Degrees and courses content*

Italian universities must publicly provide detailed information about their degree programmes and courses due to Ministerial Decree 270/2004 and the ANVUR's AVA[7] system. The SUA-CdS[8], an annual standardized form, is crucial for this, ensuring transparency for students, families, employers and is tied to accreditation and quality assurance.

Programme and course descriptions must include objectives, expected learning outcomes, teaching and assessment methods, credits (European Credit Transfer and Accumulation System or briefly ECTS, and responsible professors. Learning outcomes are explicitly structured according to the Dublin Descriptors (knowledge and understanding; applying knowledge; making judgements; communication skills; learning skills), in line with the Bologna Process and European standards.

[7] The ANVUR's AVA system is a comprehensive framework for assessing and accrediting higher education institutions and their programs in Italy. The accreditation is the final outcome of the AVA process, where the ANVUR decides whether the institution or program has met the established quality standards. ANVUR is the Italian National Agency for the Evaluation of the University and Research Systems.
[8] SUA-CdS stands for the Annual Study Programme Datasheet and is an official document used in Italian universities to describe a specific degree program providing information on graduate profiles, educational objectives, the course of study, learning outcomes, roles and responsibilities related to the Study Program quality assurance system.

Although there is no single central website for all course descriptions, the Ministry provides a national portal, Universitaly (www.universitaly.it), which collects information on all accredited degree programmes. For detailed course unit descriptions, each university publishes its own online course catalogue, generally following a very similar format, since the structure is dictated by the requirements of DM 270/2004, the SUA-CdS template, and the ANVUR accreditation criteria.

Since 2013, the SUA-CdS (Annual Programme Form) has been mandatory for every study programme. This form, collected and updated annually, ensures the systematic publication of standardized data. Consequently, the collected data now include extensive textual information, adhering to international standards, which details aspects such as learning objectives, goals, and assessment methods, and has a relatively long observation period.

This information is publicly available and easily accessible via the specific university website. Since it often follows a consistent template (e.g. via Universitaly), data from different courses, departments, and universities can be easily compared, allowing for the observation of their evolution over time.

Irene Spada, Simone Barandoni, Vito Giordano, Filippo Chiarello, Gualtiero Fantoni & Antonella Martini (2023)[9] analysed 54,535 learning outcomes from degree programmes across 92 Italian universities (State, Private, and Online) over 10 Academic Years (2013/2014 to 2022/2023). By using a series of natural language processing (NLP) techniques, they identified 6,062 distinct topics, with an average of 23 per program, and measured their relevance, introduction, and growth rates.

The most recently introduced and rapidly expanding topics in these programmes include: (i) the impact of technological transformation on products, services, and organizations; (ii) Artificial Intelligence; but also (iii) Sustainability, (iv) Research and development in the medical field and (v) Renewal in law.

These topics aim to equip students with the necessary skills for a rapidly changing job market. Additionally, many universities are adopting interdisciplinary approaches. This allows students to explore connections between different fields, fostering knowledge exchange and promoting vertical specialization to prepare them for fast-changing career paths. The research work not only demonstrated the possibility of analysing a huge amount of data and transforming it into valuable insights but also showed how NLP can convert textual data, often left qualitative, into quantitative insights.

3.2 *Lecture contents*

Course data is standardized. However, detailed lecture information (date, duration, teacher, title, and content description) is not uniformly tracked or publicly accessible across all universities. Typically, each lesson record includes the date, time, type, and a brief, two-line description of the topics covered.

When they are publicly available and not restricted to students belonging to the specific university or course, the data format is still different, thus requiring a long process of standardization, necessary for comparison. This lack of granular data and the different information they capture prevents a real possibility of detailed comparative analyses.

[9] Spada, I., Barandoni, S., Fantoni, G., Martini, A., et al., *What users want: A natural language processing approach to discover users' needs from online reviews*, "Proceedings of the Design Society", Vol. 3, 2023, pp. 3879-3888. https://doi.org/10.1017/pds.2023.387.

However, when available or accessible, they could complement more general analysis with insights emerging from the detailed descriptions that explain how each course is implemented in reality. Moreover, having the possibility of analysing comparatively the same course (e.g. Physics I) taught with different sequences and maybe with different results (in terms of students' proficiency) could help in improving teaching approaches.

The evolution of the course, lecture by lecture, actually provides an interesting opportunity to discover the real curriculum or even the hidden curriculum (Jane Roland Martin, 1976[10]). Diana Domenichini, Vito Giordano, Gualtiero Fantoni & Filippo Chiarello (2023)[11] developed a method using Natural Language Processing to create personalized glossaries for new teaching courses. This approach addresses the diverse backgrounds of students by focusing on their expected skills, derived from lectures attended, rather than their CVs. The knowledge and skills documented in each lesson record were cross-referenced with the handouts of the new course. The resulting personalized glossaries highlight terms and topics unfamiliar to students, providing a strong foundation for learning new material.

Given that many educators already provide slides and handouts for their courses, a subsequent enhancement would involve linking these materials directly to specific lecture content. This would also include creating explicit links to other relevant courses, outlining prerequisites, highlighting overlaps, and identifying other connections that might not be immediately apparent.

3.3 *Study materials: books, lecture transcripts, slides, and handouts*

Learning materials encompass various resources like handouts, glossaries, textbooks, articles, videos, exercises, and quizzes. While AI-driven systems have been developed to leverage this material for personalized learning path recommendations, as noted by Amir Hossein Nabizadeh, José Paulo Leal, Hamed N. Rafsanjani, Rajiv Ratn Shah (2020)[12], Felipe Leite Da Silva, Bruna Kin Slodkowski, Ketia Kellen Araujo Da Silva, and Cazella, Silvio Cesar (2023)[13] highlight significant limitations. Indeed, these systems often fail to consider all the factors influencing a student's learning process.

Due to the rapid pace of technological change, companies must continuously develop new upskilling and reskilling programmes for their workforce. These programmes are often generic, and designing specific courses can be demanding and time-consuming. To create effective and efficient learning paths, Irene Spada, Gualtiero Fantoni & Antonella Martini (2023)[14] proposed a Prerequisite Discovery approach. This method maps dependencies among skills to be acquired, while also considering field-specific requirements. The approach utilizes text mining techniques and machine learning algorithms to identify and predict prerequisite relationships. It begins by identifying and extracting skills from structured texts such as books, handouts, or course transcripts. Once extracted, each skill is linked to

[10] Martin, J. R., *What should we do with a hidden curriculum when we find one?*, "Curriculum Inquiry", Vol. 6, no. 2, 1976, pp. 135-151.
[11] Domenichini, D., Giordano, V., Fantoni, G., et al., *Towards Personalized Educational Materials: Mapping Student Knowledge Through Natural Language Processing, Joint European Conference on Machine Learning and Knowledge Discovery in Databases*, "Cham: Springer Nature Switzerland", Vol. 2134, 2023, pp. 64-79. https://doi.org/10.1007/978-3-031-74627-7_5.
[12] Nabizadeh, A.H., Leal, J.P., Rafsanjani, H.N., et al., *Learning path personalization and recommendation methods: A survey of the state-of-the-art*, "Expert Systems with Applications", Vol.159, no.113596, 2020.
[13] Da Silva, F. L., Slodkowski, B. K., Da Silva, K. K. A., et al., A *systematic literature review on educational recommender systems for teaching and learning: research trends, limitations and opportunities*, "Education and information technologies", Vol. 28, no. 3, 2023, pp. 3289-3328.
[14] Spada, I., Martini, A., Fantoni, G., *How to Discover the Prerequisites in Education and Training Courses: A Data-driven Method to Design Learning Path*, Riunione Scientifica Annuale AiIG, Palermo. 2024.

all sections where it is mentioned, but specifically attributed to the section where it is most elaborated and frequently cited. When two or more competences appear in the same section, the correlation between competences emerges and the prerequisite relationship is determined. They are linked one with the other and the prerequisite follows the logical order in which different competencies appear and are elaborated within the text.

4. *The labour market side of education*

In the past, a degree in a specific field virtually guaranteed immediate employment and a good salary. Today, however, the rapid evolution of technology and the labour market quickly render obsolete job profiles that were highly sought after less than five years ago (e.g., social media manager). Data on hiring, firing (including voluntary resignations), and vacancies, broken down by age, industry, and region could provide a real-time mapping of professional and skill-based dynamics to be analysed, understood and faced with new university or training programmes.

4.1 *Long, short and immediate impact of education*

Assessing the impact of a course or degree programme often presents challenges. While initial data exists and is collected systematically by all Italian universities, the problem arises when this information needs to be linked to students' careers after they have completed their university studies. The connection with students who have passed through a specific institution is lost or managed by different entities that often do not coordinate. There are, in fact, alumni groups organized into associations, some career services offices that systematically connect with alumni, or, to get all the data, one would have to integrate information from all the unstructured groups of connections and friendships among former students – Facebook, LinkedIn, and WhatsApp groups – but this is difficult, if not impossible, to do.

Universities with the foresight to establish an alumni office can more easily manage data and information concerning the career progression and development of their former students. This means having the ability to monitor the job profiles that their alumni go into, stratified by background, graduation score, etc., and their remuneration in the short, medium, and long term. Without this information, it's challenging to assess the return on investment and the alignment between a new student's aspirations for a university programme and their eventual job market placement. Similarly, it's difficult to gauge the discrepancy between expected salary and the effort needed to achieve it. But, while it helps the single university to compare its internal educational offerings, it does not provide any information about potential comparison and benchmark.

An interesting and quite wide source of information has been managed by AlmaLaurea since 1994. AlmaLaurea is an Italian inter-university consortium that connects universities, students, graduates, and businesses. It has since expanded with the gradual inclusion of many Italian universities. The purpose of collecting data is twofold:

- to gather and analyse statistical data regarding graduates' university careers and employment;

- to function as a "CV database", facilitating the connection between job seekers and available qualified positions.

Participating universities contribute administrative data concerning student careers. Undergraduates and graduates further enrich this database by completing questionnaires at graduation and then again after one, three, and five years[15]. These questionnaires collect personal information, details on educational experiences, and work history. Universities utilize this database for placement services, internal reporting, and monitoring the career progression of their graduates. Businesses can access CVs and post job advertisements through the platform.

What the AlmaLaurea surveys reveal: employment trends, salaries, mismatch (i.e., the gap between skills acquired at university and those actually used in the workplace), social trends. AlmaLaurea data allow the analysis of graduate employment rates, entry times, and degree-job mismatch[16]. It reports roles and average net monthly wages five years post-graduation, measuring the impact of investment. The data also covers gender differences in salaries, social dimensions, and family origin, including the social transmission of cultural capital.

4.2 *Compulsory communications*

While the correlation that could be achieved in by analysing ex post the medium and long-term impacts demonstrated to be largely true, more immediate data as those emerging from compulsory communications from employment centres could reveal fine grain behaviour, usually not observed when a wider timeframe is considered. Of course, the former e.g. those from AlmaLaurea are fundamental for promoting more difficult but higher value-added courses, but short-term or geographical impacts can be detected instantaneously by compulsory communications. Such data are even more interesting if we consider to linking the labour market results of specific cohorts or degree courses (especially Master Degrees). In this way, it is possible to have fresh data from the market, monitor what is happening in reality and not just what is declared, and understand if there are mismatches between the designed profile of the graduate and the actual demands of the job market. However, this does not mean that the expectations of stakeholders during the selection phase of a university course are the correct ones; rather, the choice is sometimes an ideological one or is linked to statistics that are no longer accurate because they are based on old data.

The creation and publication of fresh information, updated annually, could reduce the gap between the choice and the outcome after four to five years in the case of a bachelor's degree or three to four years for a master's degree. In this way, it would be possible to provide a more precise image of the real demand for and supply of educational programmes and profiles, thereby making the selection process transparent and informed. Transforming mandatory communications into an open statistical system, as proposed by Baldi, C., Giuseppe De Blasio, G., Di Bella, G., Lucarelli, A., & Rizzi, R., (2014)[17], would enable policymakers and universities to analyse publicly accessible, aggregated data (with appropriate privacy

[15] The response rate of the questionnaire is 93,3% since it is mandatory to be answered before the final defence.
[16] Caroleo, F. E., Pastore, F., *Overeducation at a glance. Determinants and wage effects of the educational mismatch based on AlmaLaurea data*, "Social Indicators Research", Vol. 137, no. 3, 2018, pp.999-1032.
[17] Baldi, C., De Blasio, G., Di Bella, et al., *Turning the compulsory communication data into a statistical system*, in Crescenzi, F., Mignani, S., (eds), *Statistical Methods and Applications from a Historical Perspective: Selected Issues*, Cham: Springer International Publishing, 2014, pp. 217-226.

and market safeguards). This would facilitate the extraction of effective and immediate insights. While mandatory communications are neither public and not easy to access, vacancies could represent a proxy of the labour market dynamics.

4.3 *Online vacancies*

Online vacancies issued by companies (especially large ones), by temporary employment agencies (i.e. Adecco Italia, Gi Group, Manpower, Randstad Italia, Umana, etc.), by matchmaking platforms (i.e. Glassdoor, Indeed, InfoJobs, LinkedIn, Monster), and by vacancy aggregators (i.e. Burninglass).

What is known, however, is that the same advertisement can be present on multiple platforms, and that the same advertisement can be repeated multiple times in the same year by the same company, either because it is searching for multiple positions or because it is not finding suitable candidates, leading in any case to an overestimation of the impact of that particular job profile being sought. On the other hand, it is also known that in some cases, the hiring of a new person occurs through the network of relationships of the company's internal staff; this is therefore not tracked through vacancies, but can be detected, for example, by changes in LinkedIn profiles, unfortunately often ex-post and only if the person has a profile on this platform or similar ones.

The Bicocca research group, Roberto Boselli, Mirko Cesarini, Stefania Marrara, Fabio Mercorio, Mario Mezzanzanica, Gabriella Pasi & Marco Viviani, (2018)[18]; Emilio Colombo, Fabio Mercorio & Mario Mezzanzanica (2019)[19]; Anna Giabelli, Lorenzo Malandri, Fabio Mercorio & Mario Mezzanzanica (2020)[20]; Anna Giabelli, Lorenzo Malandri, Fabio Mercorio & Mario Mezzanzanica (2021)[21], has extensively researched the value of web vacancies in the Italian labour market. They developed an intelligence tool that uses text mining, NLP algorithms, and machine learning to analyze job vacancies. This tool calculates measures to assess skills and job profiles, such as the skill requirements for each occupation (Colombo, et al., 2019). It has been applied to analyze skill demand and changes in job profiles affected by Industry 4.0[22] and in human resource management (HRM) to monitor evolving skill needs in job offers[23].

Nowadays, their research has been integrated in a commercial tool provided by burning glass and used by many Higher Education Institutions, thus showing how job offers captured via online vacancies can help HEIs to periodically revise their offer and to better link their courses with the labour market.

[18] Boselli, R., Cesarini, M., Marrara, et al., *WoLMIS: a labor market intelligence system for classifying web job vacancies.* "J. Intell. Inf. Syst", Vol. 51, no. 3, 2018, pp.477-502.
[19] Colombo, E., Mercorio, F., Mezzanzanica, M., *AI meets labor market: Exploring the link between automation and skills.* "Inormation Economic and Policy", Vol. 47, 2019, pp. 27-37.
[20] Giabelli, A., Malandri, L., Mercorio, F., et al., GraphLMI: *A data driven system for exploring labor market information through graph databases,* "Multimedia Tools Appl", Vol. 81, 2020, pp. 1-30. https://doi.org/10.1007/s11042-020-09115-x.
[21] Giabelli, A., Malandri, L., Mercorio, F., et al., Skills2Job: *A recommender system that encodes job offer embeddings on graph databases*, "Applied Soft Computing", Vol. 101, no.107049, 2021. https://doi.org/10.1016/j.asoc.2020.107049.
[22] Giabelli, A., Malandri, L., Mercorio, F., et al., *Skills2Job: A recommender system that encodes...* cit.
[23] Giabelli, A., Malandri, L., Mercorio, F., et al., GraphLMI: *A data driven system for exploring labor market...cit. Boselli, R., Cesarini, M., Marrara, et al., WoLMIS: a labor market intelligence...* cit.

5. *The skill side of education*

Skills are fundamental units used by various stakeholders to define prerequisites, the educational value offered to students, and the demands of the job market. To ensure mutual understanding, skills and job profiles have been standardized within extensive and interconnected ontologies. These ontologies serve multiple purposes but, mainly, enable a shared language.

5.1 *ESCO and O*NET as standardized ontologies for jobs and skills*

Detailed information regarding lectures, courses, and programmes serves as a valuable resource for individual or integrated analysis. However, a complementary approach could involve examining the market's acquisition of skills learned at university. Two primary labour market databases, O*NET in the US and ESCO in Europe, offer a broader and more stable perspective on skills for this purpose. They are also fundamental to standardizing job profile and skill descriptors, which are fully described and defined in the two databases.

These systems not only provide a standardized ontology for recruitment and contracts by mapping job profiles and associated hard and soft (transversal) skills, but provides also key information: They offer insights into the balance between hard and soft skills, the presence of managerial skills, and the portability of skills across different job profiles. Furthermore, it is particularly insightful to observe how the information within these databases changes and evolves over time. Moreover ESCO, being multilanguage, allows the comparison among different countries, different labour markets (demand) and HEI or VET offers.

While the databases of jobs, skills and competences ESCO in Europe remained unchanged for years, at a certain point, see Table 2 the maintenance converted into redefinition of profiles, addition of new skills, that now happened at least once per year.

Table 2 - The evolution of ESCO

VERSION	YEAR / DATE	MAIN FEATURES
SCO v1	July 28, 2017	First full release of ESCO (esco.ec.europa.eu)
ESCO v1.1	January 2022 (webinar on Feb 10, 2022)	Added 68 new occupations, 354 new skills, 158 new knowledge concepts; new transversal skills hierarchy; labels for green/digital/research skills (esco.ec.europa.eu)
ESCO v1.1.2	February 2024	Minor update: improved Ukrainian translation, no new conceptual content (esco.ec.europa.eu, ec.europa.eu)
ESCO v1.2	May 2024 (webinar on May 21)	Major update: 35 new occupations, 42 new skills, 196 new knowledge concepts, 677 new alternative labels, 96 hidden terms, 12,000+ updated concepts; focus on green and digital transition (esco.ec.europa.eu, ec.europa.eu, en.wikipedia.org)

Conversely, O*NET[24], the United States' occupational database, has a more structured and continuous update process since its inception. Nevertheless, there's an increasing frequency in the acceleration of changes and the number of new occupations introduced.

These two sources, despite differences in the number of occupations and skills, serve as valuable references. They can be used to standardize job profiles within companies, clearly define company needs (for accurate vacancy descriptions), and facilitate comparisons across different markets. The standardised databases are used by companies to refer to the same skills and profile in different countries but have been also used to create a common language to interpret the labour market.

The European Commission itself, through Cedefop (European Centre for the Development of Vocational Training) provides evidence, analysis, and policy support. Cedefop is an EU agency dedicated to enhancing vocational education and training (VET) across Europe. Through its work on themes such as Skills & Labour Market, Delivering VET & Qualifications, VET Knowledge Centre, and National VET Systems, Cedefop monitors changing skill needs, investigates how education and workplace shifts affect labour markets, and analyses how VET systems can respond. It supports the development of qualifications and credentials, learning outcomes, cross-border transfer of qualifications, and the validation of non-formal and informal learning.

With a rich suite of online tools and databases – including skills forecasts, apprenticeship schemes databases, and tools for evaluating key indicators on VET – Cedefop helps policy-makers, practitioners, and researchers to design and evaluate policies aimed at improving skills development, reducing skills mismatches, and enhancing lifelong learning. Cedefop offers a range of tools, datasets and databases designed to support policy-making, research and practice in vocational education and training (VET) and lifelong learning.

Among its online tools there are a series specifically designed for labour market and skills intelligence such as Skills Forecasts, Matching Skills (surveying policies anticipating future skills needs), STAS (short-term anticipation of skills trends and demand), and Skills-OVATE. Among them, it is worth citing Skills-OVATE that provides information on occupations, skills and regions based on international classification. It acts as an integration tool where occupations (ISCO-08) are classified according to sectors (NACE rev. 2) and regions (NUTS-2). Moreover, Cedefop provides two ways to display information on skills: via ESCO version 1 or O*Net, thus giving the US and European perspectives on the data.

Although the power of tools and data-driven insights (as trends) is enormous, they are not systematically used by universities to adjust or redesign their purposes.

5.2 *Skills required to manage new (and standard) technologies*

The current century presents considerably more uncertainties (VUCA[25]) than the last, making it difficult to predict stable and desirable future scenarios. Unforeseen events such as "black swans"[26], wars, and

[24] Occupational Information Network.
[25] Volatility, Uncertainty, Complexity, Ambiguity.
[26] High improbable negative events, as described in Taleb, Nassim Nicholas, 1960- author. *The Black Swan: the Impact of the Highly Improbable.* New York: Random House, 2007.

international tensions, once almost inconceivable, are now realities[27]. Furthermore, the transformation of capitalism[28] has the potential to shift global power dynamics towards nations or continents better positioned for capital growth.

Contrary to predictions by Carl Benedikt Frey & Michael A. Osborne, (2017)[29], the rapid advances in technology (Industry 4.0 and 5.0), coupled with international policies and laws, have not negatively impacted the labour market. Instead, these factors have reshaped market dynamics, leading to changes in the types of jobs and skills in demand. Evidence of this evolution in occupations, skills, and jobs can be found through the analysis of online vacancies and changes in reference occupation databases across both the USA and Europe.

While job vacancy analysis quickly reflects current labour market demands, it struggles to predict future skill needs. Chiarello, et al., (2021) demonstrated a method to identify skills emerging from new technologies or paradigms like Machine-to-Machine communication and sustainability. They collected scientific publications on a specific topic (e.g., Industry 4.0) and used Named Entity Recognition (an NLP technique) to extract relevant technologies. By measuring how well ESCO, a multilingual classification of European Skills, Competences, Qualifications and Occupations, was updated with these new technological paradigms, their analysis revealed that some technologies were well-represented, while others, despite being central to Industry 4.0 and known for years (e.g., Manufacturing Execution Systems), were entirely absent.

5.3 *From hard skills to soft skills*

Approaches like those of Giabelli, et al., (2021) and Chiarello, et al., (2021) can help in identifying required soft skills in the market or those linked to specific technologies or disciplines, Silvia Fareri, Nicola Melluso, Filippo Chiarello & Gualtiero Fantoni (2021) developed a tool specifically designed to extract soft skills from various texts. Their research introduced a named entity recognition (NER) system, trained on over 5000 scientific papers using a support vector machine (SVM). This tool not only detected soft skills but also calculated the connections between them, with potential applications for linking them to technologies, hard skills, and domains.

Fareri and colleagues also utilized this soft skill map to analyse job profiles. By examining job profiles through the lens of shared soft skills, they uncovered clusters that revealed unexpected proximities between theoretically disparate professions and occupations, suggesting that many perceived differences are not as significant as believed.

5.4 *Skills for a green and sustainable future*

The United Nations' Sustainable Development Goals have prompted a thorough re-evaluation of production, logistics, social dynamics, and education across industries, labour markets, and educational systems. Higher Education Institutions have responded by integrating new or existing content into

[27] Aresu, A., *Geopolitica dell'intelligenza artificiale*, Feltrinelli, 2024.
[28] Sabella, G., *La Grande Transizione del capitalismo*, Rubbettino, 2025.
[29] Frey, C. B., Osborne, M. A., *The future of employment: How susceptible are jobs to computerization?* "Technological Forecasting and Social Change", Vol. 114, 2017, pp. 1-72. https://doi.org/10.1016/j.techfore.2016.08.019.
[30] Fareri, S., Melluso, Fantoni, F., et al., *SkillNER: Mining and mapping soft skills from any text*, "Expert Systems with Applications", Vol. 184, no. 115544, 2021. https://doi.org/10.1016/j.eswa.2021.115544.

their curricula. However, identifying the essential skills and competencies required to update higher education offerings remains a complex challenge.

The study performed by Irene Spada, Vito Giordano, Filippo Chiarello, Marco Abate, Francesca M. Dovetto & Gualtiero Fantoni (2024)[31] showed how universities were slowly absorbing the new mandate. For making it easier and operational, Irene Spada, Vito Giordano, Filippo Chiarello, Antonella Martini & Gualtiero Fantoni (2025)[32] analysed two EU employment policies: the EU Taxonomy for Sustainable Activities (EU-TSA) and the Green Concepts within the European Classification of Skills/Competences, Qualifications and Occupations (ESCO). Their research aimed to identify the crucial skills and mindsets for sustainability that can foster new growth models. They utilized a Natural Language Processing approach to assess the alignment between these policy documents and to operationalize their content in terms of specific skills, thus making them available to policy makers and chairs of programme degrees in universities.

6. *New venues and methods for education*

While the web has existed for decades, its structured application for training and courses is a relatively recent development. The COVID-19 pandemic significantly accelerated the growth of online learning. This surge led to the proliferation of online platforms offering self-paced courses, available 24/7, covering a vast array of topics. These platforms, some with coaches and teachers and others without, also facilitated experimental approaches, including attempts to blend education with entertainment. Gamification began influencing traditional courses, with efforts to boost student motivation and engagement often serving to drive sales. Various business models emerged, ranging from those capitalizing on trending topics and large student numbers to those exploiting the “long tail” where low-cost teachers offer niche courses to smaller audiences.

6.1 *The online side of training and education*

Online learning platforms (often known as MOOC, Massive Open Online Courses) such as Coursera, edX, and Udemy provide valuable insights into current learning trends. Coursera and edX offer structured, university-led programmes and formal qualifications, with edX specializing in STEM fields. In contrast, Udemy provides a vast catalogue of affordable, self-paced courses focused on practical skills rather than academic credentials.

While detailed information (transcripts, slides, etc..) may no longer be publicly accessible, these platforms offer a wealth of metadata (e.g., course titles, participants, ratings) and data (e.g., content, reviews). This information provides a clear overview of courses and topics. Analysing the evolution of participant numbers, user evaluations (Nasa Zata Dina, Riky Tri Yunardi, Aji Akbar Firdaus & Nyoman

[31] Spada, I., Giordano, V., Fantoni, G. et al., *Tracing topic evolution in higher education: A text mining study on Italian universities*, “Studies in Higher Education”, Vol. 49. no. 11, 2024. pp.1965-1983.
[32] Spada, I., F., Martini, A., Fantoni, G. et al., Text mining on green policies for integrating sustainability in higher education, “The International Journal of Management Education”, Vol. 23, no. 2:101126, 2025. https://doi.org/10.1016/j.ijme.2024.101126.
[33] Dina, N. Z., Yunardi, R. T., Firdaus, A. A., et al., *Measuring User Satisfaction of Educational Service Applications Using Text Mining and Multicriteria Decision-Making Approach*, “International Journal of Emerging Technologies in Learning”, Vol. 16, no.17, 2021. https://doi.org/10.3991/ijet.v16i17.22939.

Juniarta, 2023)[33], and content can help determine current trainee demands. Such trends can offer interesting insights into perceived high-value skills and abilities, as well as the changing perception of formal education.

Beyond formal online training, a rich array of valuable, current, and reinterpreted content is available through less structured channels. TED Talks, TEDx, and podcasts, often well-organized by topic, offer daily updates and recontextualize information in light of recent news and geopolitical developments. TED, a global conference series, began in 2006 and covers a wide range of subjects, from business to science to entertainment. TED talks have been made available on the TED website. These informal resources provide an enjoyable way to stay updated or explore unfamiliar topics. Davide Taibi, Shailendra Chawla, Stefan Dietze, Iolanda Marenzi & Besnik Fetahu (2014)[34] created an open database with a series of metadata (Title, Speaker, description, location, etc) but also content (keywords, transcript, etc.), thus making available and searchable the entire content.

Alongside traditional academic education, other forms of learning are crucial for upskilling, reskilling, and introducing innovative content. By analysing platforms such as Massive Open Online Courses and blogs (e.g., Medium), we can gauge student and practitioner interest in emerging topics and strategically integrate these into standard learning curricula.

6.2 *Microlearning and the challenge of attention in the digital age*

Research suggests that social media addiction, characterized by a preference for short, fast content and endless scrolling, may contribute to shorter attention spans[35]. In response, a growing number of companies are promoting microlearning on social media platforms. They often present it as a solution to combat social media addiction, yet frequently replicate the very “look and scroll” mechanisms that foster dependence. This raises a crucial question: can all content be effectively transformed into microlearning? Furthermore, can microlearning provide the deeper understanding achieved through connecting concepts, building causal chains, and establishing dependencies among different and unlinked pieces of micro information?

Microlearning, while convenient for quick consumption during corporate life’s spare moments, presents challenges for structured learning. It excels in training for specific tools or operational tasks but falls short in developing critical thinking and problem-solving skills, which are fostered by the holistic approach of classic courses. The effectiveness of learning numerous small, separate notions is questionable when compared to the comprehensive understanding offered by traditional methods.

Similarly, in learning support materials, condensed study guides (like a “Bignami”) may hinder the development of learning strategy, planning, and study tactics, unlike a complete textbook. Developing educational materials with excessive simplification, necessary for information fragmentation, risks eliminating crucial connections between parts, thereby impeding deep understanding. Omitting seemingly “irrelevant” sections can compromise overall learning, as these may contain connections that become clear with maturity and subsequent readings.

[34] Taibi, D., Chawla, S., Dietze, S., et al., *Exploring TED talks as linked data for education*, “British Journal of Education Technology”, Vol, 46, 2015, pp. 1092-1096. https://doi.org/10.1111/bjet.12283.
[35] Iotti, L. *8 secondi: viaggio nell’era della distrazione*. Il Saggiatore. 2020.

Conversely, it is hypothesized that learning small notions could stimulate curiosity and motivate deeper exploration. However, it remains to be seen if this approach is sufficient for developing a complete discipline of study and structured learning. The question remains whether comprehensive information can truly be replicated within a microlearning format.

6.3 *Microcredentials*

The need of new courses to respond to market demands, the necessity of filling some skill gaps between the standard courses and the ability to proficiently deal with new technologies, pushed the European Commission to conceptualize the microcredentials.

The European Commission defines microcredentials as certifications for knowledge, skills, and competencies gained over shorter periods than traditional qualifications. These flexible, portable, and labour market-relevant credentials enable individuals to quickly update or acquire new skills, addressing the demands of digital and green transitions and supporting lifelong learning and career changes. They are often confused with or overlapped with open badges, which represent any type of learning outcome, from simple recognition of participation to more structured courses. They are extremely flexible in their application and can be issued by any organization or individual.

Microcredentials are a broader political and pedagogical concept, aiming to create a standardized European ecosystem for the certification of small-scale learning outcomes. The European Commission is working to define common standards and ensure the quality, transparency, and recognition of microcredentials across the EU. The emphasis is on their formal value and their integration into existing education and training systems, as well as their recognition in the labour market.

Evaluating the impact of microcredentials in Europe, regarding their adoption, results, and overall effect, is currently challenging. This is due to their flexible nature and the absence of a standardized reporting format in a dedicated open repository. Therefore, any such analysis would necessitate a significant investment in data collection.

6.4 *Gamification*

Before the emergence of Generative AI, the COVID-19 pandemic spurred the growth of numerous education and training startups. These companies offer a range of solutions, from profile analysis and assessment tools to online platforms that accelerate learning, applications that support studying and track progress, and apps designed to aid in planning and developing effective study methods.

Concurrently, gamification has emerged as a significant paradigm for content delivery in education[36]. Gamification refers to the use of game design elements in non-game contexts and its aim is to simplify the learning process by stimulating attention and creating mnemonic shortcuts, potentially for short-term memory. This approach has been widely applied across various subjects and content areas, making learning experiences resemble electronic games. Gamification extends beyond mere content to encompass exercises, progress tracking, and even exam preparation planning.

[36] Bassanelli, S., Vasta, N., Bucchiarone, A., et al., *Gamification for behavior change: A scientometric review*, "Acta Psychologica", Vol. 228, no. 103657, 2022. https://doi.org/10.1016/j.actpsy.2022.103657.

Many of these startups have expressed ambitions to become the "Netflix of education", highlighting a broader trend of integrating entertainment with educational content. This concept is not entirely new; the television industry, in its pursuit of niche markets, has long featured specialized channels dedicated to documentaries on almost every subject imaginable, from history and animals to cooking and gardening. This trend is also evident in websites and podcasts, demonstrating a consistent effort to blend informational content with engaging delivery.

Also, the research in education tries to develop gamified platforms to support students' learning, stimulating a sense of accomplishment, to engage them with the serious games, and sometimes also to provide a retrospective in order to consolidate what students have learnt. Different gamification techniques could be ported from digital to real classes or vice versa.

While engagement and appreciation metrics are readily available, predicting the long-term impact of this learning paradigm is challenging. Further specific and comparative studies involving large numbers of students across different educational levels are needed due to the phenomenon's nascent stage.

6.5 *Treating a class as a continuous experiment*

A robust monitoring system facilitates in-depth analysis of class learning. Regular assessments offer valuable insights into the class's comprehension, enabling instructors to tailor lectures to the students' ability to absorb information. Moreover, progressive performance data can help teachers forecast student behaviour and outcomes, providing essential direction for annual or even in-course lecture modifications.

Assessments and tests are vital, not only for tracking progress but also for fostering motivation. Motivation can stem from a desire to achieve goals, such as acquiring skills and competencies for employment, or finding a job that allows for self-expression and talent utilization. However, even in higher education, the fear of poor grades and the pressure of others' opinions and judgments can sometimes be more powerful motivators than intrinsic drive. But this is only a small part of the value tests and assessments that can be provided.

Each lesson can be treated as a laboratory experiment: There is a certain number of "guinea pigs" (students) who are subjected to a "treatment" (the lesson). Their learning can be measured through a series of continuous and well-structured tests to see how the individual has learned the lesson. However, this is not enough. In fact, as demonstrated by Diana Domenichini, Sebastian Strauß, Sebastian Gombert, Nikol Rummel, Hendrik Drachsler, Knut Neumann, Filippo Chiarello, Gualtiero Fantoni & Marcus Kubsch (2025)[37], it is possible not only to identify homogeneous subgroups of learning within the class, but also to predict, based on belonging to such subgroups, what the final outcome of the different students will be.

At this point, given the different cognitive styles, different starting points, and different learning speeds, it is possible to consider separating the class into homogeneous subgroups and planning specific

[37] Domenichini, D., Strauß, S., Gombert, et al., *Leveraging AI and network analysis to uncover learning trajectories of energy to foster knowledge-in-use in science education.* "Disciplinary and Interdisciplinary Science Education Research", Vol. 7, no.28, 2025.

learning activities for each of them, thus reducing the gap in the final evaluation and, consequently, in learning.

The combination of automatic data gathering plus AI systems (in the paper the authors presented an unsupervised clustering technique for grouping students according to their performance) could help the teacher in monitoring the class, understanding the specific need, designing and providing specific contents or exercises to improve the absorption of missed contents.

7. *AI and Generative AI: the disruption of the "old" education system?*

The 2024 Nobel Prize in Physics for AI discoveries and the rise of generative AI are profoundly transforming academia and industry. Many roles traditionally held by knowledge workers and managers, previously unaffected by technological advancements, now face potential replication by intelligent machines. This shift is fuelling anxieties, intensified by public advertisements suggesting the recruitment of AI over human employees. Simultaneously, the impressive speed at which AI solves complex problems generates considerable enthusiasm.

AI and Gen AI will impact individuals, influencing how and what they choose to learn, as well as the skills companies seek in a market where AI handles diverse tasks. Concurrently, AI can enhance traditional education, assisting teachers in improving their methods and reducing administrative burdens.

A bibliometric analysis by Kashif Ahmad, Waleed Iqbal, Ammar El-Hassan, Junaid Qadir, Driss Benhaddou, Moussa Ayyash & Ala Al-Fuqaha (2024)[38] explored AI research trends in education from 2014 to 2022. This study, conducted when Generative AI was still emerging, detailed the applications and outcomes of AI in education, highlighting both realized and unfulfilled potential.

The capabilities and limitations of AI are frequently misunderstood. While often used as a replacement for search engines or analytics, AI can produce unsatisfactory results without a defined strategy for integrating and validating data sources, proper search and selection, or appropriate analytical and statistical tools. Without adequate control, in-depth analysis, and cross-referencing, users risk being misled by "stochastic parrots" that merely reiterate mainstream information.

7.1 *Generative AI to support students*

The emergence of GenAI caught universities off guard, despite predictions by scholars and its inclusion in Gartner's analyses for a decade. When ChatGPT launched, students were early adopters, as shown by Vito Giordano, Irene Spada, Filippo Chiarello & Gualtiero Fantoni (2024)[39], who analysed approximately 4 million tweets to understand how people were using the technology. In 2022, university educators either enthusiastically integrated Generative AI into their courses or actively resisted its use within academic settings.

[38] Ahmad, K., Iqbal, W., El-Hassan, A., et al. *Data-driven artificial intelligence in education: A comprehensive review* "IEEE Transactions on Learning Technologies", Vol. 17, pp. 12-31, 2024, doi: 10.1109/TLT.2023.3314610.
[39] Giordano, V., Spada, I., Fantoni, G., et al., *The impact of ChatGPT on human skills: A quantitative study on Twitter data.* "Technological Forecasting and Social Change", Vol. 203, no. 123389, 2024. https://doi.org/10.1016/j.techfore.2024.123389.

GenAI's effectiveness is contingent on the task, purpose, topic, language, user background, and prompting style. Therefore, a comprehensive framework is needed to guide its appropriate use. This framework should first address fundamental questions (i.e. 5W2H[40]) regarding who should use it, where and when it generates the most value, and why its application is significant.

The extensive and often uncritical use of these tools can lead to a measurable decline in skills. A preliminary study of Nataliya Kosmyna, Eugene Hauptmann, Ye Tong Yuan, Jessica Situ, Xian-Hao Liao, Ashly Vivian Beresnitzky, Iris Braunstein & Pattie Maes[41], though not yet peer-reviewed, indicates that consistent reliance on AI writing assistants may diminish neural connectivity during writing tasks. This suggests a reduced cognitive engagement compared to individuals who compose without such external assistance. The observation supports the concept of "loss of skills". The study found that participants using AI showed reduced brain connectivity (in alpha and beta bands) compared to those who wrote without external aids (the "brain-only" group). This suggests that regions of the brain responsible for executive processes, attention, or memory were less active when AI was involved.

In a subsequent session, individuals who initially used AI and then switched to "brain-only" mode performed worse in recalling and citing their previous writing. This implies that relying on AI can diminish one's ability to independently work with material that has not been deeply internalized. The authors introduce the term "cognitive debt", which describes a mental debt incurred when cognitive functions are delegated externally, leading to a weakening of internal capabilities. If certain cognitive operations (such as logical structuring, argument articulation, active memory, and synthesis) are practiced less frequently, it is likely that these "skill losses" will not be isolated. Instead, they could impact higher-level skills. For example, a lack of mastery in constructing independent reasoning may hinder the development of advanced skills like critical thinking, innovation, and complex argumentation. In essence, a localized "skill loss" risks impeding the emergence of higher-level skills that depend on foundational ones.

7.2 *Generative AI to support chairs of programme degree*

Too often chairs of programme degrees are mired in bureaucracy and formalities, and there is little time left for analysis (except for mandatory analysis) and planning. Furthermore, increasingly scarce resources and the growing teaching load delivered by each teacher do not facilitate co-designing and the necessary evolution of content (given new knowledge and technologies) and teaching methods (given the changing incoming population and new pedagogical practices).

AI-powered office automation can significantly reduce bureaucratic burdens and free up time by handling low-value tasks. Beyond this, it can also facilitate the redesign and upgrade of courses. Generative AI, utilizing internal or online data, can prepare analyses, compare courses domestically and internationally, and evaluate the social and economic impact of teaching and learning activities, both overall and on a per-course basis.

[40] 5W2H is the acronym of a well-known management tool used around the world and consists of responding to 7 simple questions defining What action must be completed, How, When, Why, by Whom, Where, and How much it costs.
[41] Kosmyna, N., Hauptmann, E., Yuan, Y. T., et al., *Your brain on ChatGPT: Accumulation of cognitive debt when using an AI assistant for essay writing task*, Cornell University, 2025. https://doi.org/10.48550/arXiv.2506.08872.

7.3 *Generative AI to support teachers*

Tools are neutral, therefore also for teachers GenAI can be a powerful aid or a false friend. Speeding up the process of slide creation or handouts frees up useful time for rethinking the course from both the content and pedagogical perspectives. The role of the teacher becomes more and more a coach, a supervisor, or a challenger.

Teachers can survey topics comprehensively, identify gaps, and suggest removals. They can also focus on creating connections and enhancing elements to capture students' attention and interest. Integrating videos, blogs, and other diverse sources can supplement traditional books, offering a rich mix of stimuli. The teacher's role is to craft an effective learning experience that not only facilitates knowledge acquisition but also addresses misconceptions, biases, and detrimental behaviours. This approach transforms class time into an opportunity to improve attention spans, dedicate more time to understanding concepts, and explore topics in greater depth.

OpenAI has capitalized on students' widespread use of ChatGPT by developing and marketing specialized tools, such as ChatGPT study mode, directly to them. OpenAI marketing claimed it as «a feature that enables ChatGPT to act like a tutor, which encourages learning and critical thinking instead of immediately generating answers like regular AI chats». This approach aims to move beyond simple requests for answers or essays, where Generative AI excels, by integrating questions and connections derived from analysing past interactions.

While Artificial Intelligence, particularly Gen AI, offers powerful tools and resources, it fundamentally lacks the capacity to ignite or cultivate intrinsic human motivation. Furthermore, it cannot bridge the gap between initial motivation and sustained discipline. A critical concern with Gen AI is its potential to foster addiction, drawing individuals away from genuine engagement and critical thinking.

Teachers' roles are evolving towards maieutic, a Socratic method of drawing out understanding. This explanation leads to more potent learning than simple information transfer. To leverage this, traditional approaches can be reversed: microlearning activities could be done at home, allowing students to learn foundational concepts at their own pace. Classroom time would then shift to interactive, project-based, and problem-based workshops. This fosters deeper understanding and critical thinking through active knowledge construction and hands-on engagement.

Educational settings require a fundamental shift. Traditional student-teacher and student-student interactions should change to integrate technology, forming a three-way dynamic. This integration necessitates understanding human limitations with technology, while recognizing its benefits when applied thoughtfully. The goal is to enhance, not replace, human capabilities and interactions, leading to a more profound learning experience.

8. *An actionable roadmap*

In this article, it has been argued that higher education can no longer treat course and curriculum design as a periodic compliance exercise, but rather programmes should be often revised to reflect changes in the discipline and in labour market needs.

It must become an evidence-led, dynamic capability that blends interoperable data, task-appropriate AI, and multi-stakeholder governance. The argument rests on five pillars: (a) From data silos to decision engines, about the strategic use – and re-use – of heterogeneous data; (b) Designing for time on the temporal mismatch and the need to build for uncertainty; (c) Technology, geopolitics, and cultural dependence on events and factors that shape what and how we teach; (d) Learning where the brain works best about cognitive, social, and motivational dynamics that determine whether learning "sticks"; and (e) Students, incentives, and the hidden curriculum of institutions where we discuss institutional operating models and incentives that either unlock or prevent change. The last argument rests on a transversal pillar (f) AI: powerful means, bounded mandate.

Below we synthesize implications and propose an actionable end-state.

8.1 *The pillars*

(a) From data silos to decision engines

Universities sit on vast – yet underexploited – stores of structured and unstructured data: programme forms (e.g., learning outcomes, assessment methods), lecture artefacts (slides, handouts, schedules), teaching evaluations, alumni trajectories, graduate surveys, job vacancies, credential-evaluation repositories, and external labour-market intelligence (e.g. ESCO/O*NET, CEDEFOP tools). Today, these assets are fragmented across offices, formats, and governance regimes; the hidden value lies precisely in cross-analysis. Interoperable schemas, common vocabularies (e.g., ESCO), and metadata standards are not bureaucratic niceties but the precondition for: (i) longitudinal monitoring of curricula; (ii) market-skills mapping at varying time horizons; (iii) continuous programme benchmarking across departments and institutions; and (iv) automated but auditable analytics pipelines to inform revisions. A standing "data & curriculum" function – lightweight but empowered – should steward integrations, quality, and analytical reuse.

(b) Designing for time: closing the 3–5-year gap

The interval between programme choice and labour-market entry (roughly 3–5 years) now spans a regime in which job families can morph, vanish, or be automated. In such conditions, "coverage of content" cannot be the primary risk hedge. Alongside readily accessible knowledge (via search and LLMs), universities must deliberately cultivate behavioural and cognitive capacities: problem-solving under uncertainty, scenario thinking, and metacognitive regulation. Microcredentials are a sensible, modular response – but their impact depends on integration into degree pathways, robust recognition, and transparent reporting, rather than their relegation to peripheral lifelong-learning units. Degree programmes should specify an explicit temporal portfolio: durable foundations, medium-term refresh modules, and fast-cycle micro-updates tied to market signals.

(c) Technology, geopolitics, and cultural dependence

Education does not unfold in a vacuum. Software stacks, hardware supply chains, and platformised learning ecosystems increasingly originate outside Europe. Alongside technological dependence lies cultural dependence: dominant training platforms tend to privilege narrowly operational upskilling. Without counterweights, curricula risk converging on "what the tools make easy", shrinking intellectual breadth and civic aims. A policy-level recalibration is therefore required: align industrial, education, and research agendas; invest in European data/AI infrastructure for education; and articulate a vision of higher education that pairs employability with critical reasoning, ethical judgement, and democratic competencies. Universities should treat vendor content as inputs – not blueprints.

(d) Learning where the brain works best

Evidence from cognitive science suggests that human performance peaks near the "edge of chaos"[42], a dynamic balance between order and variability that supports flexible reasoning, transfer, and creativity. Educational practices can scaffold this state: progressively complex tasks, problem- and project-based learning, reflective enquiry, and (for some learners) contemplative practices that modulate attention and executive control. Conversely, over-scaffolded microlearning, while useful for tool onboarding, risks fragmenting knowledge and eroding deep comprehension if it becomes the default. Gamification can motivate, but if reward schedules replace meaning, it fosters dependency rather than mastery. Institutions should rebalance towards *deliberate difficulty*, interleaving, and spaced retrieval – backed by regular, low-stakes assessments that turn each class into a monitored experiment rather than a one-way transmission.

(e) Students, incentives, and the hidden curriculum of institutions

Student cohorts are changing – prior knowledge, attention habits, expectations, and mobility patterns differ markedly from a decade ago. Employers, meanwhile, increasingly expect "job-ready" graduates and are less willing to fund onboarding. Within universities, incentive structures often privilege research outputs over teaching innovation (especially acute where career paths for researchers and teachers are undifferentiated), while student-satisfaction surveys may inadvertently penalize rigor. If we want better educational outcomes, we must realign incentives: reward high-quality teaching, curriculum leadership, and demonstrable learning gains; protect space for instructors to iterate; and couple student voices with multiple evidence streams (learning analytics, longitudinal outcomes, external peer review).

(f) AI: powerful means, bounded mandate

Generative AI has been adopted unevenly, sometimes with uncritical enthusiasm and sometimes with blanket bans. The right stance is neither. Relying solely on AI or GenAI for tasks traditionally handled by data analysis, statistical methods, and algorithms risks prioritizing efficiency over effectiveness. These tools demand careful attention and a clear purpose. Directly seeking immediate insights from data, rather than elaborating information and translating it into a reasoned interpretation, often sacrifices depth for speed. While Large Language Models (LLMs) can be useful for ontology alignment in skills mapping for a limited number of documents, they prove insufficient when policymakers need to analyze vast quantities of heterogeneous documents, such as patents, papers, and job vacancies. Furthermore, utilizing LLMs for the initial drafting of syllabi can stifle creativity and promote homogenization. Their

[42] Robson, D., *Between order and chaos*, "New Scientist", Vol. 267, no.3559, 2025, pp. 30-34.

more effective application lies in refining or correcting syllabi after they have been elaborated by humans.

Alternatively, more deterministic approaches as BERT[43] by Jacob Devlin, Ming-Wei Chang, Kenton Lee & Kristina Toutanova (2028)[44] could be effectively used to perform tasks such as skill extraction, content extraction, similarity analysis, clustering etc, and obtain more stable and reliable results. At the same time, institutions should guard against cognitive debt: if LLMs routinely do the framing, synthesis, and argumentation, students practice those skills less. A simple operating rule helps: «*AI accelerates production; humans own direction and judgement*». For teachers and chairs of programme degrees, AI can offload bureaucracy, surface comparisons, and simulate options – but final curricular decisions remain human, contextual, and accountable.

8.2 *A forward-looking framework (with an example)*

Vacancy analytics, alumni data, and compulsory employment communications (where accessible) each offer signal – and bias. Duplicates, re-posts, and informal hiring channels distort counts; alumni data are uneven across institutions; compulsory notifications are difficult to access and standardize. The remedy is triangulation: combine near-real-time vacancy trends, medium-term alumni outcomes (e.g., AlmaLaurea-like surveys), and structured occupational taxonomies (ESCO/O*NET) to anchor noisy signals. CEDEFOP's tools can serve as integrators across regions and sectors. Methodological transparency – documenting sources, caveats, and confidence – must be part of every curriculum decision.

To transform principles into actionable strategies, we propose a streamlined and scalable operating framework. This framework begins with establishing robust governance & roles, notably a cross-functional Curriculum Intelligence Hub comprising Career Services, Alumni, Programme Chairs, QA, IT, Legal/GDPR, Industry Liaisons, and Credential Evaluators. This hub would be chartered with maintaining taxonomies, conducting analytics, proposing updates, evaluating impact, and publishing an annual "Curriculum & Skills Observatory" report.

Crucially, interoperability and data architecture are foundational. This involves implementing a skills/learning-outcome ontology layer that is ESCO-aligned with institution-specific extensions. The creation of standard data products – such as program/LO tables, assessment schemas, lecture artefact registries, vacancy snapshots, and alumni outcome panels – is essential. These should be built using reproducible pipelines with versioned code and data lineage, all governed by GDPR-compliant practices.

For continuous improvement, evidence-based curriculum cycles are key. The cadence of the review could be around 12-18 months for each program, following a cycle of market scan, gap analysis, proposals (major/minor), piloting, evaluation, and finally, scaling or rolling back. To facilitate agile updates, microcredential "slots" should be embedded within degrees, with clear recognition and stackability.

[43] Bidirectional Encoder Representations from Transformers (BERT) is a language model introduced in 2018 by Google researchers and was the accelerators for the new generation of Large Language Models.
[44] Devlin, J., Chang, M. W., Lee, K., et al., *BERT: Pre-training of deep bidirectional transformers for language understanding, 2018*. https://doi.org/10.48550/arXiv.1810.04805.

Assessment for learning is paramount, treating each course as a continuous experiment. This entails frequent formative assessments, cohort clustering to identify learning subgroups, targeted interventions, and post-hoc evaluation of design changes. The aim is to balance student satisfaction with objective indicators of deep learning and transfer.

Regarding human development and pedagogy, the design should embrace the edge-of-chaos, incorporating progressively complex, collaborative, and authentic tasks. Explicit training in metacognition and optional contemplative practices for attention and self-regulation are encouraged. It's important to use microlearning and gamification sparingly and purposefully, rather than as default curricular approaches.

Clear AI usage rules are indispensable. This includes publishing a task-to-tool matrix that outlines appropriate AI applications, what remains human, and required documentation and citation. For AI-assisted student work, process artefacts such as prompts, drafts, and rationales should be required, while forbidding AI in specified formative contexts to safeguard practice opportunities. For staff, AI should prioritize analysis preparation and comparative review, not final judgments.

Partnerships and external alignment are vital. This involves formalizing two-way data sharing with industry partners (skills frameworks, placement outcomes) and credential evaluators (fraud signals, recognition insights). Engagement with policy actors is also crucial to co-develop open, anonymized statistical products from compulsory employment communications where feasible.

Finally, incentives and capacity building will drive adoption. This means recognizing curriculum leadership and measurable learning gains in promotion criteria. Furthermore, faculty development should focus on data literacy, learning science, and AI-supported design, while administrative load is reduced through targeted automation.

To illustrate the proposed framework in action, we present a use case example: the revision of a MSc degree in Mechanical Engineering to address the "Green Transition". The case involves the triangulation of data sources described in § 4 and the operational role of the Curriculum Intelligence Hub.

Phase 1: Signal detection and triangulation
The revision cycle is driven not only by intuition but also by data integration. This process draws on three sides:

- Labour Market Signals (Demand side): The Hub aggregates data from online vacancies and identifies a spike in demand for Sustainable Manufacturing and Life Cycle Assessment skills. Concurrently, an analysis of the ESCO v1.2 update reveals new standardized "green skills" and knowledge concepts that were previously absent.

- Alumni Feedback (Outcome): Data from the AlmaLaurea repository (or other sources with similar data) is analyzed, specifically focusing on the "mismatch" indicator. The analysis reveals that recent graduates working in the energy and automotive sectors report a gap between the technical skills acquired and the environmental compliance competencies required by their employers.

- Internal Audit (Supply side): Using Natural Language Processing (NLP) techniques similar to those applied by Spada et al. (2023), the Hub scans the current SUA-CdS (programme description forms) and course syllabi. The audit detects that while "efficiency" is a frequent keyword, specific terms related to "circular economy" and "sustainability reporting" are missing from the declared learning outcomes.

Phase 2: Gap analysis and AI-supported design

The Curriculum Intelligence Hub produces a gap analysis report for the Program Chair. Based on the report evidence the following four tasks are performed:

- Strategic Decision: Rather than waiting three years for a full program overhaul, the Chair decides to implement a fast-cycle micro-update working on the introduction of green skills on single subjects in collaboration with the teachers.

- AI-Assisted Drafting: The Chair employs a Generative AI tool, fed with the specific missing ESCO skill definitions and the current course syllabus. The AI is tasked with suggesting a new module structure that integrates these skills without altering the core engineering foundational constraints. Such proposals are discussed with the faculty and integrated in the more suitable subjects.

- Human Refinement: The faculty reviews the AI-generated syllabus to ensure pedagogical rigor, applying the human-in-the-loop principle where AI accelerates production but humans own the judgment.

- New knowledge and skills: Sustainability is broader than just environmental issues, therefore the faculty, under the emergence of new literature on alternative approaches to the dominating capitalistic paradigm, can decide to provide students with information on civil economy, an economic approach that integrates ethics, politics, and solidarity into the market, proposing an alternative model based not only on profit, but on the common good. Such a choice introduces new elements to develop students' critical thinking.

Phase 3: Implementation via Microcredentials

Let's imagine that the faculty and the Chair decide to launch a 3-ECTS internal microcredential to address the immediate temporal mismatch.

- Format: This modular course is immediately available to current students and offered as a lifelong learning update for alumni.

- Interoperability: The microcredential is tagged with the relevant ESCO metadata, ensuring that the skills acquired are recognizable by the labour market and machine-readable by recruitment algorithms.

Phase 4: Continuous monitoring

The course is treated as a "continuous experiment". Continuous assessment data identifies learning

subgroups, allowing the faculty to adjust teaching methods in real-time if students struggle with the interdisciplinary nature of the new legal-technical content. The impact of the course is analyzed by observing the career evolution of alumni first and of students later. The profiles of participants (alumni) is monitored in order to refine the program also in terms of labour market needs.

9. *Conclusions*

The digital transformation of higher education is not merely a technical challenge of digitizing content, but a structural imperative to realign the ecosystem's core dynamics. Throughout this article, we have argued that the traditional disconnect between Supply (faculty and students) and Demand (the labour market and firms) can no longer be sustained in an era of rapid technological flux. Bridging this gap requires moving beyond anecdotal evidence to a systematic integration of data that respects the complexity of both educational and professional landscapes.

The above alignment depends heavily on the quality and interoperability of the intelligence we gather. As explored in our analysis, this requires a dual approach to data sources. On one hand, institutions must leverage proxies such as online vacancies; while these offer immediate, granular insights into emerging skills, they remain imperfect descriptors of the total labour market, often over-representing digital roles while missing informal hiring channels. On the other hand, we must strive to unlock real data, such as compulsory employment communications and longitudinal alumni tracking. Although these sources are historically difficult to access and standardize, they provide the ground truth necessary to validate trends and correct the biases inherent in digital proxies. The "Curriculum Intelligence Hub" proposed in this work serves precisely this function: to triangulate these diverse signals into actionable insights for programme design.

However, data-driven alignment should not be mistaken for market subservience. While the immediate goal is to reduce skills mismatches, the ultimate mandate of the university remains its civil purpose. A higher education system that looks only to the immediate needs of industry risks preparing students for a world that will have vanished by the time they graduate. True alignment means preparing learners for a future we cannot yet fully predict.

An adaptive university does not chase every technological wave; it learns which waves matter, when, and for whom. Programmes become portfolios with explicit time horizons and specific users (not customers); microcredentials complement – not cannibalize – degrees; student evaluations inform but do not dictate rigor; AI accelerates work without hollowing out cognition; data products flow across previously isolated units; and governance makes trade-offs explicit. Most importantly, graduates leave not only with skills that map to today's vacancies, but with the habits of mind – curiosity, disciplined imagination, ethical reasoning, collaborative problem-solving – that let them thrive when today's vacancies no longer exist.

Education is a societal infrastructure. Cohesive, deliverable visions of the future can mobilize both institutions and learners, but visions must be matched with interoperable data, fit-for-purpose AI, and recognitions that reward what we claim to value (not just incentives). The task before higher education is therefore not to defend yesterday's forms, nor to outsource tomorrow's aims to platforms, but to build a resilient ecology of learning capable of moving at the speed of change without sacrificing depth and judgment, but fostering human flourishing.

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