

UNIVERSAL DESIGN FOR LEARNING, ACCESSIBLE LEARNING DESIGN AND ARTIFICIAL INTELLIGENCE: AN EXPLORATORY STUDY ON PRE-SERVICE TEACHERS

PROGETTAZIONE UNIVERSALE PER L'APPRENDIMENTO, *LEARNING DESIGN* ACCESSIBILE E INTELLIGENZA ARTIFICIALE: UN'INDAGINE ESPLORATIVA CON I FUTURI DOCENTI



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Lia Daniela Sasanelli

Università Telematica Pegaso
liadaniela.sasanelli@unipegaso.it



Umberto Barbieri

Università Telematica Pegaso
umberto.barbieri@unipegaso.it



Di Fuccio Raffaele

Università Telematica Pegaso
raffaele.difuccio@unipegaso.it



ABSTRACT

This study investigates the effectiveness of integrating a chatbot based on the UDL 3.0 guidelines as a tool to support the design of inclusive lessons for pre-service teachers. A quasi-experimental pre- and post-test design was used to assess the effectiveness of the intervention, measuring familiarity with the chatbot, understanding and application of the UDL 3.0 guidelines, the most optimised areas of lesson design, the aspects of the chatbot most valued, and the challenges faced by participants. Preliminary results suggest that the chatbot's ability to provide immediate feedback, practical suggestions, and tailored teaching solutions helped to accelerate the planning process, improve content accessibility, and differentiate teaching strategies.

Questo studio analizza l'efficacia d'uso di un chatbot costruito sulle Linee guida UDL 3.0 come strumento di supporto alla progettazione di lezioni inclusive per futuri docenti. Per valutare l'efficacia dell'intervento è stato utilizzato un disegno quasi sperimentale pre e post-test, misurando la familiarità con il chatbot, la comprensione e l'applicazione delle Linee guida UDL 3.0, le aree di progettazione più ottimizzate, gli aspetti del chatbot più apprezzati e le sfide affrontate dai partecipanti. I risultati preliminari suggeriscono che la capacità del chatbot di fornire feedback immediati, suggerimenti pratici e soluzioni didattiche personalizzate ha contribuito ad accelerare il processo di pianificazione, migliorando l'accessibilità dei contenuti e implementando la differenziazione delle strategie didattiche.

KEYWORDS

UDL, Learning Design, Artificial Intelligence, Exploratory Research. Progettazione Universale per l'Apprendimento, Learning Design, Intelligenza Artificiale, Ricerca esplorativa

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Introduction

The beginning of the 21st century has been a period of profound renewal for education, accompanied by a shift in theoretical frameworks. Contrary to previous approaches, which conceived the relationship between teaching and learning in linear terms, the complex and non-linear nature of knowledge acquisition processes is now recognised (Calvani, 2000). Didactics is thus redefined as a dynamic process, centred on a recursive dialogue between teacher, student and class group, which implies an activity of "care and support [...] aimed at the concrete identification of modest supports capable of favouring flexible and multidimensional learning pathos" (Calvani, 2000, p. 11). Among the new educational paradigms, that of teaching as a design science, developed since the 1990s in the field of information sciences, has proved particularly fruitful and significant. This paradigm becomes even more relevant in the current context, where teachers are required to rapidly develop new teaching practices and, in parallel, to enhance their digital skills. As Laurillard states, "Ideally, teachers should be able to implement design science as part of their normal professional practice and have the means to act as design researchers themselves, documenting and sharing their designs. Conversely, instead of leading to new knowledge about teaching and learning, they remain the recipients of research and are unable to critique and challenge the technology that is transforming their profession (2014, pp 22-23). Numerous studies have examined the ways in which educational professionals design and act in different contexts (Schön, 1993), with a central role for design research (Gero, 1990; Gero & Kannengiesser, 2002). These reflections led to the development of *Learning Design* (LD), understood as the intentional design of experiences that can respond to the challenges of knowledge (Laurillard, 2014). Teaching is therefore configured as a "discipline similar to the sciences of design" (Hevner, 2007), with teachers taking on the role of "design researchers who document and share their projects" (Laurillard, 2014, p. 22). In the last decade, didactic planning has been further articulated thanks to the exponential growth of educational technologies, inserted in the logic of socio-constructivism and active learning, which change the 'what' and 'how' students learn. Technologies have expanded and transformed the teaching and learning possibilities offered to teachers (Laurillard, 2014, p. 115), who must learn to control their use more effectively. Indeed, to fully exploit the potential of technologies, it is essential to

know how to select and evaluate them carefully, critically integrating them with already established traditional methods.

1. Theoretical framework of the research

In this context, *Universal Design for Learning* (UDL- Meyer - D.H. Rose- D. Gordon, 2014; 2024; Novak, 2022) emerges as a reference framework to ensure inclusivity and accessibility, recognising the individual variability of students as an intrinsic and essential element of human. UDL framework, based on the principles of Design for All and Universal Design, promotes the construction of universal curricula that are flexible and adaptable to ensure equal opportunities for access and participation in educational experiences (Salamanca Declaration). It is based on three fundamental principles: engagement (encouraging active participation by explaining the 'why' of learning), representation (presenting content in a variety of ways; this is the 'what' of learning) and action and expression (providing students with different ways of expressing what they have learned; this is the 'how' of learning). The implementation of these three principles uses a dynamic tool that supports the creation of learning environments without barriers and that valorise the differences inherent in students: the UDL Guidelines (CAST, 2024). First developed in 2008 by the *Centre for Applied Special Technology* (CAST), they are a dynamic and flexible tool that is constantly evolving to reflect advances in learning research and best practice in inclusive education, with the aim of designing learning environments that significantly reduce barriers and valorise all the differences inherent in students (Hitchcock et. al., 2002).

1.1 Learning Design, UDL and Artificial Intelligence

The synergy between Learning Design and UDL is manifested in the design of experiences that take into account the diverse needs and preferences of students from the outset, overcoming the 'one size fits all' approach. However, the complexity inherent in the design of personalised and inclusive learning environments, especially given the increasing range of technologies that can be used (Laurillard, 2014, p. 115), requires ever greater support for teachers. In this context, Artificial Intelligence (AI) is proving to be a powerful ally, offering new perspectives and tools to support and enhance the instructional design process. Indeed, AI can make a significant contribution in several areas, including the analysis of learning

data to identify student patterns and difficulties (Baker, 2016), the personalisation of content and learning paths (Hwang et al., 2020), and the provision of automated feedback and individualised support (Holmes et al., 2019; Hyatt & Owenz, 2024). In particular, new AI-based tools, such as educational chatbots, offer new opportunities to support the learning design process and the implementation of UDL principles. Chatbots are defined as computer programs that reproduce human-like conversations using natural language structures (Garcia Brustenga et al., 2018; Pham et al., 2018). They can take the form of text messages (websites or mobile applications), voice-based (Alexa or Siri), or a combination of both (Pereira et al., 2019; Sandoval, 2018). The use of chatbots has become widespread due to their accessibility, low cost (Chocarro et al., 2021), development options (Sreelakshmi et al., 2019; Wang et al., 2021) and easy adaptation to social networks and mobile instant messaging applications (apps) such as WhatsApp, Line, Facebook and Telegram (Cunningham-Nelson et al., 2019). There are many scientific studies that confirm how these bots facilitate collaborative learning (Schmulian & Coetzee, 2019), multimodal communication (Haristiani et al., 2019), scaffolding, real-time feedback (Gonda et al., 2019), encouraging learning and interaction (Schmulian & Coetzee, 2019) and the creation of new knowledge (Verleger & Pembridge, 2019) even for a large number of students. Recent research highlights how chatbots can automate repetitive tasks, such as answering frequently asked questions or correcting routine exercises, easing teachers' time and workload (Fryer et al., 2019). Furthermore, they can provide personalized feedback to students in real time, supporting the principle of engagement and *action and expression* (Hwang et al., 2020). Other studies focus on using chatbots to generate adaptable learning content, which can be customized to individual students' needs (Song et al. 2024), helping to support the principle of *representation* (Hussein et al., 2019).

2. Methodology

This investigation examined the effectiveness of an AI-mediated co-design platform, operationalized through conversational interface modes, specifically engineered to incorporate UDL3.0 Guidelines and facilitate multimodal transposition of instructional materials. The research protocol assessed three distinct outcome variables: (a) changes in teachers' epistemological frameworks regarding the inclusive affordances of AI, (b) qualitative transformations in UDL-

aligned instructional design schemes, and (c) perceived technological fit parameters.

2.1 Mixture of Agents Architecture

The core of the platform is the Mixture of Agents (MoA) infrastructure (Wang et al., 2024) consisting of four small language models - Mistral-NEMO, Llama 3.2-vision-11B, Llama 3.2-3B and GPT-4o-mini - trained on the same UDL 3.0 principles. We do not assign each model a rigid task; instead, each teacher input is analysed by all agents in parallel and each agent produces a proposed response with estimated confidence (Hiranandani et al., 2025). A modulator calculates a combination weight:

$$\alpha_i = \text{softmax}(c_i), \quad i = 1, \dots, 4,$$

Where c_i is the confidence logit returned by the agent i . The final answer is the weighted average:

$$y = \frac{\sum_i \alpha_i y_i}{\sum_i \alpha_i}$$

The largest model, GPT-4o, acts as an orchestrator: it supervises the merging, maintains the coherence of the conversation and decides whether to ask the teacher for clarification or to invoke external functions (e.g. to adapt a PDF or generate a glossary).

2.2 Shared memory system

In order to personalise proposals, the platform stores two types of memory: the episodic memory records the last chat rounds, so the assistant maintains coherence in the interaction without having to re-read the entire dialogue; the semantic memory is a vector archive that indexes lesson plans, multimodal materials and the teacher's profile (Barbieri et al., 2024; Xu et al., 2025). When the teacher mentions, for example, "concept maps on UDL guidelines", the system retrieves similar chunks already refined in the past and offers them as a starting point.

Both memories are updated in real time; redundant chunks are discarded in order not to overload the context.

2.3 Calling external functions

The platform exposes a catalogue of Python functions - UDL evaluation, file adaptation, task generation, chat synthesis - that can be invoked by any agent. Each prompt is analysed to see if one of these functions is needed and, if so, the orchestrator executes the call and puts the outcome back into the conversation loop (Chu et al., 2025).

A typical example is the adaptation of material: the teacher uploads a PDF; the MoA examines it, invokes the function *adapt_material()* three times (text summary, concept map, glossary) and returns the new files to the teacher.

2.4 Teacher Interaction Cycle

The cycle starts with a message from the teacher (learning objective, lesson description or request for feedback) and follows four phases:

The first phase is dedicated to comprehension and fusion, where the message enters the MoA and a preliminary response is processed according to Eq. (1)-(2). Then, in the immediate feedback phase, the evaluation cycle is initiated and the platform returns a qualitative scale indicator measuring UDL adherence, with thresholds (low, intermediate, advanced) guiding interpretation. The third phase involves guided co-design, during which the teacher interacts through questions and answers; at each turn the teacher can upload materials or ask for additional proposals, while the agents, thanks to shared memory, adapt and offer increasingly refined versions. Finally, in the delivery phase, when the teacher is satisfied, the system returns the materials and the versions remain in semantic memory for future use.

2.5 Assessment of adherence to the UDL 3.0 Guidelines

The platform implements an evaluation system based on the UDL 3.0 Guidelines, structured according to a hierarchical ontology consisting of 3 fundamental principles (Involvement, Representation, Action & Expression), 9 guidelines (LG1-LG9) and 38 design options (OP1.1-OP9.4).

Each computational agent assigns, for each design option, a discrete score belonging to the set $\{0, 0.5, 1\}$, where 0 indicates an unsatisfied option, 0.5 partially satisfied and 1 completely satisfied. This evaluation process is optimised by means

of a corpus of 1,200 synthetic teaching activities previously annotated with their corresponding OP labels.

The scores are subsequently aggregated by means of a bottom-up process: for each guideline, the score is calculated as the arithmetic mean of the scores of all design options associated with that guideline; the overall score of the entire system is then determined by calculating the arithmetic mean of the scores of the nine guidelines. This hierarchical approach ensures a systematic and consistent assessment of adherence to the UDL guidelines, while providing a concise indicator of the overall quality of instructional design; showing the teacher a final report with the score and adaptive suggestions. Agents in such a system update in real time: when the teacher accepts a suggested change, the new task and OP vector are stored in semantic memory for further incremental finetuning (Fig. 1).

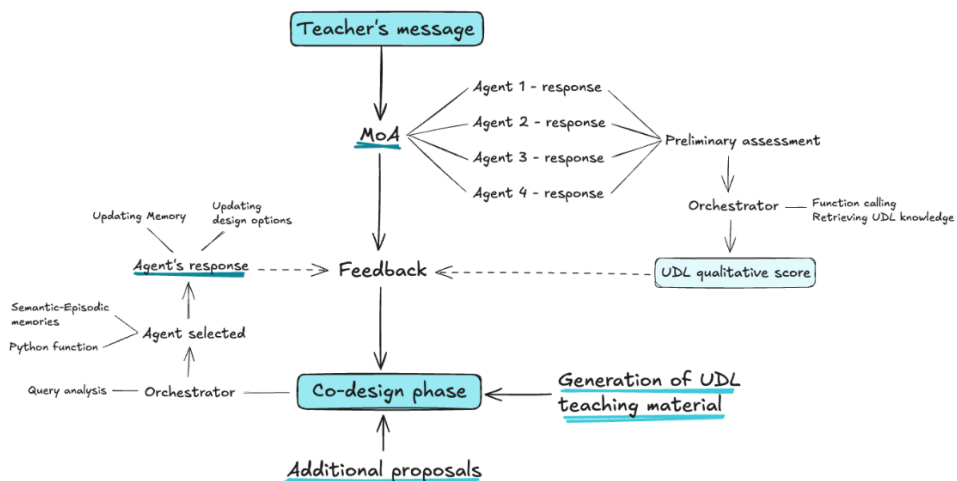


Figure 1. Flowchart of the entire platform.

3. Procedure

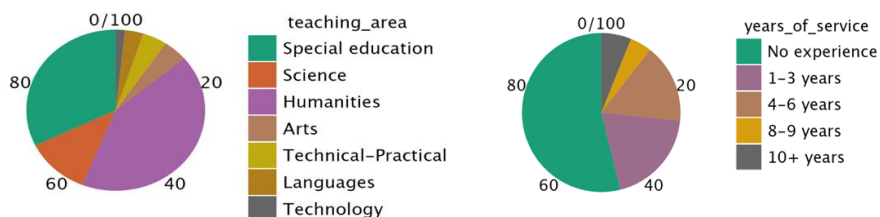
The study was divided into five phases. The first phase involved intensive training of the participants on the UDL framework and the UDL 3.0 guidelines, with the aim of providing a theoretical and practical foundation. Subsequently, in the second phase, the participants, organised in small groups of five members, developed a learning unit using traditional methods (pen and paper) and applying UDL principles. In the third phase, a pre-intervention questionnaire was administered to

measure the participants' knowledge, attitudes and skills in relation to inclusive design before they were exposed to the chatbot. In the fourth phase, the groups participated in a co-design activity in which they redesigned the previously created learning unit using the UDL 3.0 chatbot as a support tool. The aim of this phase was to verify and improve the compliance of the learning unit with the UDL 3.0 guidelines, while at the same time optimising the accessibility of the learning materials. Finally, the fifth phase focused on evaluating the impact of the intervention through the administration of a post-intervention questionnaire, which allowed data to be collected on the perceived effectiveness of the chatbot and changes in participants' attitudes towards inclusive design.

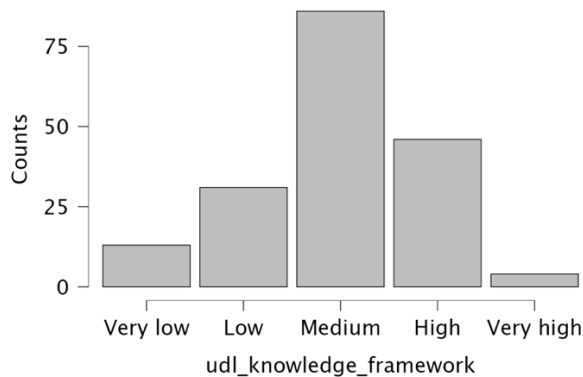
4. Results

This section illustrates the data collected before and after the implementation of the intervention, highlighting the dynamics of the effects of the use of the UDL chatbot on the participants' instructional design and the main methodological criticalities that delimit its inferential scope.

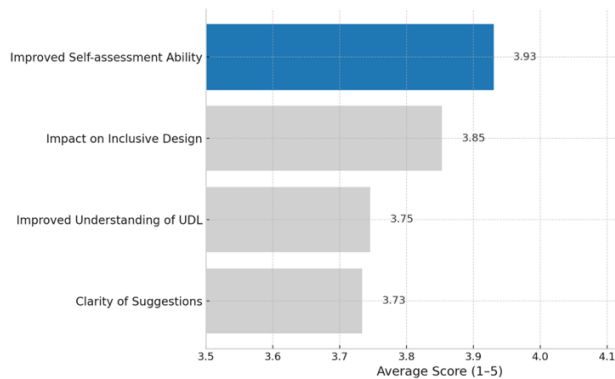
Pre-intervention analysis. The initial sample consisted of one hundred and eighty Italian university lecturers ($N_{female} = 164$; 91.1%), with an average age of 39.7 years ($SD = 13.6$) and very little seniority: 73.3% declared three years or less of teaching experience. The most represented subject areas coincided with the humanities (42.2%), support (32.2%) and science-technology (11.7%). On a daily basis, the adoption of AI-based tools showed a bias towards mainstream solutions: Canva was used by 74.4% of the sample and ChatGPT by 73.9%, whereas more advanced applications such as NoteBook LM (16.1%) or Perplexity (6.7%) were much less widespread.



Prior to exposure to the platform, the overall knowledge about the UDL framework was at a low-medium level ($M = 2.98$; $SD = 0.90$, scale 1-5), while the belief in its inclusive effectiveness denoted a positive trend ($M = 3.92$; $SD = 0.86$). Comfort with educational technology was intermediate ($M = 3.46$; median = 3) and interest in educational chatbots slightly higher ($M = 3.64$; $SD = 0.97$).



Post-intervention analysis. One hundred seventy-one teachers completed the follow-up administration, representing a retention rate of 95%. More than half of the participants (51%) took less than five minutes to familiarise themselves with the conversational interface, indicating a low cognitive input load. The indices of perceived facilitation, measured on a five-point scale, lie in a range between 3.70 and 3.91 ($M_{global} = 3.77$; $SD = 0.76$), with the highest value recorded in metacognitive support for the self-assessment of inclusiveness. At the same time, the indicators of improvement in UDL design show averages between 3.85 and 4.06 ($M_{global} = 3.94$; $SD = 0.68$); the differentiation of teaching strategies and methodologies represents the most marked area of growth ($M = 4.06$; $SD = 0.89$), followed by the adaptation and accessibility of materials. With regard to the technological component, the thirty-three-item questionnaire returned an average usability score of 4.70 out of 7 ($SD = 1.55$) with excellent internal consistency ($\alpha = 0.97$). The breakdown by dimension shows values ranging from 4.46 (reliability and security) to 4.98 (perceived usefulness), while the intention for future reuse stands at 4.78. The final analyses show that 81.9% of the teachers would recommend the chatbot to a colleague and 84.2% expect to use it on an ongoing basis in their design.



Limitations. The results must be interpreted in the light of certain methodological restrictions. Firstly, the reliance on self-assessment measures may have introduced social desirability and subjective attribution biases, limiting their ecological validity. Secondly, the use of a pre-experimental convenience sample design without a randomised control group prevents the causal link between the intervention and the observed outcomes from being rigorously established. Thirdly, the generalisability of the data is limited to the Italian academic context and does not cover school populations of different order and grade. Finally, the lack of standardised evaluation rubrics and objective indicators on project products does not allow for the corroboration of subjective perceptions with evidence of actual performance. Future investigations should therefore integrate direct observation methods, learning measurements and computational analysis of interaction logs in order to overcome these constraints and strengthen the inferential robustness of the proposed model.

Conclusions

The data that emerged paint a picture of the adoption of artificial intelligence as a tool for educational co-design that, while moving in a pre-experimental context, provides some relevant theoretical and applicative evidence. Firstly, the significant increase in all facilitation indices, accompanied by a perception of qualitative improvement in six different design areas, confirms the hypothesis that a conversational interface, if appropriately engineered on the UDL 3.0 guidelines, can support inclusive planning processes even in teachers with limited experience and

average technological skills. This result aligns with the recent literature on the use of Large Language Models as metacognitive mediators in instructional design (Hu, B., Zheng et al., 2024), however, broadening the horizon from textual assistance to multimodal co-construction of materials.

The average score of 4.70 out of 7 on the usability scale and the corresponding Cronbach's α of 0.97 attest to the high internal consistency of the measurement instrument and suggest that the platform functionally fulfils the requirements of learnability, efficiency and satisfaction. The speed of familiarisation recorded in more than half of the sample strengthens the argument of scalability, highlighting a potential for deployment even in training contexts characterised by limited onboarding time. Relevant, from the point of view of sustainability of use, is the advocacy attitude expressed by 81.9% of the participants, who declared that they would recommend the chatbot to their colleagues, and by 84.2% who envisage its future re-use; these percentages, although referring to measures of intent, represent an indicator of technology acceptance higher than the benchmarks reported in similar studies conducted with traditional authoring systems.

Despite the consistency of the results, the pre-experimental nature of the design imposes caution in causal inference and the absence of a randomised control group limits the possibility of uniquely attributing outcomes to the intervention, while the use of self-reports may have amplified social desirability phenomena. Further research should therefore adopt quasi-experimental or experimental methodologies, integrate independent evaluation rubrics on design artefacts and consider metrics of student learning exposed to co-designed materials. From a theoretical perspective, the study contributes to clarifying the role of AI as a “distributed intelligence” artefact capable of extending, rather than replacing, teacher agentivity in selecting UDL teaching variables (Hyatt & Owenz, 2024; Song, et al., 2024; Evmenova et al., 2024). In line with Ayanwale and Ndlovu (2024), the experience increased motivation and engagement, confirming the potential of AI as a qualifier for teacher education. The significant impact recorded on the differentiation of methodological strategies suggests that the relationship between prompt engineering and operational affordances should be further investigated in design-based research in order to identify replicable conversational patterns. In summary, the results attest to the preliminary effectiveness of a UDL-oriented chatbot in enhancing the inclusive quality of design and highlight its sustainability of use in a sample of early-career academics. Although within the highlighted methodological limitations, the study provides a solid empirical basis for future

randomised trials and lays the foundation for the definition of operational guidelines on the integration of AI systems in teacher training.

Author contributions

The article is the result of discussion and scientific collaboration among the authors. However, the attribution of scientific responsibility is as follows: L.D. Sasanelli paragraphs 1 and 4; U. Barbieri paragraphs 2. and 3; R. Di Fuccio Introduction and Conclusions

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