Advancing the Integration of Artificial Intelligence in Meta-Design

Barbara Rita Barricelli
University of Brescia
Brescia, Italy
barbara.barricelli@unibs.it

Gerhard Fischer
University of Colorado
Boulder, USA
gerhard@colorado.edu

Daniela Fogli
University of Brescia
Brescia, Italy
daniela.fogli@unibs.it

Anders Mørch
University of Oslo
Oslo, Norway
andersm@uio.no

Antonio Piccinno
University of Bari
Bari, Italy
antonio.piccinno@uniba.it

Stefano Valtolina
University of Milan
Milan, Italy
stefano.valtolina@unimi.it

ABSTRACT

Meta-design promotes 'design for designers' or, in other words, the creation of socio-technical environments that can evolve in the hands of the users. The long-term goal of meta-design is improving the quality of life in each person's everyday activities, that is, living, working, and learning with the aid of technology. Today, advances in Artificial Intelligence provide new opportunities and frontiers for meta-design to empower users much more than in the past, giving them new perspectives, strategies, and tools to be exploited in the 'design for design' process.

CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**; **Interaction design theory, concepts and paradigms**.

KEYWORDS

End-user development, Cultures of participation, Meta-design, Human-centered artificial intelligence, Design trade-offs, Large Language Models

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1 THE HISTORY OF META-DESIGN

The term meta-design is adopted in several disciplines to indicate a design thinking, activity, or process that enables reflecting and reasoning about design itself [14, 17, 21, 23, 24]. In Human-Computer Interaction (HCI), the term was introduced by Gerhard Fischer in 1999 [10], pointing out the necessity of bringing together different viewpoints on design problems to explore alternatives, discover tacit knowledge related to the domain at hand, and allow end users to become co-designers of their digital artifacts at use time rather than merely consumers of them. Indeed, the world changes; therefore, the systems that model and support the world must change accordingly. Furthermore, since the need for changes is felt by end users and not by the system designers, end users must be empowered, motivated, and rewarded to carry out these changes themselves. When designing an artifact enabling a design activity that never finishes but needs to undergo continuous evolution, in HCI, the most well-known approaches are *user-centered design* (UCD) and *participatory design* (PD). In UCD, users are observed and interviewed at design time to collect the requirements and create models of users to support the development of systems that are as easy to use as possible. In PD, a more active role is played by users at design time; some user representatives become members of the design team and participate in design workshops and prototype development. On the other hand, in *meta-design*, the activities performed at design time are the results of the collaboration between meta-designers and user representatives, the latter bringing the users' perspective as in PD. However, meta-design differs from PD in that the developed system will not only be used as-is, but it will evolve in the hands of a few users (*users-as-designers*), who might be in charge of or desire to perform continuous system design at use time. The concept of meta-design was refined over the years by Fischer and other scholars by proposing methodologies for the design of systems supporting End-User Development (EUD) activities. EUD empowers end users with tools and techniques to create, modify, and extend digital artifacts throughout their entire lifecycle, aligned with users' expertise, practices, and skills [4, 16, 19]. The relationship between meta-design and EUD has been deepened in a 2004 paper [12], where meta-design was defined as the set of "objectives, techniques, and processes for creating new media and environments allowing 'owners of problems' (that is, end users) to act as designers."

During the last 20 years, different social phenomena fostered by meta-design have been observed in several complex projects. By social phenomena, we mean the broadest sense of social interaction, including interaction with humans and objects. Furthermore, the technologies have evolved, allowing researchers and developers to explore and exploit meta-design potentials in different application domains. Particularly, Artificial Intelligence (AI) has become a trending topic all over the scientific world, with a significant impact

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on the way humans interact with technology. One of the most popular scientific contributions in this direction is Human-Centered Artificial Intelligence (HCAI), a novel approach to designing AI-based systems [20] focused on the importance of establishing an adequate balance between automation and human control. Nevertheless, HCAI does not consider that end users should be involved in the shaping of their own systems. As highlighted in [6], there is still a lack of meta-design methodologies aimed at improving EUD with AI.

In this paper, we reflect on meta-design through the lens of current AI-based technologies from a socio-technical perspective by deepening the technical possibilities offered by AI and eventually reinvigorating the ideas that characterize meta-design - e.g., rich ecologies of participation, cultures of participation, co-evolution of users and systems, and conviviality [5].

2 META-DESIGN, EUD, AND AI STARTED TO MEET

Current AI technological advances can be exploited to enhance the meta-design potentialities: without taking control away from users (as pure AI scholars seem to advocate), we claim that combining meta-design with AI may create new possibilities for users to collaborate and thus perform EUD. We anticipate that new ways of sustaining system evolution by end users and new modalities to make end users participate in design will increase dramatically. Furthermore, meta-design can support the design of systems, including AI features that monitor user interaction and adapt content and interface automatically. These systems, also known as *adaptive systems*, usually do not require direct user intervention, except in cases where system adaptations are considered wrong by the user [11].

Let us consider a smart home scenario and the possibility of amateur designers controlling and customizing smart things' behavior in households. In this context, the use of Virtual Assistants (VAs) (e.g., Google Assistant, Amazon Alexa, Apple Siri) for smart home control is becoming more and more popular (e.g., [3, 7]). These are AI-infused systems that allow users to ask for information, communicate with other home inhabitants, and operate on smart devices through natural language interaction. In addition, machine learning algorithms provide users with contents and device behaviors tailored to their habits and needs, but users can participate in such a tailoring activity by defining sequences of actions to be activated when some given event occurs (these are called *routines* by most VA producers).

The synergy between meta-design and AI might push users' possibilities further. Particularly, the widespread adoption of Large Language Models (LLMs) for Generative AI since the introduction of OpenAI ChatGPT in November 2022 opens novel ways to help users create, extend, and modify digital artifacts. For example, LLMs can be used to provide users with more flexible ways for routine creation, such as suggestions about triggers and actions suitable to given situations. However, LLMs require that users evaluate the correctness of what AI has generated, especially when this is a software artifact, as in EUD. For instance, in the case of routine creation, the user must be able to judge if the routines suggested by LLMs satisfy their needs, are not dangerous, and respect users' privacy. In general, during the design of an AI-infused EUD environment, meta-designers must know the type and behavior of AI algorithms, for example, recognizing the probabilistic nature of LLMs, to guarantee that users-as-designers can always keep their control on the system and be able to provide feedback and modify what AI has generated.

Vice versa, the EUD activities fostered by meta-design could, in turn, feed VAs and their underlying AI with information about users' habits and preferences, including the reasons for users' choices. This could bring about new VA's proactive behaviors in the form of suggestions about the routines that could be created or the order in which actions might be executed in a routine. Such proactive behaviors have not been made available for smart homes and VAs yet, but they are a glimpse of the possibilities that meta-design can bring in modern AI-based systems to make them more controllable, acceptable, explainable, and reliable.

Meta-design should not only include the design of such AI features but also foresee the creation of socio-technical systems that help users live in a smart environment and make responsible, shared, and democratic decisions. Some of these aspects are exemplified in two case studies related to the authors' research experience, where meta-design, EUD, and AI started to meet.

2.1 Case 1: Learning Management System

For a teacher, creating a new course from scratch is often a time-consuming activity. Finding suitable existing course materials among the plethora of available options (owned by the teacher, shared in a community, or publicly available online) becomes a challenge, often compromising the creation process.

This case study illustrates a meta-design approach to supporting teachers in creating a digital course using an e-learning platform named WhoTeach[1]. The idea relies on using learning objects (LOs) as fundamental elements to compose a course [8, 18, 22, 25]. We endowed our customized Learning Management System (LMS) with a chatbot-based recommendation system (RS). The chatbot implements the EUD strategy offered to the teachers for creating a digital course. It assumes the role of a prompter to assist teachers in finding and selecting relevant LOs in a transparent and well-explained way by retrieving them from some of the best-known repositories: ARIADNE[2], NSDL[3], and MERLOT[4]. Specifically, it asks the teachers for the main characteristics of the course, including the age of the students, difficulty level, and topics covered. Then, the chatbot parses these data using Sentence-BERT [9], a machine-learning model based on Transformers, for identifying the LOs that are most semantically similar to the data entered by the teacher. Once the teacher selects a set of LOs, the chatbot suggests how to combine them in the proper sequence, considering prerequisite relationships between LOs, and provides other related LOs that can be used. In Figure 1, these suggested LOs are placed in the first line at the top of the image and depicted as white dashed rectangles. The other colored rectangles represent the LOs selected by the teacher. Below this, the RS suggests other LOs and how to combine them in different learning paths. The branches depend on the output of the

[1]https:/ www.whoteach.it/
[2]https://www.ariadnelearning.it/
[3]https://nsdl.oercommons.org/
[4]https://merlot.org/merlot/

previous LO. If the LO ends with a test, the choice of the next LO depends on the obtained result. Without a test, the choice is left to the student. After this, the teacher can choose the desired sequence of LOs and then define different branches based on the outputs of the LOs to specify alternative teaching paths.

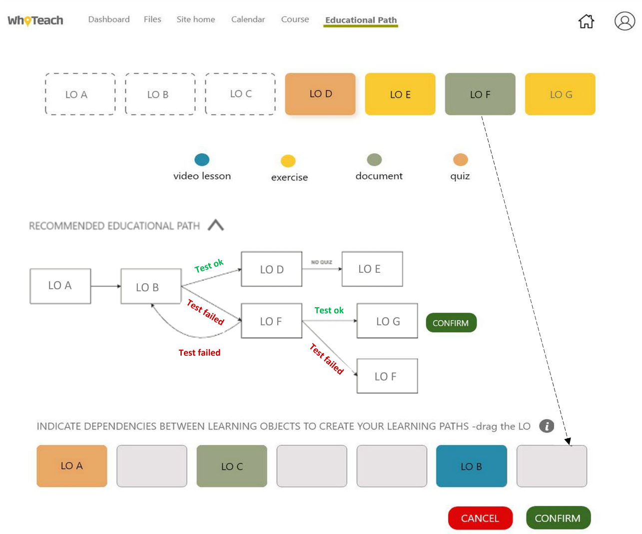

Figure 1: The teacher is supported in the composition of a course.

The RS defines a set of topics related to each LO, finds a group of wiki pages describing these concepts, selects the best wiki page to explain the LO, and finally defines the sequence of relations among the various topics using the wiki page contents (prerequisites) [1]. During these phases, the teachers can tune the RS by working on and assessing the topics they find, selected wiki pages, final wiki page content, and prerequisite relations. Moreover, teachers can rate LO content and provide feedback about recommendations by indicating if the proposed LOs fit well for a specific topic.

The RS will use this feedback to improve future recommendations. This social involvement aims to put the teachers in the loop of the recommendation generation process, according to the social perspective of meta-design. In this way, the environment for creating digital courses seeks to endow the LMS with richer teacher involvement in the course development process. This participation aims to support teachers by allowing them to share ideas, comments, and points of view to make them active evaluators of the RS behavior. This creates a fertile ground for enabling social interactions to improve sharing, collaboration, and conviviality among teachers.

2.2 Case 2: Speech therapy

Speech therapy has the goal of treating speech impairments. They are the disruption of "normal speech" caused by a range of different phenomena, such as brain developmental issues, vocal cord paralysis, and brain or muscle damage. Resolving these issues at a young age can be beneficial for the patients' social and working life [15]. This case study involves three actors: speech therapists, patients (from 4 to 7 years of age), and caregivers. Therapists have the role of making diagnoses, and of creating and administering therapies while monitoring the progress of their patients. Therapies consist of a variety of exercises to be performed periodically, with the aid of a professional during the visits, which requires children and their caregivers to physically attend appointments in medical facilities, and at home with the aid of caregivers [2].

The proposed system offers an alternative to the traditional approach to speech therapy, enabling children to carry out exercises from the comfort of their homes, with the supervision of their caregiver in a controlled environment. A web application called e-SpeechT has been designed and developed. It offers different functionalities and graphical interfaces for each type of user. Concerning therapists, they can create diagnoses for each child, schedule appointments, and assign therapies composed of speech exercises of three types: a) *Naming images*: enunciate the name of the object shown in an image; b) *Minimum pair recognition*: recognize the image of the object that the system vocally indicates; c) *Repetition of words*: words with similar phonetic characteristics are presented by the system in sequence and must be enunciated by the child in the correct order.

AI is employed in the functionality that performs the automatic correction of the exercises. The files of the children's audio recordings are processed by natural language processing algorithms that are used to determine the correctness of the patient's pronunciation of words. More specifically, the Levenshtein distance is computed between the input and the ideal pronunciation of the word. The correction depends on the assessed severity of the speech impairment. The therapist defines the number of classes and their level of severity (e.g., *Slight*, *Moderate*, and *Severe*). A multi-class classifier assigns the patient to one specific class among those chosen by the therapist. The classifier is trained with the data (recordings) previously obtained from the same child. This classification is only proposed to the therapists, who can change or confirm it, and the automatic corrections can be confirmed or refused by both the caregiver and the therapist. Furthermore, e-SpeechT supports unexpected requirements because it allows for the modification of therapies at run time, putting the owner of problems in charge of modifying the system. e-SpeechT offers the patient a playful graphical interface that can be customized by caregivers according to the child's preferences (see Figure 2).

As to the social perspective of meta-design implemented in e-SpeechT, cultures of participation are supported on professional therapists' side and on patients' side. On the therapists' side, e-SpeechT allows them to share the pool of words, exercises, and, thus, therapies that they can administer to their patients. Dispensing the same resources (possibly in a convivial environment like an online community) also supports the co-evolution of users and system, since therapists benefit from each other's experiences by reusing exercises. Similarly, the application evolves through the creation of new exercises and therapies from therapists or through the involvement of professional developers. On the patient's side, gamification is employed thanks to cookies, which are prizes earned by the child each time an exercise is correctly performed. The sum of the obtained cookies is used to create a ranking of all the patients, feeding motivation, engagement, and the sociality aspect.

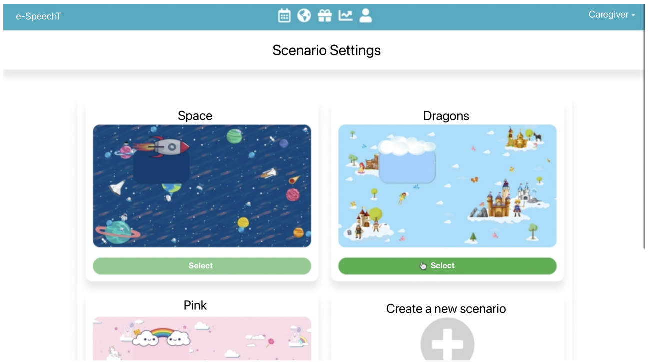

Figure 2: The caregiver can choose, and further tailor, the scenario of the game to be played by the child.

3 INTEGRATION OF AI IN META-DESIGN

The analysis of commercial AI-based solutions enabling EUD and of our cases in education and healthcare led us to reflect on interesting features, commonalities, and limitations.

The following guidelines have been derived from this reflection, which should help meta-designers achieve the integration of AI in meta-design according to a human-centered AI perspective:

- *Support rather than replace domain experts*: the integration of AI features can facilitate and speed up domain experts' tasks; these features must enhance rather than substitute experts' professional skills [13]. In both our cases, the integration of AI in meta-design has brought to support domain experts in performing their daily work more efficiently and effectively with recommendations that they can or cannot accept.
- *Give users-as-designers power over artifacts created with the support of AI*: users-as-designers must have the possibility to verify the correctness of AI output and provide their feedback for correction when needed [20]. For example, in the LMS, teachers can provide feedback on recommended LOs to make the system improve its performance in the future. As to e-SpeechT case study, the computed AI Levenshtein distance between the input and the ideal pronunciation of the word is only proposed as a support to correct the behavior of the system in the speech recognition.
- *Make proactive behaviors transparent, explainable, and controllable*: meta-designers must ensure that proactive behavior based on collected users' activities is always transparent and clear to the users, and that they can intervene to override the proposed suggestions. Recommendations of LOs and how to combine them are designed in LMS to be as transparent as possible. Similarly, automatic exercise corrections are proposed in e-SpeechT to therapists and caregivers, considering their expertise and giving the possibility to confirm them or not.
- *Overcome information overloading through AI*: meta-design must foresee the creation of infrastructures that help users share and re-combine knowledge and artifacts within their community; integration of AI features in these infrastructures can improve the search of relevant knowledge and artifacts, allowing to overcome information overloading. The solution proposed in our LMS addressed the need to empower teachers as course designers while alleviating the burden of navigating vast amounts of online material. As to e-SpeechT case study, the suggested severity level let the speech therapist avoid listening to all the speeches recorded by the patients.
- *Sustain human-human collaboration mediated by AI*: to favor multi-disciplinary collaboration, meta-design must not only pay attention to designing customized environments for the different stakeholders, but also foresee the design of an AI-based communication infrastructure, allowing automatic content adaptation and translation, so that each stakeholder can contribute from their own perspective and expertise. In our cases, the idea of creating an online community where different stakeholders can share and re-use digital material has been pursued, even though mechanisms for automatic content adaptation and translation would have been beneficial.
- *Strengthen co-evolution opportunities*: the integration of AI in meta-design provides new and easy ways to make end users participate in system evolution. On the other hand, this enriches systems with machine learning capabilities that allow automatic adaptation to context and users' behavior. Meta-designers must manage co-evolution cycles by exploiting new opportunities offered by AI to foster participation and design activities. In the systems discussed in our cases, co-evolution is fostered by the creation and sharing of digital courses or exercises, which may, in turn, make the stakeholder community grow and co-evolve with the system.

4 CONCLUSIONS

In this paper, we have explored the social and technical perspectives of meta-design through the lens of the new possibilities offered by AI technologies and algorithms. Initial experiments have been put in place to integrate AI in meta-design, with the purpose of expanding and making EUD activities easier and sustaining social interactions through collaboration with (future) users, rich ecologies of participation, and conviviality. On the other hand, a future research direction might consider enriching AI-based systems, especially those exploiting Generative AI, with EUD features to empower users in balancing proactivity with adaptability, thus obtaining more control over the system behavior and increasing users' trust in AI technology in general.

In conclusion, as the integration of AI and meta-design progresses, exciting possibilities emerge. AI has the potential to revolutionize user interaction throughout the process of creating, extending, and modifying artifacts. This empowers users to become the designers themselves, breaking down traditional barriers and promoting multi-disciplinary collaboration. The synergy between meta-design and AI not only enhances users' skills and practices but also ensures advanced systems that are highly acceptable, trustworthy, and controllable by the users. This advancement promises to greatly improve the quality of life for individuals and society.

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