H2O Learn - Hybrid and Human-Oriented Learning: Trustworthy and Human-Centered Learning Analytics (TaHCLA) for Hybrid Education

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Abstract—**This paper presents the H2O Learn (Hybrid and Human-Oriented Learning) project, a coordinated research project funded by the Spanish Research Agency, which just started in 2021 and will last for three years. The main goal of the H2O Learn project is to build Trustworthy and Human-Centered Learning Analytics (TaHCLA) solutions to support human stakeholders when designing, orchestrating and (self-, socially- or co-) regulating learning in Hybrid Learning (HL). The contributions of H2O Learn consider key requirements for trustworthy Artificial Intelligence (AI), as defined by the European Commission: 1) fostering human (i.e., teachers, learners…) agency; 2) enabling transparency of the Learning Analytics (LA) systems; 3) seeking socio-emotional and inclusive wellbeing; and 4) promoting accountability by enabling the assessment of algorithms and design processes.**

Keywords— Learning Analytics, Artificial Intelligence, Trustworthiness, Transparency, Well-being, Human Agency, Accountability.

I. Introduction

The interdisciplinary field of Learning Analytics (LA) is defined as the "*measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs*" [1]. From the research perspective, LA combines elements of Learning (e.g., educational research, educational technology, etc.), Analytics (e.g., statistics, visualization, Artificial Intelligence - AI, etc.), and Human-Centered Design (e.g., usability, participatory design, etc.) [2]. Actually, LA borrows methods from AI, relies on sophisticated Machine Learning (ML) algorithms [3] and has produced promising results aimed at improving learning in settings that are very diverse in nature. For instance, recent research articles are aimed at predicting students' performance in large-scale online learning settings (e.g., [4]), at understanding the behavior of students in small-scale face-to-face learning activities (e.g., [5]), or at identifying self-regulated learning strategies and tactics employed by students in blended learning settings that combine online and face-to-face activities (e.g., [6]).

Education has become an integral part of the ongoing debate about the strategic importance of AI, together with **the tension between the increasing use of AI and its influence on human behavior and wellbeing** (see, e.g., the "G20 AI dialogue on Trustworthy AI in education" [7] from the OECD). This debate and tension concern policy makers at the European level (see, e.g., [8] from the European Commission), and at the national level (see, e.g., [9] from the Spanish Ministry of Science, Innovation, and Universities in the case of Spain). Interestingly, this latter policy document stresses the opportunities of AI for achieving a more inclusive, adaptive, and personalized education (explicitly mentioning LA as an enabling technology). But this same document highlights significant risks associated with the use of AI in education, for example, those derived from the non-negligible lack of digital skills of teachers, as well as those associated with the ethical implications in the collection and processing of educational data. These issues have been identified as two of the main challenges for LA research in a recent study made by SNOLA [10], the Spanish Network of Learning Analytics.

Indeed, **the tension between technology adoption and its impact in education and society has become more evident in the light of the recent COVID-19 pandemic** that has suddenly pushed educational systems to new forms of teaching and learning, which were technically feasible, but came with barriers, bottlenecks, and undesired impacts [11][12][13]. The COVID-19 crisis implied an abrupt and emergency-like transition towards several ways of the so-called remote emergency teaching [14] (for which neither teachers, nor students, nor institutions were adequately prepared), but it is also very likely that post-COVID education will not be the same as before. Hence, there is a strong call for a much more profound transformation of education and its technological support [15][16][17], which will imply a transition to new modes of "**Hybrid Learning**" [18]; this affects all areas of knowledge but can be particularly critical in the area of engineering due to the intrinsic difficulty of the subject. Hybrid Learning (HL) goes beyond more established ways of Technology-Enhanced Learning (TEL), such as blended learning, flipped classroom or Computer-Supported Collaborative Learning (CSCL): "As such, the term hybridity stresses the mixture and fusion of traditionally separate parts to create a new hybrid that is not a blend or something flipped, but something in its own right, something different" [19] (p. 67). **HL happens, as during the COVID-19 crisis, when traditional "dichotomies" in education are blurred and/or dissolved**. Examples of these dichotomies are physical/digital learning spaces; informal/formal learning contexts; face-to-face/online education; individual/collaborative active learning methodologies, etc. [19].

Many advances in educational technology have already been gradually contributing to the blurring of those dichotomies, being LA one of the most important. In this same line, it is worth mentioning the use of LA for educational scenarios supported by so-called **Smart Learning Environments (SLEs)** [20]. SLEs [21] aim at providing automatic learning interventions that are personalized according to the learning context of the students (where they are, what is happening around them, etc.), their current status or "model" (educational level, previous learning experiences, etc.), and the pedagogical intentions of teachers, typically expressed by means of so-called "learning designs" [22]. **SLEs provide a technological support that is also suitable for HL**, as previously explored in the literature (see, e.g., [23]). LA plays a central role in SLEs, helping mostly in the analysis of learning traces coming from the technological components they are made of (see, e.g., [24]).

However, despite advances in SLEs and LA for the support of HL, these systems are not an exception and face the above-mentioned risks related to the use of AI in education. A historical analysis of the application of AI and LA in education shows threads and missing links that are problematic in different ways and that hinder higher levels of adoption, positive social change, and human wellbeing (see, e.g., [25][26][27]). For example, Ferguson et al. [28] analyzed through expert reviews envisioned scenarios for the future that apply LA in terms of their feasibility and desirability. Visions in the scenarios include, for example, "classrooms monitor the physical environment to support learning and teaching", "most teaching is delegated to computers", "analytics are rarely used in education", "individuals control their own data" or "LA are essential tools for educational management". The analysis shows that major themes of power, validity, complexity, and ethics have implications in utopian and dystopian views of the future and suggest that these themes should be carefully considered when advancing the implementation of LA.

This paper presents the theoretical foundations and research plan of H2O Learn, a coordinated research project funded by the Spanish Research Agency and with the participation of three Spanish Universities (Universidad Carlos III de Madrid, Universidad de Valladolid and Universitat Pompeu Fabra), which addresses the aforementioned challenges in the fields of HL and LA. More specifically, H2O Learn will address the **challenges in HL** of **1) providing teachers with actionable learning indicators about activities happening in a hybrid of learning spaces and pedagogical approaches** where not all students are expected to use the same tools, be located in the same (physical and/or digital) spaces, etc., and **2) helping students regulate their individual and collaborative learning**, interacting with teachers and/or students face-to-face or remotely, using a changing set of technological tools, etc., even in situations of potential social isolation. All these objectives will be supported by **LA solutions that consider their impact on the behavior of the human actors** (teachers and learners, but also education managers, researchers...) and their wellbeing. Therefore, the goal of H2O Learn is to build **Trustworthy and Human-Centered LA (TaHCLA) solutions to support human stakeholders when designing, orchestrating and (self-, socially- or co-) regulating learning in HL**.

The rest of the article is structured as follows. Section II delves into the concept of TaHCLA (Trustworthy and Human-Centered Learning Analytics) and the several requirements that constitute this concept. Section III presents the initial hypothesis addressed by the H2O Learn project and the research objectives. Section IV summarizes the methodology and the work plan for the three years the project lasts. Finally, Section V draws the main conclusions of this article.

II. TAHCLA: TRUSTWORTHY AND HUMAN-CENTERED LEARNING ANALYTICS

The European Union High-Level Expert Group on AI recently released its report on "Ethics Guidelines for Trustworthy AI" [29]. This report claims that AI systems, in order to "maximize the benefits of AI systems while at the same time preventing and minimizing their risks," need to be [29] (p. 4): **human-centered**, since AI systems must serve humanity and the common good, "with the goal of improving human welfare and freedom"; and **trustworthy**, since the lack of trust in AI systems will hinder its uptake and therefore the "realisation of the potentially vast social and economic benefits that they can bring". According to this same report, trustworthy and human-centered AI should be lawful, ethical and robust, based on the ethical principles of a) respect for human autonomy; b) prevention of harm; c) fairness; and d) explainability. To achieve such a vision for AI, **7 key, interrelated requirements** should be observed (see Figure 1): ***1) human agency*** (AI systems should support human autonomy and decision-making), ***2) technical robustness and safety*** (AI systems should avoid unexpected and unacceptable harm), ***3) privacy and data governance*** (also covering data quality and integrity), ***4) transparency*** (all elements of an AI solution, including data, system, and business model should be "explainable"), ***5) diversity, non-discrimination and fairness*** (AI solutions must avoid unfair bias while assuring universal access), ***6) wellbeing*** (AI systems should be used to benefit all human beings, including future generations) and ***7) accountability*** (algorithms, data and design processes need to be assessed to ensure responsibility for the AI systems).

Figure 1: Seven requirements for a human-centered and trustworthy AI. Figure taken from [29].

Education should not be oblivious to this call for a more **human-centered** and **trustworthy** approach to AI [7]. Indeed, research on educational technology should explore how the fulfilment of the described 7 requirements can contribute to minimizing the risks associated with the incorporation of AI systems in TEL ecosystems, such as those based on LA. The incorporation of human-centered and trustworthy approaches to LA permeates all aspects of educational technology and affects (and involves) all stakeholders that play a role in technology-enhanced learning ecosystems [30]. **In the specific case of supporting Hybrid Learning**, there are **four significant research challenges** for **"Trustworthy and Human-Centered LA" (TaHCLA)** that are aligned with four of the requirements for trustworthy and human-centered AI: A) Human Agency; B) Transparency; C) Accountability, and D) Wellbeing.

A. *Human Agency*

Placing humans at the center means a shift from emulating humans to empowering people [31]. Instead of trying to emulate or substitute human stakeholders (e.g., teachers, learners...), the challenge is to design tool-like user interfaces that are aimed at augmenting their capabilities to do the tasks themselves, i.e., maintaining their **AGENCY** and control over the learning situation. Therefore, TaHCLA for HL would imply augmentation for two stakeholders: Teacher augmentation (for design and orchestration) and Learners' augmentation.

Teacher augmentation for Design. Adoption of LA solutions in real-world HL contexts depends on the involvement of human stakeholders in their design [32]. However, "given the complexity of LA systems, it can be challenging to meaningfully involve non-technical stakeholders throughout their design and development" [33] (p. 27). This challenge calls for research on "Human-Centered Learning Analytics" (HCLA) [34] in which approaches and techniques from the field of Human-Computer Interaction (HCI) should be explored and adapted to the particularities of HL so as to produce intuitive, effective, and easy to use LA solutions. How to design in complex TEL ecosystems has been an important research topic, addressed by the research teams in this project (see, e.g., [35]), although the design of LA solutions (and their AI components) that support HL is still an open research issue.

Teacher augmentation for Orchestration. HL approaches rely on complex ecosystems of educational technology. LA solutions, based on modern AI approaches, add a new component to the already complex "ecosystems" of educational technology [36], in which different ICT (Information and Communication Technology) tools need to live with (and be used by) human stakeholders (e.g., teachers, students, policy-makers...), supporting particular pedagogical approaches (e.g., inquiry-based learning, collaborative learning, project-based learning,...), in particular contexts (e.g., at school, at the University, at home...), across different learning spaces (physical, virtual or hybrid) [37]. Long-term adoption of LA solutions call for a consideration of all the interrelations that happen inside those ecosystems. The research strand within TEL that deals with "productively coordinating supportive interventions across multiple learning activities occurring at multiple social levels" ([38], p. 12) is called "orchestration". How to orchestrate complex TEL ecosystems has been an important research topic for some time (see, e.g., [39]), although the orchestration of LA solutions (and their AI components) that support HL is still an open research issue.

Learners' augmentation. HL environments require that learners develop strategies to learn autonomously, supported by the teacher and the available tools. Self-regulated learning (SRL) refers to learners taking control of their learning through an iterative process of planning, monitoring, evaluation, and change. Social modes of regulation (socially-shared regulation and co-regulation) emphasize the regulation processes taking place in groups [40]. Throughout the last decade, a number of LA-based tools promoting self-, co-, and socially-shared regulated learning have been proposed to capture the phases and help learners and teams develop their SRL skills, including tools that detect traces of SRL (e.g., [41]). This topic has also been addressed by the research teams in this project (e.g., [42]), but further work is needed to build tools that capture the complexities of social forms of regulation. Also, more work has to be done to support learners in their regulated learning processes with tools that comply with the principles of trustworthiness, to increase their effectiveness and opportunities for adoption. More specifically, a focus should be put in creating supporting tools that promote learners' agency [40], which is considered a fundamental element in these models.

B. *Transparency*

Paying attention to "Ethics" and the impact of LA systems in human wellbeing [26] underlines the importance of considering **TRANSPARENCY** in the design of AI-based LA algorithms. Achieving transparency in LA systems, as a requirement to fulfil before it can be widely accepted by human stakeholders [43], implies that their underlying AI components need to be more "interpretable" (i.e., humans can understand the reasons for the AI systems' outputs) and "explanatory" (i.e., AI systems provide humans with information about their reasoning) [44]. As stated by Rosé et al.: "Rather than relying on AI expertise alone, we suggest that learning engineering teams bring interdisciplinary expertise to bear to develop explanatory learner models that provide interpretable and actionable insights in addition to accurate prediction" [45] (p. 2493). However, ethical considerations leading to more transparent LA solutions for supporting HL are still an open issue [18], which is particularly challenging since the collection and analysis of data about the students in different spaces (i.e., at the classroom, but also at home, outdoors, etc.) are at its core.

C. Accountability

ACCOUNTABILITY has already been acknowledged as one of the main principles that should lead the deployment of LA solutions in educational institutions [46]. The principle of accountability implies the identification of the entities, within the institution, that "are accountable for specific data and analytics areas" ([46], p. 448) and that should be part of a constant assessment process of how learning data is collected, analyzed, secured, etc. HL support breaks the boundaries of traditional educational institutions, gathering learning data from external learning tools and platforms, and thus posing significant challenges to the accountability of LA processes and supporting systems [21].

D. Wellbeing

A recent literature review [47] underlines that, although research on the impact of LA in human **WELLBEING** has been tackled by several researchers (see, e.g., [48]), there is still a need for "addressing metrics and techniques to help educational technology stakeholders in safeguarding human values and wellbeing when they design, develop, implement and evaluate LA tools and solutions" ([48], p. 135). LA systems should promote socio-emotional wellbeing, avoid frustration, foster inclusion and positive relationships between people and lead to critical citizens in a healthy society. Modes of HL that emerged during the COVID-19 pandemic showcased clear examples of risks for students and teachers' wellbeing [11][12][13]. Therefore, the next generation of LA solutions for new HL technological ecosystems should face this challenge and take care of the wellbeing of their human stakeholders.

III. Initial Hypothesis and Objectives

The H2O Learn project focuses on the technological support for Hybrid Learning (HL), under the initial hypothesis that the *incorporation of Trustworthy and Human-Centered approaches to Learning Analytics (TaHCLA) will increase their effectiveness and acceptability which, in turn, will foster higher levels of adoption of such technological support for HL, positive social change and, ultimately, human wellbeing.*

Therefore, the main goal of this project can be formulated as: "**to incorporate trustworthy and human-centered Learning Analytics (TaHCLA) approaches in the design, development and use of technological solutions for the support of Hybrid Learning**". The project focuses on four requirements for such trustworthy and human-centered approaches to LA that are aligned with the research challenges described in the previous section: **human agency, transparency, accountability, and wellbeing**. Taking those four requirements into account, the main objective of the project is decomposed in the following five sub-objectives (see also Figure 2):

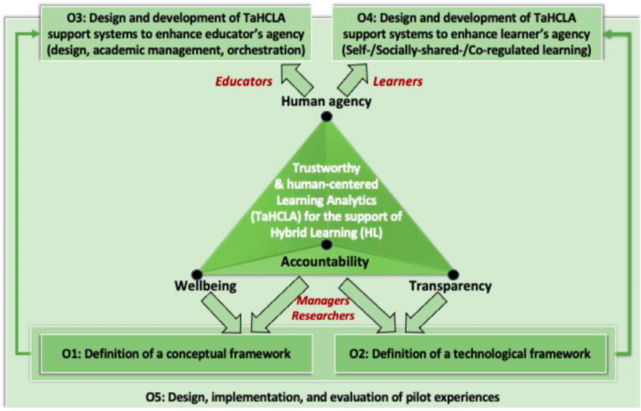

Figure 2: Main objective (center), sub-objectives (O1-O5), four requirements (Human Agency, Accountability, Transparency, and Wellbeing) and key stakeholders (Educators, Learners, Managers, and Researchers) of the H2O Learn project.

- O1: **to define a conceptual framework** that will provide the knowledge, models and principles regarding TaHCLA for HL, with special emphasis on the requirements for **wellbeing support and accountability**. This conceptual basis will be used throughout the project and will include: a systematic analysis of the *state-of-the-art* when combining trustworthy and human-centered principles of AI, LA and HL; the definition of *pedagogical models* for HL that underline the role of LA and how it can provide support to the different stakeholders (learners, teachers, managers, etc.); the definition of a set of HL *scenarios*, based on the defined pedagogical models and co-designed with stakeholders, that illustrate the implications of applying the trustworthy and human-centered principles to LA; a set of *design principles* for TaHCLA; and, the definition of a set of *research instruments* adapted to the scope of the project and aimed at the support of its design, development, and evaluation tasks.
- O2: **to define a technological framework** that will provide a *selection of platforms, tools, and devices* for HL support, aligned with the pedagogical models and scenarios employed in the project, and that follow the principles of **transparency and accountability**. The framework will also propose technical requirements for the enrichment and provision of *smart contents*, and for *multimodal LA from participants' interaction in HL*, as well as a set of principles for TaHCLA *indicators, algorithms, and visualizations*. These requirements and principles will guide the development of the TaHCLA solutions proposed by the project, and that will improve the current technological solutions for the support of HL.
- O3: **to design and develop TaHCLA support systems that will enhance *<u>educators' agency</u>*** in making informed decisions that improve the learning **(re)design**, **academic management** and activity **orchestration** of individual and social learning scenarios implemented in HL settings. The systems designed and developed will offer *indicators, visualizations, and semi-automatic interventions* and implement the trustworthy and human-centered techniques required to generate them.
- O4: **to design and develop TaHCLA support systems that will promote *<u>learners' agency</u>*** by promoting

higher levels of autonomy in HL based on processes of **self-, socially-shared, and co-regulated learning**. The systems designed and developed will offer *indicators, visualizations, and semi-automatic interventions* and implement the trustworthy and human-centered techniques required to generate them.
- O5: **to design, implement and evaluate pilot experiences**, in real settings, of the outcomes of the project following a human-centered approach. Given that the contributions of the project are of technological and methodological nature, they can be applied to a wide variety of disciplines and educational levels including the area of engineering education. Pilots will demonstrate their potential, by considering a diversity of educational topics, and in diverse educational levels e.g., primary/secondary education, higher education, and lifelong learning, with a special focus on promoting STE(A)M (Science, Technology, Engineering, Arts, and Mathematics) and SDGs.

IV. Methodology and Work Plan

In similar ways as posited for Human-Centered AI [31], TaHCLA requires the adoption of research methods that put the users at the center, borrowing methods and techniques from the user experience design field, measuring human performance, and aiming at designing tools that put humans in control [34][49]. The objectives of the H2O Learn project, focused on the creation of technological solutions, lead to following the principles of a Design Science approach, such as the Design Science Research Methodology (DSRM) [50]. DSRM attempts to "create things that serve human purposes" with a research-oriented perspective [51]. This methodology is aligned with the H2O Learn project, that aims to design solutions that meet the needs of the stakeholders in the targeted HL environments [52][53]. As pointed out by Eteläaho, et al. [54], DSRM can be enriched by including principles of user experience research in its lifecycle. This is the methodological approach to be followed in H2O Learn.

DSRM defines a process model involving six phases: **1) identify a problem and motivate its interest** (problems are characterized by unstable requirements and constraints based on ill-defined environmental contexts, complex interactions among components of the problem, inherent flexibility to change the design process and artifacts, as well as taking into account the dependence upon human cognitive and social abilities to produce effective solutions); **2) define the objectives of a solution** (the objective of DSRM is to develop technology-based solutions to relevant problems); **3) design and develop an artefact** (design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation); **4) demonstrate** (effective design science research must provide reliability in the areas of the design artifact, design foundations and/or design methodologies); **5) evaluate it** (DSRM relies upon the application of rigorous methods in both the construction and evaluation of the designed artifacts); and **6) communicate effectively to both technology-oriented and management-oriented audiences**. The activities do not need to happen necessarily sequentially. Refinements of the proposed solutions are foreseen by iteration [50]. All these activities will be enriched by adding a user-centered perspective, including early involvement of users in the identification of the problem and the definition of the goals; co-design processes where stakeholders participate in the decisions made about the models and tools; and user testing (including co-orchestration) and prototyping at different stages of the design process. User and stakeholder involvement will consider principles of diversity, inclusion, and gender balance, guaranteeing the participation of women and groups in risk of social exclusion. This adaptation of DSRM will ensure that the work carried out in the project is coherent with the principles of trustworthiness and human-centered approaches that are at the core of the proposal.

Following the DSRM, the work plan for H2O Learn will be organized in 6 work packages (WPs); each of the first 5 WPs will pursue one of the 5 objectives (O1-O5) defined in the previous section while the last WP will deal with the coordination of the project.

- *WP1: Conceptual framework for wellbeing-driven and accountable TaHCLA in HL.* This WP includes tasks related to the state of the art, pedagogical models and scenarios, Principles for wellbeing-driven design with a focus on accountability, and research instruments for TaHCLA in HL
- *WP2: Technological framework for transparent and accountable TaHCLA in HL*. This WP includes tasks related to the selection of platforms, tools, devices, smart contents, transparent multimodal systems, indicators, algorithms, and visualizations for TaHCLA in HL.
- *WP3: Educator Agency in TaHCLA systems for academic management, learning design and orchestration in HL*. This WP includes tasks related to the definition of principles and techniques, indicators and visualizations, and interventions to support educators' tasks in HL.
- *WP4: Learner Agency in TaHCLA systems for the support of regulated learning in HL.* This WP includes tasks related to the definition of principles and techniques, indicators and visualizations, and interventions to support *-regulated learning (self-, socially- or co-) processes in HL.
- *WP5: Pilot experiences*. This WP includes tasks related to the the design of the evaluation plan, the co-design, implementation, and evaluation of pilot experiences, and the sharing of related datasets.
- *WP6: Coordination, dissemination, and data management*. This WP is transversal to the H2O Learn project and includes specific tasks for coordination, dissemination, and data management.

Figure 3 shows the adaptation of the DSRM methodology for the specific case of H2O Learn considering the tasks to be addressed. There are three main iterations planned, matching each year of the project (duration is three years in total). Each iteration will be composed of the aforementioned DSRM phases, depicted in Figure 3. Two of these phases are critical and require special attention: the definition of the objectives at the beginning of the project and of each cycle; and the evaluation of the proposals in the second and third cycles. The definition of the objectives needs to consider the end users' perspective, to provide systems that are appropriate to their needs. To that aim, end users' representatives will be involved in task T1.2, for the definition of models and scenarios; and in T1.3, T3.1, and T4.1, for the definition of the principles of the different dimensions of trustworthiness that will be proposed in WP2, WP3, and WP4. T1.2 is a critical task, as it will be the base to define requirements for the systems in the rest of the WP. The second critical phase

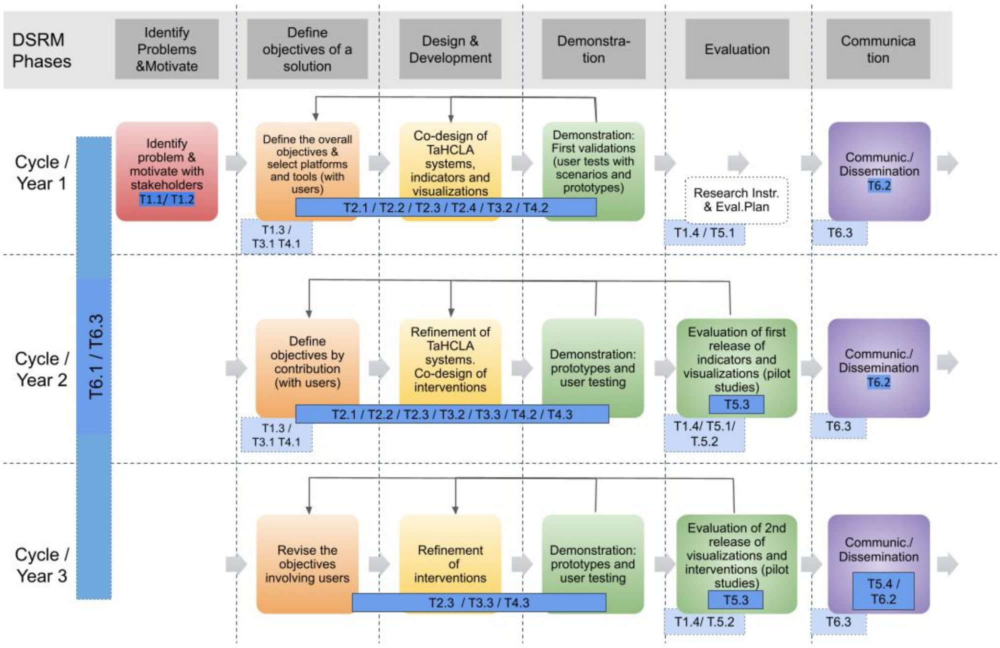

Figure 3: Evolution of the project following the DSRM phases in three cycles. Blue labels represented project tasks.

is evaluation, as it is crucial to assess whether the project is on track and if the proposed systems meet the goals specified at the beginning of each cycle. However, evaluation is costly, and it requires tools that are mature enough to show them to the end users. In this sense, all proposed solutions will be tested (demonstrated, in terms of DSRM) by means of proofs of concept and controlled experiments before they are evaluated in the pilot experiences. These preliminary tests will be part of the activities within the tasks that define each output (i.e., the ones in WP2, WP3 and WP4). The results of these tests will help refine the proposals and achieve more mature solutions, which will be evaluated in real educational situations in the pilots that will take place in the second and the third iterations of the project (T5.3). These pilots will take a participatory approach, with the involvement of end users in their co-design (T5.2).

Finally, another challenge is related to the complexity of the envisioned learning scenarios, which involve new technologies, HL environments, different types of interaction, the enactment of pedagogical innovations, etc. This complexity demands the use of mixed research methods for their analysis [55], combining quantitative with qualitative methods, to get a more complete and accurate vision of the achievement of the research goals.

V. Conclusions

The H2O Learn project aims to design and develop novel TEL (technology-enhanced learning) solutions that make intensive use of Artificial Intelligence (AI) and Learning Analytics (LA) for supporting increasingly common Hybrid Learning (HL) environments. Such solutions are expected to address the ethical concerns related to AI raised by different national and international institutions and governments. To face this aim, H2O Learn identifies relevant ethical guidelines and coins the notion of "Trustworthy and Human-Centered Learning Analytics (TaHCLA) solutions". Then the project proposes to explore this notion in TEL supporting teacher's agency in design and orchestration tasks and learners' agency in (self-, socially- or co-) regulating learning actions. H2O Learn objectives include the formulation of a conceptual and a technical framework, in addition to the design and development of TaHCLA systems applying human-centered methods and following a Design Science Research Methodology.

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