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Automated generation of pedagogical activities adapted to the learning context

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ABSTRACT. Most of intelligent tutoring systems orient the learner towards learning objectives that fit an a priori profile. In AI terms, the teacher establishes a task model that the learner must realize according to a given frame of knowledge, methods and tools. The unique feedback from learners comes from their evaluation. For including the learner in the training-design loop, the task model must be replaced by an activity model of the learner realizing the task. This approach improves the acquisition of new knowledge, competences and skills by the learner This acquisition phase depends essentially on the learner's background. Making the learning context explicit facilitates this knowledge acquisition. Three frames of references are proposed: for learner modeling, for training specifications and for learning activities. Each frame of reference is described by contextual elements usable for all the learners, but instantiable with a specific value for each learner and each step in the training session. This "learner-driven" training is more relevant than the usual "profile-driven" training.

RÉSUMÉ. La plupart des tuteurs intelligents oriente l'apprenant vers des objectifs d'apprentissage qui sont établis pour un profil donné. En termes d'IA, l'enseignant établit un modèle de tâche que l'apprenant doit réaliser dans un cadre donné de connaissances, de méthodes et d'outils. Le seul feedback de l'apprenant est son évaluation. Pour inclure l'apprenant dans la boucle de conception d'une formation, le modèle de tâche doit faire place à un modèle d'activité de l'apprenant réalisant la tâche. Cette approche améliore l'acquisition de nouvelles connaissances, compétences et aptitudes par l'apprenant. Toutefois cette phase d'acquisition dépend des acquis de l'apprenant. Rendre le contexte d'apprentissage explicite facilite cette phase d'acquisition. Nous proposons pour cela trois référentiels pour : une modélisation de l'apprenant, les spécifications de la formation, et les activités d'apprentissage. Chaque référentiel est décrit par des éléments contextuels applicable à tout apprenant, mais qui sont instanciables spécifiquement pour chaque apprenant et chaque étape de la session d'apprentissage. Cet « apprentissage guidé par l'apprenant » est plus réaliste qu'un apprentissage basé sur les profils a priori.

KEYWORDS. Training, learning, task model, activity model, context, contextual elements, instantiation, learner-driven training.

MOTS-CLÉS. Formation, apprentissage, modèle de la tâche, modèle de l'activité, contexte, éléments contextuels, instanciation, formation guidée par l'apprenant.

1. Introduction

The use of Artificial Intelligence (AI) in lifelong education and training is growing and being integrated into commonly used tools [1], as shown in Table 1 below. The International Artificial Intelligence in Education Society (IAIed) encourages the research and development of interactive and adaptive learning environments for learners of any age and in any domain [2]. Their comprehensive review of the literature revealed that AI covers four areas in high education, namely: Adaptive and customization systems, upstream and downstream evaluations, profiling and prediction, and intelligent tutoring systems.

Most intelligent tutoring systems orient the learner towards learning objectives that are appropriate to a selected learner's profile. This profile is generally obtained from, on the one hand, a base of knowledge, competences and skills to acquire, and, on the other hand, from a pedagogical model. As a consequence, all current studies and achievements are devoted to the development of recommendation tools and, at best, to the development of adaptive education tools. Assessment and evaluation systems (both formative and summative) as well as profiling and predictive systems have the same objective, that is, providing adaptive courses from stored contents. The main point here is that the four areas identified by IAIed are based on the approach followed in the training, not its objective.

Different types of current AIEd systems (modified from Holmes et al. 2019, p. 165)

Student teaching	Student supporting	Teacher supporting	System supporting
• Intelligent tutoring systems (including automatic question generators) • Dialogue-based tutoring systems • Language learning applications (including pronunciation detection)	• Exploratory learning environments • Formative writing evaluation • Learning network orchestrators • Language learning applications • AI Collaborative learning • AI Continuous assessment • AI Learning companions • Course recommendation • Self-reflection support (learning analytics, metacognitive dashboards) • Learning by teaching chatbots	• ITS+learning diagnostics • Summative writing evaluation, essay scoring • Student forum monitoring • AI teaching assistants • Automatic test generation • Automatic test scoring • Open Education Resources (OER) content recommendation • Plagiarism detection • Student attention and emotion detection	• Educational data mining for resource allocation • Diagnosing learning difficulties (e.g. dyslexia) • Synthetic teachers • AI as a learning research tool

Table 1. *Different types of AIEd systems [1]*

The Web contains numerous tools largely used in education as well as in training. Most of them endeavor to adapt course development according to a learner's profile. For example, this is the case for Google's Gooru Navigator: *"Use Navigator to help you learn anything, from early learning and K-12 to Skills training and professional development. If we don't yet have relevant open content, bring your own, and use it just for your learners."*

We propose to associate a learner model with an activity model, while the designer only considers a task model (an activity is the way in which a learner realizes the task). This observation recalls Richard's viewpoint [3] on the distinction between logic of functioning (here, the teacher) and the logic of use (the learner). However, differentiation and personalization of course planning depends on the learner's motivation. Motivation must be strong enough to acquire new knowledge, competences and skills. In the classical way, this supposes that a pedagogical session and its resources also must be adapted to the learner's profile. However, learners are the best placed to facilitate the extraction of relevant information based on their experiences, which cover contextualized knowledge, competences and skills. Thus, relevant information is acquired by the learner if the new information can be integrated to the existing learner's knowledge. The more the learning context is made explicit, the easier the learning process. Thus, AI, through context modeling and use, may make an educational system valuable.

2. Proposal for a learner context-driven AI

In the spirit of the General Semantics of Korzibsky [4], the map is not the territory. Thus, an approach to learning objects and pedagogical methods must rely on (potentially) relevant "maps" in pedagogical training. Concretely, we propose to use three frames of reference for reaching this objective.

- A **frame for modeling the learner**: This is constituted by all contextual elements that may constrain the learning process. Some contextual elements to instantiate correspond to different classes:
  - Physical characteristics: Age, sex, mental faculties, handicap, health, etc.
  - Socio-cultural characteristics: language, culture, religion, traditions, habits, etc.
  - Sociability: intra/extrovert, charisma, leadership, aptitude to help and to teach, etc.
  - Emotional: curiosity, flexibility, susceptibility, self-confidence, etc.
  - Intellectual: skills, aptitudes, competences, abilities
  - Motivational: self-determination, cognitive engagement, intrinsic and extrinsic motivation
  - Learning objectives: personal development, professional, learning by doing, etc.
  - Learning profile
  - Physical state (e.g., tired)
- A **description of the training specifications**: This is supposed to represent domain concepts and their organization for an apprenticeship. Different classes of contextual elements are, for example:
  - Training objectives (competences to acquire)
  - Operational objectives
  - Global pedagogical objectives
  - Context of the session: location and environment, material conditions, available means
- A **representation of learning activities**: This represents learning activities (manipulation of Learning Object), which would address the problems of a particular learner.

For each frame of reference, we introduce four types of parallel instantiations of contextual elements: a priori instantiation (from factual data), instantiation by user (or people around) questioning (360° assessment), dynamical instantiation by integration (context, behavior, etc.), and instantiation by inference from parameters previously instantiated.

3. Discussion

In conventional approaches to adaptive learning, the course is modulated according to strengths and weaknesses of the learner. Each learner progresses at his/her own rhythm depending on the answers given to problems and the solutions at each exercise. However, the teacher proposes the same courses, problems and exercises to all the learners regardless of the learners' context.

Conversely, a "learner context-driven" approach would allow the instantiation by inference of the pedagogical activities, depending on the context, and the competences that the learner aims to reach. The successful implementation of such a device requires information coming from the learning environment, the personalized adaptation to competence acquisition, the integration of the cognitive approaches of the learner, and the modeling of teaching strategies. The objective is to propose a service (a teaching strategy) that is tailored to its use (learning strategy).

According to Bates [5], "*The rational approaches of teaching design show the links between the wished learning results, learning theories and teaching (or pedagogical) methods*". So, we think that the result discussed in the previous paragraph can be obtained by:

1. Selecting one or more teaching strategies (instructional strategies) and their modeling;
2. Modeling pedagogical media and technologies for an automated selection (generation) relying on an AI approach; and

3. Modeling learning strategies (i.e. all learner's behaviors during a session) and all that may influence them [6] and developing an adaptive learning environment.

For the first point, there is work in several different theories like behaviorism, constructivism and socio-constructivism to model several pedagogical approaches. Each theoretical stream provides a rationale underlying the choice of learning outcomes, the design of the learning environments and the teaching (pedagogical) methods, such as a teaching machine by a linear model [7] or a branching model [8], learning for mastery [9], direct instruction, activity pedagogy [10].

– The development model of learning and technology (see Figure 1) partially illustrates the second and third points. However, some phases correspond to the teaching strategy and are therefore to be distinguished from learning.

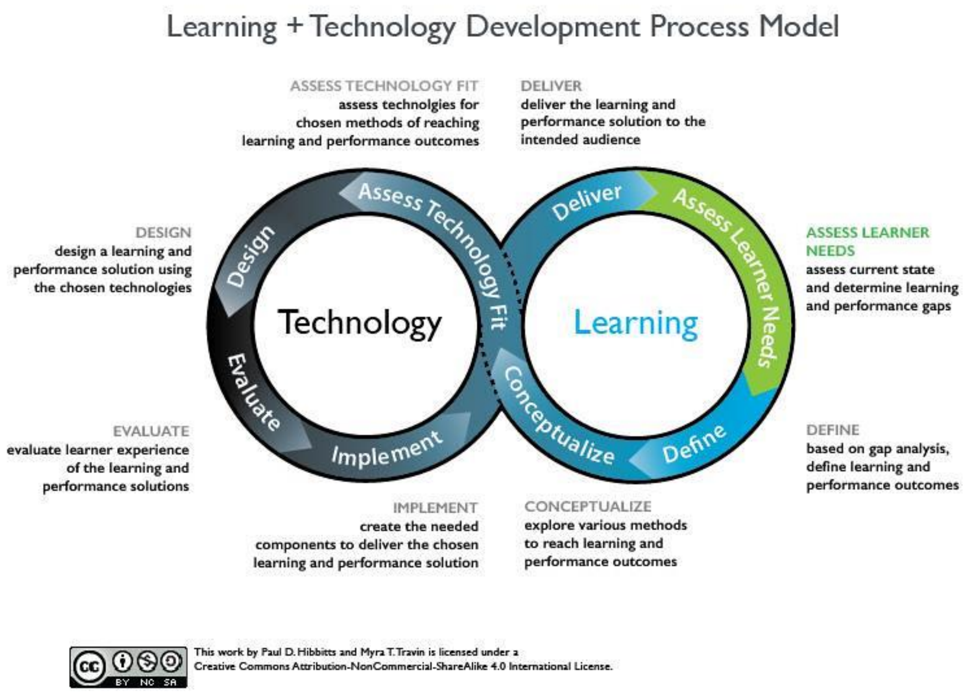

Figure 1. *Model proposed in [11]*

In our approach, design, evaluation and performance depend on teaching, while conceptualization and implementation depend on learning, and thus on the learning task. For example, the approach in learning for mastery involves:

– An operational definition of what the learner should know how to do at the end of the course, that is, the operational objectives of our frame of reference 2 "Training specifications";

– The decomposition of these complex skills into simpler skills (i.e. the training objectives);

– A frequent evaluation of the level of mastery of the intermediate skills;

– Remedial activities when the learner does not master an intermediate skill;

The third frame of reference, "Learning activities", defines the learner's context and a profile of the learner. Thus, a learning strategy is proposed to the learner. The strategy integrates the relevant learning objects, which can be generated by a combination of different tools such as computer vision, deep learning, machine learning as well as natural language processing.

This learning strategy is close to the metacognitive strategy, treatment strategy and execution strategy proposed in [6]. The strategy is implemented in a personalized learning space that integrates both the pedagogical framework and the tools allowing the execution of the formal and informal learning strategies of the learner concerned.

4. Conclusion

Taylor [13] proposed five generations of remote teaching:

1. Correspondence education;
2. Integrated use of multi-media such as print and broadcast, or recorded media such as video tapes;
3. Two-way synchronous distance learning using audio or video conferencing;
4. Flexible learning based on asynchronous online learning combined with interactive multimedia online learning;
5. Intelligent flexible learning, which adds a high degree of automation and learner control to asynchronous online learning and interactive multimedia.

This paper offers an outline of what this last generation of remote education will be. Its implementation is still a challenge because the object of complex processes involving a wide range of combined and entangled variables. However, digital technologies are not the magic wand of education but represent means and opportunity to rethink pedagogy [14]. We argue for a context-driven approach that takes into account the (contextual) elements, which do not appear explicitly during a session but constrain strongly the success of this learning session. A forthcoming paper will develop this context-driven approach.

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