Chapter 23
Designing Intelligent Tutoring Systems With AI:
Brain-Based Principles for Learning Effectiveness

Roberto Trinchero
University of Turin, Italy

ABSTRACT

This chapter describes the research problems inherent the design of effective intelligent tutoring systems (ITS) based on cognitive neuroscience research (brain-based approach) and evidence-based education. Effective student-ITS interaction requires a thorough understanding of the brain processes that underpin learning. The knowledge of these principles allows you to select optimal pedagogical strategies to monitor and guide the process. AI-based tutors have great potential in constantly adapting teaching content and tactics to the changing cognitive needs of the individual student in order to foster deep understanding, increase motivation, and develop a sense of self-efficacy in the learner. The brain-based approach can give ITSs a significant increase in effectiveness in promoting learning.

INTRODUCTION

Research on intelligent systems that can support learners in learning process have seen an important debate since 80's. AI seemed immediately a concrete possibility to provide efficient ways for the individualized education (Beck, Stern, Haugsjaa, 1996; Shute, Psotka, 1996; Mark, Greer, 1999; Ohlsson, Mitrović, 2006; D'Mello, Graesser, 2010; Szalay, Bahçeci, Gürol, 2016). In 1982 Sleeman and Brown coined the term "Intelligent Tutoring Systems" (ITS) to refer to a software capable of supporting learning by providing tutorial services that demonstrate "intelligence" in this role.

ITS is defined "a computer learning environment that helps students master knowledge and skills by implementing intelligent algorithms that adapt to students at a fine-grained level and that instantiate complex principles of learning." (Graesser, Hu, & Sottilare, 2018). Features of ITSs are grown following the pos-

DOI: 10.4018/978-1-7998-7638-0.ch023

sibilities of AI technologies and, from the beginning, have delineated new opportunities for virtual learning environments (VLE). ITSs can offer the scaffolding of a tutor 7 days a week and 24 hours a day. ITSs can "learn" interacting with the learner and adapt their scaffolding to the exigence of the moment. The system generates exact questions, explanation, examples, counterexamples, sessions of practice, illustrations, activities or demonstrations, tailored to the learner by dynamic adaptation of content and form.

ITSs have been shown to be as effective as expert human tutors (Kulik, Fletcher, 2016; VanLehn, 2011; Bloom, 1984) in one-to-one tutoring for well-defined domains (e.g., mathematics or physics) and significantly better than traditional classroom training environments (Graesser, Rus, & Hu, 2017). The main advantages are in a real possibility of individualized instruction and in a powerful opportunity of constant and capillary learner monitoring during the whole learning process, gathering data useful for learning analytics purpose (Siemens, 2013).

Despite advancing in ITS theory development, ITSs are not so widely diffused in training and education. A possible reason is that it is very difficult and expensive to create exhaustive knowledge bases about topics or domains, so this effort is worthy only if scale economies can be realized, e.g. in military training, basic courses, etc. The difficulty increases if the interface between ITS and expert domain requires programming or other complex interaction (Aleven, McLaren, Sewall, Koedinger, 2009).

Another problem is the flexibility of the knowledge base. Good tutoring in arithmetic, for example, requires a "basic" knowledge base and an "advanced" knowledge base taking into account arithmetic applications in the real world of today (that are different from applications in the real world of twenty years ago). Contents and user interfaces that look dated, make the ITS unusable. The investment in building an ITS is only worthwhile if it can update itself automatically, through interaction with learners but also with experts that feed continuously the knowledge base. A "static ITS" is not a good investment. A "learning and self-updating ITS" maybe.

In this contribution we focalize some principles useful to design "effective and self-updating ITS". This means on the one hand to interact with students in order to recognize, in fine-grain level, their cognitive state, how they think, feel and learn, and the most appropriate tactics and strategies to propose an effective tutoring, on the other to interact with experts in order to elicit and to "grasp" their expertise. The limits inherent to the process of inferring the learner's cognitive state from his performance was a big failure of ITSs of the past. No wonder that the diffusion of ITS in school and training is so limited.

Contemporary IA and web collective applications offer several opportunities to improve this self-updating process. Virtual intelligent assistants like Google Assistant, Siri, Bixby, Alexa, Cortana, and other chatbots are now in our everyday lives and demonstrate the opportunities of man-machine natural language interaction. Similarly, image recognition offers a simple way to communicate with the machine. These technologies can be very useful to implement a new generation of ITS. Chatbots can be trained to answer several questions that a learner may pose to ITS, with speech and drawings, and can use AI to recognize problems and formulate solutions.

Background

A good tutoring intervention is always the result of applying a precise plan. To be complete and effective, a ITS must represent and manage subject matter knowledge, learners' reasoning and behavior, teaching tactics and strategies, goals and sub-goals, in order to generate flexible tutoring plans, able to detect mismatches between learner acquisitions and system expectations and revise the plan (or generate a new plan) to face this mismatching. The tutoring action is representable with an OPDCA cycle: Observe–Plan–Do–Check–Adjust