CHAPTER 17 – Pushing and Pulling Toward Future ITS Learner Modeling Concepts

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Introduction

In the previous sections, we examined the learner modeling literature, the state of current practice in learner modeling, and emerging concepts in learner modeling. In this section, we examine ideas related to future capabilities for adaptive tutoring systems, the technologies needed to realize these capabilities, and the maturity of those technologies today. We discuss how breakthrough technologies perceived to be outside the ITS domain today have the potential to change how we think about AI tutors in the future. Recommendations for long-term research are also provided that support both identified needs (technology pull) and innovation (technology push).

A Vision for Future Tutoring Systems

As we look forward toward increasingly intelligent and adaptable tutoring systems, an ontology is needed to characterize essential capabilities and establish standards of performance. Capability definitions might compare and contrast: the degree of tailored instruction that the tutor can provide; how effectively the tutor can support/enable learning; the ability of the tutor to perceive the learner as a basis for tailoring instruction and optimizing performance; or the tutor's compatibility with existing training platforms (e.g., serious computer-based games). Whatever the capabilities of future ITSs, the real measures of success lie beyond learning effect. Future tutoring systems must be easier to develop, access, and use than their counterparts today. They must incorporate reuse standards to reduce time and cost for development. They must provide tailored user interfaces to support usability by learners, domain experts, teachers/instructors/trainers, ITS developers, instructional designers, and researchers.

The theoretical concepts of today will evolve into the practical implementations of tomorrow. The capabilities characterized in ideal future tutoring systems will not just be the result of compromising practicality, mapping (compatibility), and computational complexity (Preface in this book) to realize a workable design, but instead will embody a collaboration between users and tutoring technologies over a lifetime of learning. The seeds of future ITSs are being sown in research that expands the definition of learner models in new directions. A future persistent learner model resides in the cloud, tracks long-term performance, and models competency, values, preferences, goals, and beliefs to help foster trust, creativity, and self esteem within individual learners and teams of learners.

Learner Models in the Future

The four chapters in this section highlight ongoing areas of research that were specifically broken out from the emerging concepts discussed in Section III of this book due to their impact to learning and their anticipated long-term evolution. Each chapter in this section identifies key challenges in developing a more useful and comprehensive learner model, tools and methods for GIFT to build upon. The research discussed points to the importance of comprehensive learner modeling in determining tailored learning experiences over a lifetime.

The chapter by Lester, Mott, Rowe, and Sabourin examines the detection of learner's affective states and their impact on cognition, motivation, and metacognition during game-based tutoring events. The relationship between affect and learning is a critical link in determining optimal instructional strategies and tactics to be employed by the tutor. Significant challenges exist in accurately and unobtrusively determining affect in real-time. Affect detection is further complicated since affect is generally inferred by through observation of the learner by a human or computer-based tutor. Additional challenges arise when a computer must infer affect in complex training environments such as serious games with high degrees of freedom of learner interaction or when a computer must resolve ambiguity between learner behaviors and physiological measures.

The chapter by Burleson and Muldner discusses the future role of ITSs as intelligent creativity supporters. Creativity is a key ingredient for moving learning forward beyond the sum of acquired knowledge and skill. In traditional classroom settings (one teacher and many students), there is generally insufficient time to support a creative curricula tailored to the individual needs of each learner. ITSs have an advantage as one-to-one tutors to provide the special attention needed to foster creativity. Future tutoring systems may be designed to adjust their instruction to promote risk-taking, support learner adaptability, encourage grit, and assess options that lead to creative solutions. A significant challenge may be the ability to efficiently author increased numbers of strategies and content as creativity support tools are linked with adaptive tutoring systems to allow greater flexiblity and assessment of solutions. In other words, ITSs with creative support should be capable of allowing more than a single "right" answer. On the flip side, a considerable advantage might be realized as ITSs are applied to ill-defined domains where creativity is at a premium, and there are multiple serviceable solutions.

The chapter by Regan, Raybourn, and Durlach puts forth a concept for a Personal Assistant for Learning (PAL) that expands the capabilities of ITSs today to include advisory functions (coaching and mentoring). As in GIFT and other tutoring architectures, the PAL learner model will be of central importance to determine instructional strategies for learning, enhance creativity (see Burleson and Muldner, chapter 19 in this book), motivate, activate, and support decision-making. The importance of this chapter in projecting learner modeling capabilities for ITS rests in its illustration of learners as drivers of their own learning experiences as opposed to someone to be guided/led by the tutor. A wealth of information is ready to be mined to enhance our future learner models. Social media is a goldmine of learner preferences, interests, habits, goals, knowledge, and skillsets in time-stamped, context-related bundles of information. These multiple sources of information call for standards for interoperability to support consumption by current and evolving ITS architectures.

The chapter by Fletcher and Sottilare examines how the architectural principles and functions described by GIFT might be extended to support the training of teams. Shared mental models represent team objectives and the actions, both individual and collective, needed to achieve them. These models represent team communication and coordination, team posture, situation, and environment, and team member roles and responsibilities. The focus of this chapter is on shared mental models of cognition and includes models of team purpose, behavior, and functions that are analagous to individual cognitive models in most ITS today. Exploration of team affective models and physiological factors influencing learning are left for future discussions, but an exploration and understanding of shared cognitive models provides insight into how non-cognitive factors might be addressed in the future. Since teamwork differs in the quantity and quality of communication and coordination required, major challenges rest in how to measure how good communication, coordination, and other factors (e.g., goals, roles, individual knowledge and skills, and preferences) support (or detract from) optimal team performance.

The Long View of GIFT

The contributors to this section of the book offered recommendations for developing the learner model component of GIFT across different dimensions (affect modeling, creativity support, data mining and open learner modeling, and shared mental models). The recommendations addressed substantial challenges and opportunities that are envisioned to evolve over an extended period of time due to their complexity. The following enumerates recommended actions for consideration in the long-term view of GIFT. Some of these recommended actions are already defined with known value (technology pull) and some are more speculative (technology push) in that their impact is difficult to predict at this time.

1. Significant effort has been expended to develop affect detectors for individual learners. A systematic analysis based on empirical studies should be conducted to evolve standards that can be applied across training tasks and are suitable for both individual learners and teams of learners.

2. Advance a new class of learning technologies focused specifically on creativity support tools that are linked directly to tutoring architecture components for domain knowledge and motivation. A systematic analysis based on empirical studies should be conducted to evaluate the effectiveness of these tools in teaching creativity and building innovation skills in individual learners and teams of learner.

3. Develop open learner models to support intelligent selection of learner control during tutoring sessions. A systematic analysis based on empirical studies should be conducted to develop and evaluate open learner models to optimize learning.

4. Enhance data-mining techniques to support persistent learner models that are automatically updated over time to reflect changes in preferences, interests, goals, knowledge, and skills. A systematic analysis based on empirical studies should be conducted to determine the effect size of various learner traits on cognition and motivation.

5. Enhance data analysis techniques to support rapid development of expert and misconception models based on crowd sourcing. Develop standard tools and methods to allow for plug and play expert and misconception models in standard ITS architectures like GIFT.

6. A prototype has been developed that implements characteristics of GIFT, including the learner model. A systematic analysis based on empirical studies should be conducted to evolve a similar comprehensive model for teams. These shared mental models should be applicable across various task domains including cognitive (e.g., problem solving), affective (e.g., value judgments), and psychomotor (e.g., controlled movement of the body) tasks. A library or repository should be established to house these models and support standards for instructional design of team training.

7. Develop a formal ontology for GIFT with the support of the ITS community to help focus attention on critical missing learner modeling elements to support authoring, instructional management, and analysis constructs. Extend this ontology to incorporate other aspects of ITS research over time.

8. Develop standards to classify tutoring system capabilities in critical areas (e.g., learning effect size, accuracy of cognitive and affective state classifiers) per the adaptive tutoring learning effect chain (see Preface of this book for individual tutoring or Fletcher and Sottilare, chapter 22 of this book for team tutoring).

9. For future capabilities to support adaptive tutoring of individuals and teams, tools and methods are needed to deeply engage learners and support their deep learning; encourage adaptability, grit (tenacity), and innovation in seeking solutions in military domains with multiple solutions; appropriate control by the learner in their own learning experiences; and shared mental models for teams. A stringent and extensive set design principles should be developed to support enhanced tutor-learner interaction and higher learning effect. A systematic analysis based on empirical studies should be conducted to develop and evaluate the following functions:

    - *Sensors* – behavioral and physiological sensor design should be unobtrusive so as not to interfere with or distract from learning processes during tutoring sessions.

    - *State classifiers* – learner modeling processes should be very accurate (near 100%) in using learner data to determine the cognitive, affective, and physical states (e.g., confusion, frustration, engaged concentration, boredom, fatigue), which are most influential with respect to readiness-to-learn and the learning gains of both individuals and teams.

    - *Measures of success* – tutor assessment engines should be designed to support easy authoring and linkage of success metrics to knowledge and skill acquisition, and performance,

    - *Adaptive instruction and support* – knowledge of the learner's states and traits should lead to optimal selection of instructional content, strategies, and tactics along with additional adaptation based on the learner's questions and goals,

    - *Individual and team modeling* – information about individual learners and teams of learners should represent their individual/collective domain competency, motivation, and expectations of success based on competency and task complexity (e.g., cognitive problem solving, affective valuing),