

Improving student models by reasoning about cognitive ability, emotions and gender

Ivon Arroyo^{1,2} and Beverly Park Woolf^{1,2}

¹ Department of Computer Science, University of Massachusetts, Amherst

² School of Education, University of Massachusetts, Amherst

{Ivon, Bev}@cs.umass.edu

Abstract. We explore how cognitive, socio-biological and emotional conditions of the student help predict behavior within an ITS, and how instruction should be adapted depending on these variables to improve educational outcomes. Cognitive, social and emotional factors tend to be more permanent in nature than student's knowledge. Our approach is to diagnose them with pre-tests before the user starts using the system.

1 Introduction

While trying to improve the effectiveness of intelligent tutoring systems (ITS), the researcher can focus on: 1) representing the student more accurately, 2) improving the quality and amount of teaching elements available, 3) improving the adaptive mechanisms of the tutoring system (i.e. the pedagogical reasoning). Our research is a contribution to all of the mentioned areas, as we explore how the cognitive and socio-emotional conditions of the student help predict their behavior within an ITS, and how help provision mechanisms can be varied depending on these variables. This research work is performed on a mathematics tutoring system for 8-11 year old children called Animalwatch. This ITS has been tested in schools and has been highly rated both by students and teachers [3].

We have analyzed students' cognitive development [6]. It is known that students at this age range can handle most concrete operations (the ability to manipulate ideas over concrete objects). Some students are transitioning to being able to handle formal operations (the ability to manipulate abstract ideas). Although students are expected to develop specific cognitive abilities at a certain age, not all children develop at the same time. This makes cognitive development an interesting variable to focus on while looking for individual differences among student-users.

Gender is an interesting variable to analyze. It is an easy variable to measure, allowing to enrich the predictability of the student model at a low cost. More importantly, recent research suggests that girls and boys have different approaches to mathematics problem solving [5]. Also, prior research makes us believe that emotional factors can contribute to gender differences in learning; it has been shown that in early adolescence, gender differences exist in math

self-concept and math utility; girls have negative emotions and self derogating attributions about their math performance [7]. These varying emotions about the subject being taught should produce different student behaviors within the tutoring system, both for boys and girls. Incorporating them into the student model should provide for the possibility to take some positive action.

The first research question in this doctoral thesis work is to what extent these variables, which cover different dimensions of a human being, can enhance the prediction of student behavior in the context of a one-to-one tutoring system. If higher accuracy is achieved in the student model, then the following question is how this information should be used to improve adaptivity in systems that support human learning. Are there some teaching strategies that are better for a student who fits some stereotype? This will involve finding interactions between student stereotypes and the available educational treatments.

2 Summary of completed work

Diagnosis of cognitive abilities. We have produced a computer-based pre-test to measure children's cognitive ability [2]. The test consists of ten highly interactive tasks that students are asked to solve. An adaptive version of this test can reduce significantly the number of questions while maintaining high accuracy. Students of this age should have abilities in the range from concrete to formal thinking. We designed tasks that measured abilities within these two stages of development. All these tasks are adapted from descriptions in [8]. The result of this test is a score that reflects students' logico-mathematical ability. This cognitive development test has been used with hundreds of 8-11 year-old students before and after using Animalwatch. The test outcomes make us believe that it is accurately measuring cognitive ability. The test produced reasonable measures of reliability, predictive validity and face validity.

Diagnosis of socio-emotional variables. We have pre and post-tested students with an instrument that measures math self-concept (the belief students have about their ability to learn math), math utility (the student's belief that mathematics is important and valuable to learn) and math liking [4]. We are building regression models from the collected student data that depend on these emotional attitudes for predicting number of mistakes and time spent solving a problem.

Design of pedagogical interventions. Adaptivity. Having accurate student models is useful if we can identify what teaching methods work for the student we are representing with accuracy. We look for kinds of pedagogical interactions that work better for students falling into some stereotype (aptitude-treatment interactions). We built alternative help provision systems: when a student makes a mistake, different types of hints could be presented to the student depending on amount of information, hint interactivity, concreteness and structure. We are looking for new descriptors of the hints we already have, and we are building new different types of hints. We gave different versions of the tutoring system to students, with different remediation mechanisms. We are building models that

predict changes in emotional attitudes depending on the remediation mechanism of the ITS. We have evidence to think that low cognitive ability students work better with highly interactive and concrete explanations, while high cognitive ability students work better with more symbolic explanations [1]. We also have evidence for girls working better with hints that are more structured, while boys do better with hints that demand less interaction.

3 Future work

The immediate future work will be to build a population model that integrates all these variables together in predicting performance along several measures: time to solve a problem, number of mistakes, generation of positive attitudes towards math, etc. We have built statistical linear regression models for this purpose, but we will also experiment with tools that produce non-linear models, always with the objective of accounting for more variance. It will be interesting then to see to what extent the model built from one population of students generalizes to a new population, and also what variables are more relevant than others. The following step will be to decide what other variables could characterize the student and the hints, and how they can be measured. Last, we plan to reason from this information, using the rules derived from the interactions in the models. We intend to put the derived teaching strategies into practice, by testing a version of an ITS which incorporates this reasoning compared to another one which does not take these variables into account. The hypothesis is that the system which reasons about the cognitive, gender and emotional characteristics of the student will be more effective than the control one.

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