

# Creating a pedagogical model that uses student self reports of motivation and mood to adapt ITS instruction

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**Abstract.** Our project focuses on the design, implementation and evaluation of a ITS pedagogical model that considers student motivation, mood and cognitive processes in making instructional decisions in the domain of secondary school mathematics. Students complete integrated self report assessments of motivation and mood. Cognitive skills such as math fact knowledge, spatial cognition, and prior math achievement are also assessed. The pedagogical model adapts instruction (problem selection, problem difficulty, topic area, choice of activity, choice of help type, and availability of help) following a model of human tutoring expertise that balances motivational and cognitive goals.

## **Introduction**

Much research in educational psychology points to the important role of motivation in student learning, in addition to cognitive processes [1]. Students who do well in school combine effective cognitive strategies for mastering the material with effective self regulation of motivation. Such self regulation strategies include goal setting, accurate appraisals of the reasons for their performance, and effective management of the emotions associated with learning activities, such as boredom and test anxiety. Other research shows that effective human instructors balance attention to the goal of promoting students' cognitive understanding of the domain content, and supporting the students' motivation.

In response to the recognition that learning involves both motivation and cognition, intelligent tutoring systems (ITS) researchers are now beginning to consider the role of student motivation. However, much of the research on user motivation while working with ITS systems has focused on the assessment of the student's motivational traits and emotional states, that is, how to tell if the learner is engaged, bored, frustrated, etc. Although assessment is critical, we must also consider the question of how an ITS should respond to different student motivational and affective states.

## **1. Research on student motivation and mood**

The challenge for ITS designers is that the optimal pedagogical responses to various student motivational states -- in terms of student learning outcomes -- are not always obvious or intuitive. For example, instructional decisions that are meant to reduce learner frustration, although well-intentioned, may not really benefit the student. Most current theories of

learning argue that some element of frustration or cognitive conflict is an essential part of knowledge change; thus, the challenge is not to provide instruction that attempts to avoid student frustration but rather to help the student manage frustration and discouragement appropriately. In the domain of mathematics learning, the most effective teachers do not directly attempt to ameliorate student frustration; rather, they convey that some degree of uncertainty and failure is to be expected when learning demanding material, and emphasize these feelings will fade as the student becomes more proficient [2].

Another important consideration is that students with diverse personal characteristics (gender, ethnicity, prior achievement) often react differently to the same instruction and feedback. For example, common-sense might suggest that a discouraged student should be provided with supportive and encouraging feedback. However, female students often interpret such feedback as an implicit indication that the teacher feels that they lack ability in the subject [3]. Similar findings have been reported for students with learning disabilities. Instructor praise for doing well on difficult material actually led to declines in motivation for high-achieving African-American students, but not their low-achieving classmates [4]. The high-achieving students felt that they were already working very hard, and the instructor's praise increased their concern that they would not be able to sustain their successes.

Students' moods also influence their learning. Students experience both negative and positive emotions at school [5]. Anxiety was one of the most frequently experienced emotions, not only in relation to taking exams, but also being in class or studying at home. Students also reported experiencing anger, boredom and shame about their performance. High-ability students experienced academic boredom when demands were too low. A number of students reported that they experienced boredom when they were not able to keep up with demands. Students also experienced positive emotions at school, for example, enjoyment of learning, hope, pride, and relief. Although mood and academic motivation interact, the constructs are distinct: Mood shows more fluctuation, and may reflect aspects of students' out-of-school life (e.g., social relationships with peers and parents) more than is the case for academic motivation.

## **2. The Wayang-West ITS**

The goal of our project is to implement and evaluate a pedagogical model that is based on the strategies used by expert human tutors and classroom instructors to help students learn while also sustaining student motivation: strategies that have been empirically validated in terms of student learning outcomes [6, 7]. The context for the research is the Wayang-West ITS for secondary school mathematics, specifically SAT-Math problem solving. (The SAT exam is a high-stakes math achievement test taken by most high school students in the United States as part of the college admission process.) Mathematics is the academic subject that is most often associated with both variations in student achievement and motivation.

The Wayang-West is a web-based ITS that includes multiple components to evaluate students' prior knowledge, and cognitive abilities that are predictors of mathematics learning and achievement:

Pre and post tests. Students take a mock SAT-M exam before and after the tutoring activity. Multiple versions of the mock tests of equal

difficulty are available. Each test includes items that require tutored and non-tutored skills, to provide an internal control.

Cognitive assessments. At the start of the activity, students complete on-line versions of a standard test of math fact retrieval proficiency, and spatial cognition. Performance on these cognitive tasks is correlated with math achievement.

Tutoring module. Students work on a series of SAT-M problems provided by the College Board (the test author). The format of the SAT-M problems is multiple-choice. Students can answer at any point, they can skip a problem, or they can request multimedia help. Two forms of help are available for most problems: one form emphasizes traditional algorithms, whereas the other emphasizes visualization strategies.

Transfer tests. Wayang-West includes three virtual adventures: simple narratives animated in Flash about environmental science themes, that include complex, multi-step math problems, e.g., calculating the ratio of legal to illegal harvesting of teak forests in Indonesia. These items require mathematics skills tutored in the ITS but the skills must be applied in the context of real-world content about endangered species topics and thus serve as an indication of transfer of learning.

We have now extended the Wayang-West ITS to include integrated motivation and mood self report instruments. Self reports are an efficient source of information about student states and do not require expensive or intrusive instrumentation or equipment that cannot be used in public school classrooms. (Also, self reports constitute something close to ground truth: if a student says that she is in a bad mood, or that she does not feel that she is any good in math, we are inclined to take her at her word.) The motivation instruments are based on prior work with the Online Motivation Questionnaire (OMQ) [8]. The OMQ is a well validated instrument that has been used to assess motivation in several academic domains, including mathematics. Its structure reflects current work indicating that motivation is context dependent and multidimensional, rather than being a static trait-like characteristic. In addition, the instrument includes an attribution assessment that is completed after the activity.

We modified the instrument to reflect the content of our specific task (preparing for math achievement tests, versus math classroom learning) and performed a week-long evaluation test with two geometry classes at an urban high school. (The detailed empirical results will be reported in [9].) The results made clear that the original instrument was too lengthy to complete in its entirety within the constraints of the class schedule. We therefore adapted a number of items and eliminated redundant items. The instrument is now intended to be completed as part of a User Profile, and includes questions to assess:

Learning goal orientation. Prior work suggests that students typically adopt either a performance goal orientation (e.g., wanting to earn a high grade), or a learning goal orientation (e.g., wanting to master the material). Students with a learning goal orientation use deep learning

strategies, seek challenge, and devote effort to demanding tasks. In contrast, students with a performance goal orientation are more likely to use shallow learning strategies, regard mistakes as evaluative threats, and withdraw when the task becomes difficult [10, 11]. In our experience, the learning-performance goal orientation must be supplemented with a third orientation that we call, "dis-engaged". These students indicate that they do not really care about doing well in school or learning the material; their goal is simply to get through the activity.

Incremental-entity beliefs. Students tend to believe either that intelligence is a fluid quality that can be enhanced through practice and effort, or that it is a fixed quantity [10]. These beliefs are especially strong in the domain of math learning. Students indicate their agreement with statements such as "I think that how smart people are stays pretty much the same throughout their life". In our prior work, students with incremental intelligence beliefs were more likely to use the multimedia help resources available in the ITS than students with entity beliefs.

Mathematics motivation. Math motivation includes beliefs about self efficacy, value of math, and enjoyment of math that have been found to mediate students' academic achievement [1]. Students with low self-efficacy do not expect to do well in math, even if they have done well in the past. Female students tend to have lower self efficacy in math than their male peers, even though females receive high grades on average in math classes. Students provide ratings in response to items such as, "This year I expect to < fail, barely pass, pass, do pretty well in, be one of the top students in > math class."

Daily mood reports. Wayang-West includes a brief mood report instrument that is completed by students each day before they begin the tutoring activity. Items include questions such as, "I'm having a < great day, OK day, bad day >".

### **3. The Wayang-West pedagogical model**

The goal of the Wayang-Weest pedagogical model is to promote student learning outcomes by balancing the goal of providing instruction with the goal of maintaining student engagement and motivation. The student who has lost interest will not attend to the instruction or use the resources that are available. Conversely, even the student who is interested will not learn if the material and help features selected for presentation are not well chosen. A major goal is to encourage students to engage in effort-based learning [12]. Human capability is open-ended and ability is created through sustained and targeted effort. To achieve this goal, we need to consider a teaching strategy which takes both cognition and motivation. Providing students with opportunities of experiencing successes through effort

enables them to have high self-efficacy in math and builds confidence that they can succeed in learning the material.

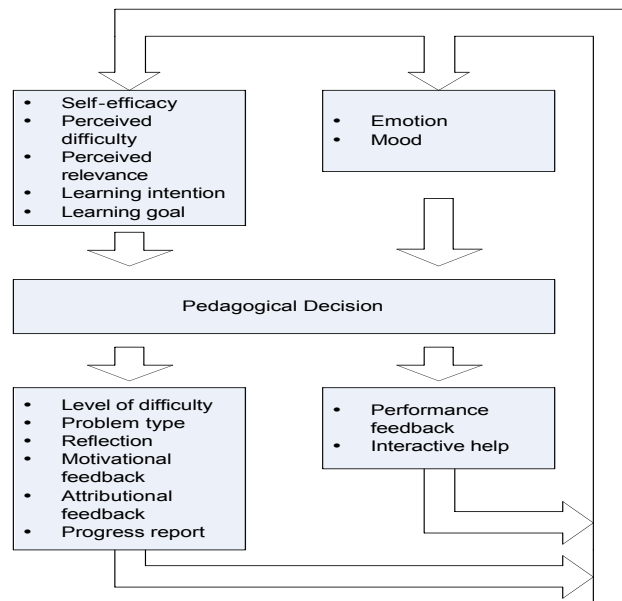


Figure 1: Pedagogical decisions in Wayang-West

The skilled human teacher has a wide range of tasks, strategies, and approaches that can be used to engage and instruct the student. As indicated in Figure 1, the ITS is more limited in the options that can be varied in the model. These include: the selection of problems to be presented to the student by difficulty (easy, moderate, difficult, in relation to student prior achievement); the selection of problems by domain topic (require the student to continue working on math problems about right triangles, shift to another topic such as corresponding angles); tutorial activity (continue with same activity, e.g., tutoring, or offer choice of another activity, e.g., adventure problems); the type of multimedia help provided to the student (visually-oriented help; algorithmic help); the availability of multimedia help (on demand, or after encouraging the student to attempt the problem independently first); provision of progress feedback, and other features to support self explanation and collaboration.

Some of the instructional decisions can be made before students enter the tutoring activity. For example, the problem selection mechanism can be adjusted on the basis of student prior knowledge, as indicated by the pre test results, and the increase in difficulty over problems can be adjusted in relation to student self efficacy. The purpose of adjusting the level of problem difficulty according to students' current performance is to enhance students' self-efficacy. Based on pre-test result, self-efficacy, perceived task difficulty, tutor may select appropriate level of problem for the student. Adjusted level of problem may increase the probability of success in solving the problems. For high achieving students, random problem selection mechanism is appropriate. For low achieving students, the ITS might show easy problems at first and progressively increase difficulty. Accumulated experiences of successes may improve students' self-efficacy in math.

The model can also offer alternate activities in response to student mood. For example, a tutor who sees that a student is having a bad day might suggest starting the session with a review of some material that the student has already mastered (i.e., providing easy material as a gradual transition into the learning activity). Human tutors offer choice to

engage reluctant students: thus, the student might be offered the opportunity to work on the virtual adventure problems; the fantasy element of the adventures is appealing to students (e.g., saving an orangutan in a rainforest fire, reconstructing a wildlife rehabilitation facility in a village destroyed by mudslides, investigate an illegal logging operation in a teak forest). Fantasy elements in software have positive effects on learning and motivation [13].

The student can also be encouraged to use the self-explanation feature in Wayang-West: after completing a problem, the student can make notes about the problem, why it was difficult, and what insights were needed to solve it. Of course, at some point the student must be directed to the tutoring activity in the ITS; it would not be pedagogically appropriate to respond to student low motivation or negative affect with avoidance of the learning activity. The point is that providing students with transitional activities and choices, even if limited, can help to engage the disengaged or discouraged learner.

Other aspects of the pedagogical model can be dynamically modified in response to student behaviors while working with the ITS. In particular, the student's help seeking can provide an indirect measure of engagement and motivation, in that requests for help are automatically recorded and available for analysis. Students vary significantly in their use of help resources: Some researchers have found that good students use and benefit from ITS help more than weaker students [14]. However, this may have been because the quality of the help was better matched to good students [15]. Others have noticed that some students have high help seeking rates because they are just searching for the right answer, clicking rapidly through the help features [16].

Our model makes the decision about whether to provide help in response to a request on the basis of a) the student's prior help seeking, e.g., if the student has requested all the hints on previous problems, the model may recommend help fading with the message to try the problem independently first; b) whether the student has seen a problem requiring the same skills before, e.g., the model might suggest the student review an earlier worked example; c) the student's prior knowledge: students with low skills should not be prevented from viewing help; d) the degree of interactivity in the help, e.g., rather than showing all hints in sequence, the student might be required to complete part of a problem before receiving more help. Interactive instruction makes students feel supported cognitively and affectively [17]. The pedagogical model can also adjust the probability of providing one type of help or another (visually-oriented, algorithmic). If students do not understand or benefit from one type of explanation, the model can increase the probability of providing the alternative type of explanation. Changing the type of explanation can also be used to re-engage the student with low motivation.

Student progress reports can also be used by the pedagogical model to address variations in learning, motivation and mood. Students want to know how they are doing, but they need more than objective information about the accuracy of their answers. Human instructors sandwich information about objective performance (such as test scores, number of problems correctly solved, etc.) with motivational feedback: "I know you can do this," and "Keep up the good work". Positive feedback can enhance students' self-efficacy but it works only when students feel that they can meet the task demands. Effort feedback is critical. This is in line with the principles of effort based learning and may change students' attributional styles from a belief in native ability to the value of effort [10].

Student progress reports should also have only individual progress information. Social comparison (information about how the student is doing compared to others in the class) can motivate some students, but is not generally very effective,

especially for low-achieving students. Their relatively poor progress may easily make them feel more helplessness and students are more likely withdraw effort to protect themselves from the implication that they lack ability [18].

#### **4. Conclusions and future work**

We are currently implementing the pedagogical model that considers student cognition, motivation and mood into the Wayang-West ITS for high school mathematics. The pedagogical model uses student self report data and observed student behaviors while interacting with the system to select appropriate teaching strategies for individual students.

The strategies reflect research on effective human teachers' teaching methods in classrooms and in one-on-one tutoring, along with factors that influence on students' motivation and cognition. We will be collecting additional data with high school students and will present empirical data about the effectiveness of the model at the workshop.

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