Targeting the affective state of students studying mathematics in a web-based ILE

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Abstract. Diagnosing and taking appropriate action based on students' motivation, effort and other affective characteristics is an important part of effective ILEs. Recognising that a student's affective state is influenced by the environment and didactical situation, we conduct research by employing an already integrated web-based environment (WALLIS) which students consider part of their everyday learning, making further research more realistic. The paper presents preliminary results from observations of students' interactions, which provide insight for the design of an affective component, and appropriate models upon which future work will focus.

1 Introduction - Background

The main focus of AIED has been intelligent tutoring systems (ITS) or learning environments (ILEs) (including adaptive and web-based ones) that would teach and assist learning in an 'intelligent' way. This is achieved by several techniques such as adapting the contents and available material to student needs and characteristics, adjusting the rate and trajectory through activities, providing individualised feedback according to their cognitive and affective (emotional and motivational) state. The latter issue has been neglected until recently where its importance has become more obvious to the AIED community [see for example 1,2]. The broader aim of the research discussed here is to investigate such issues. From prior experience in real tutoring situations and AIED research, we believe that diagnosing and acting appropriately, based on affective characteristics and particularly *effort* (as described below), are important skills of teachers and therefore of an effective tutoring system.

Developing educational systems that take account of affective issues is difficult due to the existence of various, usually contradictory, theories and because of the pervasive influence of affective factors. There are many examples which show that the affective state of students and their interaction with an educational system is crucially influenced by the teacher, the environment, and the didactical situation in general, interrelated with the students' individual differences. Mathematics in particular, constitutes a special case, often generating disaffection for some students who are 'afraid' of the subject. In addition, the importance of the accurate display of notation, the rather unnatural answer input, and the existence of multiple acceptable methods and syntactically correct answers, are issues as inherently significant as the teaching itself. These should neither be neglected, nor be assumed without evidence, when conducting research related to affect. Therefore we propose that it is better to conduct research in a specific context and environment. A particularly interesting group of students is those in science and engineering who study mathematics as support for their courses. Teaching these students is challenging, mainly because they have

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diverse backgrounds, they are often demotivated to study mathematics (since they fail to recognise its importance for their main subject), and yet they attend the same "one size-fits all" module. To improve this situation, the School of Mathematics is developing a web-based system, named WALLIS [3]. The fact that the first author is involved in the system's development and its integration into the teaching and learning process helps in controlling factors that could otherwise influence research on its affective component (some of the factors are covered at the end of section 3). Before describing the system in more detail, the following section illustrates the theoretical motivation and background that relates to this research.

2. Theoretical underpinnings

One of the many learning strategies, which also relates to affective issues and influenced the design of WALLIS, is the students' capacity to selectively ask for and receive help and the tutor's ability to provide feedback upon their actions. Notions proposed to describe exactly this tutorial process are *scaffolding* and *contingent instruction.* Wood suggested that tutors serve several key tutoring functions by 'contingent instruction' [4]. In brief, this means that when a student gets into difficulty, the tutor offers (as soon as possible) gradually more specific instruction or help than in the previous instance of difficulty. Additionally, the tutor must always try to provide the minimal help needed to ensure success by reducing (fading) the level of help. This process is related to Vygotsky's zone of proximal development [5,6] which provides a metaphor for the distance between what a learner can achieve independently and what her potential development is as determined under guidance by an expert — or a system if it takes the expert's role (see [7] for example). On this basis, WALLIS already provides a type of contingent feedback during the interactive activities (see next section and [3]).

Although the relationship between these theories and affect is not explicit there is a huge array of affective factors influencing the decision to help or not to help as well as to seek or not to seek help. Because ost of these (and similar) theories are addressed in human social interaction where one is more adept at recognising the emotional state of a learner the affective aspect of scaffold was more or less implied. A tutoring system, on the other hand, does not have the same information as a tutor has, and in order to design it to cope with affective characteristics we need more insight from other areas. Weiner [8], for instance, finds that the perceived benefit and cause of the need for assistance determines the decision to offer help. He also provides many related examples concluding that 'causes perceived as subject to personal control by the student in need, give rise to neglect (or are treated with punishment), whereas cases perceived as uncontrollable, generate help ...' and introduces, along with *ability,* the important (and often intuitively recognised but overlooked) characteristic of *effort*. In experiments, high effort or motivation was rewarded more for success, and punished less for failure, than lack of effort or motivation – which accompanied by high ability elicited greater punishment. Although little is discussed about the results of this appraisal method, the fact that it is natural in human teachers suggests that it may also be effective. Such an assumption is strongly supported by results in a rather different research field: that of belief (or meaning) systems [9], where people are seen as developing 'beliefs that organise their world and give meaning to their experiences'. According to this theory, people who believe intelligence and ability are malleable and changeable cultivate their intelligence through effort, task involvement, strategy development and challenge. Following failure, they remain confident that they can succeed, and believe that effort will actually increase their intelligence. Dweck's findings suggest that teachers should encourage students 'to relish challenge and effort, and to use errors as routes to mastery' [9 p. 4]. When teachers praise effort and strategic behaviour, students develop learning goals and a mastery orientation instead of performance goals that may lead to a learned-helpless orientation. Finally, Keller's theory of motivation, performance and instruction [10] emphasises the fact that effort is directly influenced by the person's motives, their personal expectations for success or failure and the design of the instructional situation. Performance is affected by effort, the design of the learning situation, and of course the individual's abilities, skills and knowledge. Keller sees behaviour as a function of both the person (motives, values, expectancy, abilities, skills, knowledge, cognitive evaluation) and the environment (motivational, learning and contingency design and management), describing the influence of these two factors on effort, performance and their consequences.

Assuming that a system has an affective component, it seems that effort is one of the characteristics that it should diagnose and act upon. Before describing how such a component could be implemented, the following section describes the current system.

3. The current system and its use as a research framework

WALLIS is described in detail in [3]. In brief, the system is delivered through a web browser and consists of three basic parts; the main frame, the toolbar frame (which apart from other tools includes an adaptive navigation tool), and the feedback frame which has a text area where help is provided and a button with which students can ask for assistance (see figure 1a and examples in [3]). In addition to static text, the main frame contains, where applicable, interactive parts (*applets*) that are embedded into the HTML page. During students' interaction WALLIS provides feedback using an adaptation of the feedback mechanism developed in DANTE [11,12]. The mechanism monitors students' actions (toolbars, menus, object manipulation and mouse activity), their achievements (goals, subgoals), and their help-seeking process. By tracking the goals that they have to achieve (eg., putting objects into certain positions, assigning appropriate values etc.) and with the help of a rule-based approach and pre-set misconceptions it provides feedback that adapts according to the elapsed time, their current hint-level and the degree of success of their previous actions. This helps students interact with the system more effectively, and understand their actions more efficiently. Other interactive activities (*JavaScript*) expect students to select an answer from a multiple choice question, fill a form (eg. a matrix), give a numerical answer or more complicated answer like a function and provide appropriate feedback on their interaction (see figure 1b and [3]).

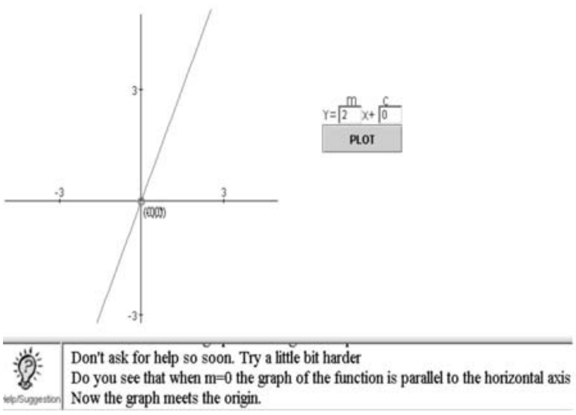

Figure 1a. An example of an interactive activity in which students have to explore the properties of linear functions

[*student tries to find standard form of a quadratic equation*]
No, that's wrong. [*student asks for hint*]
The eigenvalues you found can help you eliminate the coefficient of xy.
[*student tries again and because it's the second time she fails the system suggests asking for additional help*]
No, it's not that. Try again or ask for some help.
[*student asks for hint*]
Write the equation in the form <eigen1><var_x> + <eigen1><var_y> = <d> and use that to derive the standard form.
[*student tries to answer again having left the right hand side equal to 2*]
No, the right hand side should be 1.[*student asks for hint*]
Did you try dividing by 2 to get a standard form ?
[*student follows that correctly but has another misconception*]
No, it's not that. Remember that, by convention, you have to use the negative eigenvalue for the $$y^2$$ coefficient

Figure 1b.An excerpt from an activity where an answer is expected (note that the text would be provided at the feedback window in appropriate notation)

In contrast to other systems [for example, 7] the student model and the scaffolding process that WALLIS employs are quite naive, context-dependent, and based on several assumptions such as the concepts the user wants to learn, the path they will follow, and their cognitive state and abilities. On the other hand, the emphasis here is not on the feedback and suggestion mechanism itself (which other research looks into improving) but rather on its effective application, acceptance and usability by the students in order to facilitate research in its augmentation to take account of affective issues.

As we mentioned before, the fact that WALLIS is integrated into the wider teaching and learning process allows more realistic research on its ability to target affective characteristics. Following a specific methodology [for example 13], WALLIS has a user-centred graphical interface, which facilitates navigation and interaction, and provides accurate mathematical notation and friendly user input which is closer to the needs of the students we are working with. This is important, as early pilot tests showed that the cognitive load for students to type, and more importantly rapidly to understand, the given feedback was a significant interference to their learning (and their affect) and would hinder further research. WALLIS' being generally accepted as part of the wider learning process allows practical observations on students' interaction with it. From these we have seen that students respond and use the feedback mechanism, follow its suggestions and in general value the system's existence in itself: *support for their studies and not an experiment in which they participate*. This way, logs and observations on their navigation patterns, and their interactions with the activities, provide more insight into their effort and other affective characteristics.

4. Preliminary results

So far, our analysis has focused only on one aspect of students' interaction, which was observed during early pilot-tests where a high proportion (56% on average) of interaction was not satisfactorily completed. The completion of an activity is one of the easiest aspects for a system to monitor and could provide useful information to its affective component but we first need to partial out any unwanted effects. From more careful observations we noticed that some of the students just wanted to see what certain pages might involve and then immediately left (for example, to come back later). Others abandoned a page because they often did not know the answer to a question, and despite the difficulties they were facing they did not ask for more help. Recognising the complexity of this issue, we added a simple prompt that proposed to students that they remain at the page and ask more help or the solution/answer for their activity. This simple mechanism served the purpose of making students reconsider abandoning the page; it also focussed attention more explicitly on this process and helped us get more results during the interviews. After implementing it, apart from the abandonment rate dropping (14% in average), we were also able to separate students in several groups that manifested certain behaviours and randomly interview some of them. Interviews from the latest group of students interacting with the system showed that they quit pages either:

(1) because the goal of the activity and its relevance to the assessment wasn't obvious to them, or
(2) because they were successful in early parts of the activity and felt really comfortable with the rest, or
(3) because they were dissatisfied from struggling without managing any of the goals and
    (3a) wanted to try to finish some other time, or
    (3b) wanted to go to the appropriate page where theory is covered and come back, or
    (3c) never came back (probably because they were completely demotivated).

All these reasons involve affective characteristics (see next section and de Vicente's motivational model) and when taken into account should allow more tailored suggestions to be achieved, increasing the system's ability to target affective aspects.

Although the majority of students remain on the page and complete the activity, the current prompting mechanism was a simple, easily integrated solution to provide some additional insight into students' behaviour. The interviews, however, raised important interface issues such as the fact that certain students (especially the ones visiting a page in order to see what it contains, or the ones leaving to come back later) were annoyed by the prompt. When told that this could improve the system's ability to suggest study material and adapt the feedback they were still quite concerned by the interruption that would occur; but they said they would not mind doing it after certain pages (see also [14] for indications that students self-updating their motivational model preferred doing that at the end of each interaction). In addition, we are now able to start imagining how such an approach could be applied to allow students to inform the system on the reason they are leaving the page. This would contribute to the system's ability to diagnose affective characteristics, while at the same time offering a practical improvement to the interface (for instance, if it is obvious that they don't need to continue with a page because they feel they have achieved its objectives, or if they leave a page immediately after they visit it, then it is doubtful that they need to be prompted).

5. Further work

We are currently experimenting with several approaches (for example a prompt to suggest more help in completing the activity, or opening a new window with the page they want to visit). These will be pilot-tested with a small group of students who have already used the system. Further analysis of their interaction, comments and interviews could show the problems they face and provide insight into the system's acceptance and how it could better be used. Moreover, our preliminary data provide ways to measure performance and effort in interactive activities, but effort in particular is not well defined and little research exists. As we mentioned before, effort appraisal is perhaps one of the ways to promote an incremental view of intelligence, which has significant impact on students' motivation. During the last use of WALLIS in a class of 126 students who used the system to study a concept that could not be taught during the term we have logged all of their interaction with the system. Replaying and analysing the logged data could inform the design of the diagnostic component. It is proposed to follow a similar methodology as in [15], in which experts were questioned about students' interactions and the analysis of their responses elicited diagnosing and planning rules (see figure 2).

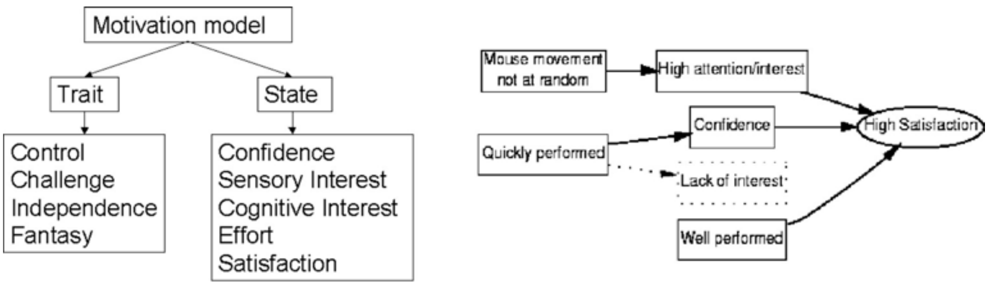

Figure 2. de Vicente's motivation model and a sample of the elicited rules (adapted by [14,15])

Of course disentangling effort from the rest of the affective characteristics (such as anxiety, boredom, sensory interest etc.) is a rather difficult task. This is why we need a more general framework that takes account of other characteristics or, at least, is able to take actions based on these. Therefore we propose to use de Vicente's model [14,15] as the general framework. The model proposes two main categories: traits (permanent) and states (transient characteristics). The trait variables provide the system with a general picture of the goals it should pursue with a particular student, and the state variables relate to transient characteristics of the material being learned (such as the ones elicited by our interviews). The model fits well with theories of motivation and recognises the importance of effort. Finally, in order to take appropriate action there is a need for a planner to regulate the interaction, such as the ones in [14, 15] and [16]. Therefore we need to look into ways of integrating these into WALLIS, and to delve further into the actions that the system should take in the context of this research.

6. Conclusion

The broad aim of the research proposed here is the investigation of affective aspects of users' interaction with a mathematical ILE, and in particular how such a system could take account of (and act according to) their motivation, effort and possibly other affective characteristics. To examine these issues we are conducting research in a specific environment using WALLIS as a prototype that is applied in the wider learning process and accepted and used by students. As we discussed above, some of the preliminary data involve actions that students may not have taken during a controlled experiment, and often reveal aspects that would have been difficult to observe otherwise. These data provide valuable insight for the design of a motivational component, but more importantly help in finding appropriate ways of integrating it into a real context. It is hoped that conducting research in such a way contributes not only to the AIED field but also to mathematics education, where affective aspects are often neglected. This may yield a type of evaluation paradigm (and research methods) in AIED, closer to those described in [13, 17].

References

[1] S. A. Cerri, G. Gouarderes, and F. Paraguau. *Intelligent Tutoring Systems, 6th International Conference*. Berlin: Springer-Verlag., 2002.

[2] F de Rosis, editor. *User Modeling and Used-Adapted Interaction. Special Issue on User Modeling and Adaptation in Affective Computing*, volume 11. Kluwer, 2001.

[3] M. Mavrikis and A. Maciocia. Developing WALLIS; a Web-based ILE for Science and Engineering Students Studying Mathematics in *Advanced Technologies for Mathematics Education* in *Supplement Proceedings of the 11th International Conference on AIED (to appear)*, 2003.

[4] D. Wood and H. Wood. Contingency in tutoring and learning. *Learning and Instruction*, 6(4), 1996.

[5] LS Vygotsky. *Mind in Society*. Michael C. et al. (eds). Harvard University Press, 1978.

[6] D. Wood and H. Wood. Vygotsky, tutoring and learning. *Oxford Review of Education*, 22(1):5–16, 1996.

[7] R. Luckin and B. Du Boulay. Ecolab: The development and evaluation of a vygotskian design framework. *IJAIED*, 10, 1999.

[8] B. Weiner. *Human motivation: Metaphors, theories, and research*. Sage Publications, 1992.

[9] C.S Dweck. *Self-Theories: Their Role in Motivation, Personality, and Development.* 1999.

[10] J.M. Keller. Motivational design of instruction. In *Instructional design theories and models.* LEA, 1983.

[11] M. Mavrikis. Towards more intelligent and educational Dynamic Geometry Environments. Master's thesis, The University of Edinburgh, Division of Informatics;Artificial Intelligence, 2001.

[12] M. Mavrikis and J. Lee. Towards more educational and affective microworlds. in *Proceedings of the 11th International Conference on AIED*, 2003.

[13] T. Conlon and H. Pain. Persistent collaboration: a methodology for applied AIED. *IJAIED*, 7, 1996.

[14] A. de Vicente and H. Pain. Informing the detection of students' motivational state: An empirical study. In *[1]*, pages 955–962, 2002.

[15] A. de Vicente and H. Pain. Eliciting motivation diagnosis knowledge. In S. P. Lajoie and M. Vivet, editors, *Proceedings of the 9th World Conference on AIED*, pages 651–653. Amsterdam. IOS Press, 1999.

[16] T. Del Soldato and B. Du Boulay. Implementation of motivational tactics in tutoring systems. *IJAIED*, 6, 1995.

[17] G. Cumming. Artificial intelligence in education: an exploration. *JCAL*, 14, 1998.