Motivationally Intelligent Educational Systems: Three Questions

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Abstract: In broad terms intelligent educational systems, whether learner-focused or teacher-focused, deploy their intelligence to assist in the development of the learner's knowledge or skill and assume that the learner is motivated to learn. By contrast, motivationally intelligent systems are able to deploy resources and tactics dynamically to *maintain or increase* the student's *desire to learn* and her *willingness to expend effort* in so doing. The design of motivationally intelligent systems is characterised in terms of (i) the data potentially available to the system for undertaking motivational and cognitive modelling and reasoning about those models and (ii) the ways that the system can dynamically react back to the learner on the basis of that reasoning. Three categories of diagnostic input and feedback reactions are outlined, each with its associated meta-level: (i) the domain and metacognitive; (ii) the affective and the meta-affective; together with their physiological and meta-physiological; and (iii) the overall educational context and meta-context. Three questions arising from this conceptualisation are presented.

Keywords: intelligent tutoring systems, motivation, motivationally intelligent systems

Introduction

According to Lepper, Aspinwall, Mumme, & Chabay (1990), expert human teachers include among their goals "first, to sustain and enhance their students' motivation and interest in learning, ... and second, to maintain their pupils' feelings of self-esteem and self-efficacy, even in the face of difficult or impossible problems."(p. 219).

The special goal of Motivationally Intelligent Systems is to maintain or even increase the learner's *desire to learn* and *her willingness to expend effort* in undertaking the, sometimes hard, activities that lead to learning. Such a goal is in addition to, but intertwined with, the more traditional educational system goals of offering information, activities and support for learning new knowledge and skills.

This paper is concerned with how motivationally intelligent systems can stimulate, maintain and (possibly) improve the student's desire and capability to learn. This means that the theories that the system is reasoning within need to take into account student attributes such as their goals, goal orientation and the reasons why they are in a learning situation at all, as well as their hope and curiosity, engagement, the degree of exertion they are willing to expend, their confidence in their abilities, their sense of control, and whether or not they are in, or would wish to be in, the "flow". By the same token such systems will need to worry about issues such as the student's possible frustration, disappointment, disenchantment, boredom, perplexity, or fatigue.

As de Rosis (2001) points out, affective issues are linked to student goals, are time-dependent, are influenced by context, depend on the internal state of the student, and are mutually interdependent so modelling them is both complex and uncertain. So how can systems take the above motivational and affective issues into account? For example, how could a system distinguish a "clever, confident but lazy student" from a "clever, anxious and hard-working one", and even if it could make this distinction how should its behaviour towards these two kinds of student differ? Especially if we accept that the overall educational goals of the system are to help the student improve their skills and understanding as well as to improve their capability as learners and their willingness to engage in further learning activities.

The structure of the paper is as follows. In the next section we discuss the kinds of data input available to motivationally intelligent systems and also the kinds of reaction open to them. In the following section we tabulate a number of systems that have operated in this area. Finally we raise three questions about how work in this are should be focused.

Categories of input and reaction

A crude but effective way to think about the design of motivationally effective systems is to think in terms of the kinds diagnostic input data available to the system and also in terms of the kinds of feedback reaction that the system might execute. Motivational theories indicate that many categories of factors combine together to determine the motivational state of a learner (see e.g. Boekaerts, 2003). One category is to do with what she knows and understands and with her metacognitive and self-regulatory insight. Another category is to do with her feelings and her awareness of those feelings, both anticipated and as experienced, including the memory of feelings as bound up with self-efficacy. Associated with feelings are their physiological counterparts, such as pulse-rate, breathing, posture and so for. Finally, there is the category of the social and physical context within which the learning is taking place and the perception and understanding of that context by the learner.

We define three broad categories within which motivationally intelligent systems operate together with their associated diagnostic inputs and feedback reactions, see Table I. By "inputs" here we mean the kind of event or measurement that provides input data to the system, such as the student asking for help, dominating a discussion with a peer, or their posture. By "reactions" we mean actions, reactions or outputs by the system, such as changing the facial expression of an online pedagogical agent, setting a harder problem, putting two students in touch with each other, or providing help and so on. These three categories are:

(i) The subject domain and metacognitive; e.g. what knowledge and skills the student has in mathematics (say) and what she knows and can manage about her knowledge and skills in that subject;

(ii) The affective and the meta-affective; how the student feels about the activity of doing the mathematics and what she can articulate and manage about her actual and expected feelings. Associated with this category are the physiological counterparts; e.g. bodily aspects such as heart and breathing rate, skin conductance, facial expression, body language and posture;

(iii) The overall context e.g. the physical, social and temporal milieu within which the student is taking part in the educational process.

Meta-cognition is normally regarded as knowledge about what we know. In relation to learning this means both our ability to <u>monitor</u> how well we understand something as well our ability to <u>regulate</u> our learning activities (Flavell, 1979). So, for example, someone who deliberately engages in self-explanation while they learn new material would be showing evidence of well-developed meta-cognitive ability.

Meta-affective understanding stands in the same relationship to affect as does the meta-cognitive to domain knowledge and skill. So meta-affective ability involves both <u>recognising</u> and being able to <u>articulate</u> one's feelings (i.e. monitoring) as well as the ability to <u>regulate</u> them. An example here would be knowing how we are likely to feel about taking a long time over some hard task such as writing a long paper, and developing strategies not just to cope with those feelings but also to manage them productively e.g. giving ourselves little treats when sub-tasks are completed.

In the same way that the cognitive and the affective are hard to disentangle, so there is a grey area between the meta-cognitive and meta-affective where each shades off into the other. Understanding our learning capabilities is hard to divorce completely from understanding the feelings that are associated with our learning.

Actions and reactions do not necessarily operate within a single category: we all recognise the *pleasurable feeling* of coming to *understand* something new, or the *feelings of frustration* when we fail to *solve a problem*. A system may take diagnostic input in one category but react in others: for example, imagine that a system is able to detect symptoms of nervousness on the part of a student, via sensors connected to the student's hands. On the basis of these symptoms the system might decide that one way to assist that particular student might be to react in terms of the educational context by changing the nature of the interaction from one-to-one, to many-to-one by inviting some of the student's peers to also take part in the same activity.

Table 1: Categories of input and reaction.

CATEGORY		DIAGNOSTIC INPUTS	FEEDBACK REACTIONS
DOMAIN	Knowledge and skills of the student.	Performance, latencies, effort, focus of attention	Activity choice, pace or order of work, provision of help
META-COGNITIVE	What the student knows, can articulate and regulate about her knowledge and skills	Difficulty of work chosen, use of available help (including gaming), goal orientation	Conversation about performance, degree of challenge, use of help, narrative framework
AFFECTIVE	How the student feels about the learning activity	Demeanour of student e.g. happy, engaged.	Praise, encouragement, criticism, politeness, teacher's demeanour.
META-AFFECTIVE	What the student knows, can articulate and regulate about her actual and expected feelings	Comments from student about expectations of feelings, motivation	Conversations about expectations of feelings, state of motivation, engagement
PHYSIOLOG-ICAL	Bodily aspects such as heart and breathing rate, skin conductance, facial expression, body language and posture.	Sensors: skin, body movements, Cameras: facial expression, posture	Breathing exercises, mantras, pauses.
META-PHYSIOLOG-ICAL	What the student knows and can articulate and regulate about her physiological responses.	Comments from student about her body	Conversations about physiological response
CONTEXT	The spatial, social and temporal milieu within which the student is learning.	Location e.g. classroom, home, library, why learning	Use of available peers and others, change of location, lighting.
META-CONTEXT	What the knows and can articulate and regulate about the context in which she is learning	Comments from the student about the context	Conversations about the nature of the context

Examples of Work

Much work has been carried out to explore various aspects of motivational systems. Table 2 gives some pointers to this work. Each cell in the table refers to a piece of work that has explored mainly in that cell, though most work has explored in more than one cell.

Table 2: Examples of recent research into the design of motivationally intelligent systems.

CATEGORY	INPUTS	REACTIONS
DOMAIN	**Qu (2005):** using focus of attention and latencies to detect whether the student is confused.	**del Soldato (1994)**: chooses appropriate next problem for student to solve depending on performance and motivational factors.
META-COGNITIVE	**Heiner et al. (2005):** predicting when students will interrupt provided help.	**Luckin & Hammerton (2002):** advising the student about her use of help and degree of challenge.
AFFECT	**De Vincente and Pain (2002):** helping teachers articulate rules that infer students affective state from interaction data. **Chaffar & Frasson (2004):** determining the student's optimum emotional state for learning. **Arroyo & Woolf (2005):** detecting the student's hidden affective state from external performance data using a Bayesian Network. **Gulz & Haake (2005):** how should pedagoigical agents represent themselves to users? **Hernandez et al. (2005):** predicting the student's affective state in terms of the OCC model. **Kim (2005):** how should a pedagogical agent present itself? **Martinez-Miron et al. (2005):** how should a system take the student's goal orientation into account. **Morales, van Labeke, Brna (2006):** modelling multi-dimensional aspects of competence, affect, motivation and metacognition.	**Blanchard & Frasson (2004):** developing systems that respect the student's sense of autonomy. **Conati & Maclaren (2004):** recognising and reacting to multiple emotions in the context of an educational game. **del Soldato (1994):** adapting to the student's motivational state. **Johnson & Rizzo (2004):** adjusting the level of politeness from a pedagogical agent. **Porayska-Pomsta & Pain (2004):** maintaining the student's "face" in educational interactions. **Alexander et al. (2005):** observation of human tutors adapting to the student's affective state. **Baylor et al. (2005):** dealing with student frustration. **Bader-Natal & Pollack (2005):** working on the issue of challenge. **Bateman & Paris (2005):** exploring the affective aspects of pedagogical dialogue. **Boff et al. (2005):** fostering collaborative learning. **Chen et al. (2005):** exploiting online animal companions in a collaborative learning situation. **Rebolledo Mendez (2005):** using narrative to improve the motivational state of the student.
META-AFFECTIVE	**Zhang et al. (2005):** detecting students affective state from their contributions to an e-drama. **Beal & Lee (2005):** using student's	**Marsella et al. (2003):** Interactive pedagogical drama for health interventions.

	self-reports to determine their affective state	
PHYSIO-LOGICAL	**Kleinsmith et al.(2005):** recognising emotional state from posture. **Prendinger et al. (2005):** recognising emotional state from body sensors.	**Mozziconacci (2001):** interpreting the facial expressions and voice. **Yussof & du Boulay (2005):** exploiting domain independent tactics such as breathing exercises to adjust the motivational state of the student.
CONTEXT	**Wolters & Pintrich (1998):** measuring students' motivation across different domains. **Tzvetanova & Tang (2005):** integrating contextual issues into reasoning about affect.	**Rickel & Johnson (1999):** adjusting the composition of a team of animated pedagogical agents to teach a complex collaborative training task.

Three Questions

Three areas of further work are identified: the role of the meta level, tradeoffs between categories and plausibility.

The Meta Level

A particular factor that has been identified in each category is its associated meta-level. The importance of these meta-levels emerges from motivational theory (see e.g. Ryan and Deci, 1990;.Bandura, 1977; Zimmerman, 2000; Pintrich, 2000; Boekaerts, 2003; Wentzel, 1997). Few systems have attempted to interact with the learner in the meta-affective and meta-physiological category or in the meta-contextual category, i.e. discussing with the learner the kinds of feelings that they are likely to experience in future learning interactions or inviting self-reflection from learners about how past learning experiences actually felt or indeed what kinds of social context they expect to make most progress within. In just the same way that there are clear benefits in bringing meta-cognition and self-reflection to the fore, we argue that meta-affective and meta-contextual reflection can produce similar benefits in terms of increases in learning at the domain level as well as more mature attitudes to future learning.

Tradeoffs Between Reactive Categories

While work in the classroom is starting to provide data on what works motivationally and what does not, there remain many similar questions in the design of systems. For example, what are the tradeoffs for diagnosing and reacting in the different categories. Imagine that you detect that a student has disengaged somewhat and has started gaming the system (Baker et al., 2004). What should the system do? At the level of the domain, it could make adjustments to the educational activity; at the meta-cognitive level it could offer advice about effective learning; at the affective level, it could offer an affective diversion – a joke possibly; at the meta-affective level, it could try to find out how the student is feeling; at the physiological level, it could suggest a screen break; at the contextual level, it could change the nature of the educational activity and make it a collaborative or cooperative one; and so on. What is for the best? The response from the system will be determined both by considerations of what might work best as well as by more pragmatic concerns. It is possible that a multi-category approach might be best. These kinds of trade-off are a whole new area of research.

Although we have described systems in terms of three categories of input and reaction, there is the need to differentiate more clearly how systems should deal with motivation and interest in learning (essentially a "level" issue) compared to feelings of goals, self-esteem and self-efficacy (an "orientation" issue), as identified by Lepper et al. (1990) at the start of the paper.

Plausibility

Reactions from a human teacher and a human peer do not always have the same effect as "identical" reactions delivered from systems. Much effort is focused on ensuring that animated pedagogical agents displaying reactions that mimic their human counterparts. But it is not yet clear how far this needs to go nor how effective it is. There is much yet to do in exploring this issue.

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