Designing Affective and Cognitive Educational Interaction

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Abstract
This chapter provides an introductory guide to the literature on the design of educational software that adapts to learner affect. It starts with some pointers into the complex, bilateral relationship between the cognitive and the affective during learning and the different kinds of affective focus that systems may be designed to embody. It then goes on to explore design choices for those interested in taking affective issues into account in building computer-based educational systems.

Introduction

When we observe how expert teachers behave, we find that they devote considerable time and effort to affective issues. For example, as Lepper and his colleagues report, 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" (Lepper, Aspinwall, Mumme, & Chabay, 1990, p.219).

This paper is about the design of educational systems, in other words the design of interactive computer-based educational systems that teach, guide and assess the learner. Knowing that the learner's feelings are an important aspect of how (and how much) they learn, the system designer needs to decide whether to take account of the potential feelings of the users as part of the design of the system, or whether to leave that kind of issue to the human teacher who runs the class within which the system is used.

Advantages and disadvantages of the approach

One advantage of taking such factors as "motivation", "interest", "self-esteem and self-efficacy" into account as part of the design of adaptive and intelligent systems is that such systems are likely to produce greater learning gains either

for learners working remotely on their own or, for a class of learners, without the need of the human teacher who is managing the class having to provide all the individual, minute by minute, affective support needed by each learner (see for example, Baker et al., 2008; Beal & Lee, 2005; D'Mello et al., 2011; Jaques, Lehmann, & Pesty, 2009; Paas, Tuovinen, van Merriënboer, & Darabi, 2005).

The disadvantage of taking these kinds of factor into account is a considerable increase in design complexity, as the system will need to detect, model and react to the learner's affective state in addition to dealing with cognitive aspects of the learner's state..

Design focus

So the first question facing the educational interaction designer with "affect in mind" is what role should affect play in the system being developed. It is a commonplace that the cognitive and affective are intricately intertwined in both learning and teaching (see for example, Boekaerts, 2007; Forgas, 2008; Kort & Reilly, 2002b; Picard, 2000), but deciding exactly how a human teacher or a system might take account of this is open to a wide range of possibilities (see for example, Ames, 1992; Balaam, Fitzpatrick, Good, & Luckin, 2010; Porayska-Pomsta, Mavrikis, & Pain, 2008).

The learner's relatively conscious appraisal of events *external* to him or her has both cognitive and affective consequences (Pekrun, 2006). For example, praise from a teacher may make the learner feel pleased, judge himself or herself to be making progress, and so decide to work harder, but in some circumstances it may have other effects (Dweck, 2002). Another is that the learner's relatively conscious appraisal of *internal* cognitive and affective events has both cognitive and affective consequences. For example, detecting that sense of increasing frustration when failing to solve a problem can trigger further affective responses (e.g. shame) as well as further cognitive reactions (e.g. deciding to give up, Diener & Dweck, 1980). In a similar vein, certain affective processes have relatively unconscious consequences for cognitive processes themselves (Forgas, 2007).

In taking account of this interplay, we distinguish design issues around (i) static aspects of the system that are the same for all learners (*non-adaptive*: see for example, Malone & Lepper, 1987), from (ii) dynamic aspects that adapt as a one-off to classes of users (*macro-adaptive*: see for example Arroyo, Beck, Woolf, Beal, & Schultz, 2000; Shute, 1993), and from (iii) dynamic aspects that adapt to individual learners at run time (*micro-adaptive*). This chapter concentrates on the micro-adaptive aspects of affective design, and to a lesser extent on the macro-adaptive.

In thinking about how adaptive decisions might be designed it is necessary to choose where the main design focus should lie.

Table 1: Possible design foci for affective and cognitive educational interactions

	Main Goal	
Main Design Focus	**Cognitive**	**Affective**
1. Cognitive	Increasing the learner's knowledge and skill	
2. Metacognitive	Increasing the learner's metacognitive capability, e.g. insight into what she understands and can do, and her ability to regulate her learning process effectively.	
3. Affective		Increasing the learner's overall sense of well-being
4. Meta-affective		Increasing the learner's meta-affective capability, e.g. her insight and regulation of her feelings as a learner.
5. Motivational	Increasing the learner's desire to learn, e.g. her willingness to expend effort on the learning process.	
6. Meta-motivational	Increasing the learner's meta-motivational capability e.g. her insight and regulation of her motivation	

Table 1 distinguishes six different kinds of primary design focus. For a more detailed discussion, see du Boulay et al. (2010). In the first row are systems that are designed to try to achieve cognitive gains (either in knowledge or skill). Apart from designing the interaction to be agreeable, but affectively the same for all users, they make only micro-level cognitive adaptations (see for example, Koedinger, Anderson, Hadley, & Mark, 1997; Mitrovic, Martin, & Suraweera, 2007). The vast majority of educational systems have been designed in this way.

In the second row are systems that are designed to increase the learner's metacognitive skills and adapt at the micro- or macro-level to that purpose. Typically they will also be concerned to achieve cognitive gains too, but take

the same design stance towards affect as in the first row. There is a growing number of such systems: see for example Aleven, McLaren, Roll & Koedinger (2006) and Luckin & Hammerton (2002).

In the third row are systems that aim primarily to increase the learner's sense of fun, excitement or well-being as a result of the educational interaction, and make either an initial macro-level, or dynamic adjustments at a micro-level to achieve this (see for example, Yussof & du Boulay, 2010).

The fourth row contains systems that aim to increase the learner's meta-affectively capability, so that are better able to identify and manage their own feelings in educational settings, e.g. working through confusion and disappointment (see for example, Burleson, 2006), or establishing an affective vocabulary for communication with the teacher (Balaam, Luckin, & Good, 2009).

It is the fifth row which starts to open up a more balanced educational design agenda between the cognitive and the affective. This focuses on the crucial educational issue of motivation. Yes, we want students to achieve cognitive gains but we also want them be able to deal with the vicissitudes of learning, as well as develop some meta-level skills of both a cognitive and an affective nature, so they are better equipped as learners in future educational interactions. Such systems are rare, but some educational games are beginning to develop capabilities in this design territory (see for example, Johnson, 2007).

Finally in the sixth row, are systems designed to achieve all the goals of the systems already mentioned, but also to help learners gain insight into their own motivational processes and capability, for example learning how to manage themselves so as to be able study despite distractions and temptations, in other words to become self-regulated learners (Zimmerman, 2008).

Which affective pedagogical theory or strategy

A number of different theories and strategies have been used by educators to manage learners' affect and motivation. The following table gives a number of examples, differentiating between macro- and micro-level adaptation. Following Pintrich (2003) we differentiate these examples in terms of whether they focus primarily on the learner's feelings, expectancies or values. Table 2 aims to provide a representative sample of theories, strategies and systems rather than an exhaustive list. For more detailed discussions see du Boulay et al. (2010) and Arroyo at al. (in press).

Most of the rows in Table 2 are self-explanatory. However we offer the following gloss on the "Detect and React" row. Many systems have been built

to detect the learner's affective state and, if that state is regarded as unconducive to learning, (e.g. boredom) try to make it more conducive. Care has to be taken as some apparently negative states (e.g. frustration) may be an essential component of some kinds of learning episode (Forgas, 2007), and do not need always to be reacted to (Baker, D'Mello, Rodrigo, & Graesser, 2010). Kort et al. (2002b) go further in that their theory of affect in learning embodies a sequence of affective states that cycles between the negative and the positive.

In the final row of Table 2 we refer to OCC Theory (Ortony, Clore, & Collins, 1988) as it enables systems to reason about learner emotions rather than simply react to them. This has been an important influence in the development of micro-adaptive systems, and so deserves individual mention. It is based on an emotional theory that describes emotions in terms of an individual's cognitive appraisal of events, objects and agents. So for example, a learner may have feelings of respect for a teacher (an agent) who operates in a very professional manner towards that student, and indeed, to other students whom the learner knows.

Table 2: Affective theories and strategies

Adapt. Level	Primary focus	Theory or Strategy	Examples
Macro	Values & Feelings	Relevance and saving face	Rosiek (2003) gives a number of examples of where human teachers find ways to make the learning material relevant to particular groups or ways to explore controversial topics. For an example of a system that macro-adapts based on gender, see Arroyo et al. (2000).
	Expectancies	Goal orientation	Various researchers have built systems based on Dweck et al.'s (1995) distinction between mastery and performance goals in learning, see for example Martinez-Miron et al. (2005).
Micro	Feelings	Empathy	Various researchers have built systems that attempt to detect the affective state of the learner and acknowledge that perception by adapting the demeanour or feedback from the tutor to demonstrate empathy (see for example, Arroyo, Woolf, Royer,

			& Tai, 2009; Burleson, 2006; Zakharov, Mitrovic, & Johnston, 2008).
	Feelings & expectancies	Detect and React	Various researchers have built systems that (i) *detect* either affective states, or cycles of states, either through observation of the learner's demeanour or his or her actions, such as gaming the system, and (ii) *react* appropriately. This may be to try to fix things if there is a problem or consolidate the situation if not (see for example, Baker et al., 2006; Graesser, Chipman, King, McDaniel, & D'Mello, 2007; Kapoor, Burleson, & Picard, 2007; Kort & Reilly, 2002a; Muldner, Burleson, & VanLehn, 2010).
	Feelings, Values & Expectancies	Model-based	Some researchers have modelled and predicted the affective states of learners. They have often adopted OCC theory (Adam, Herzig, & Longin, 2009; Ortony, et al., 1988) in the design of their systems, see for example (Conati & Zhou, 2002; Jaques & Vicari, 2007). .

Which pedagogical interventions should be available

The designer will need to consider the design of individual lessons and their components. So a designer may wish to ensure that the introduction to a lesson has both an explicit cognitive and an explicit affective dimension. For this to be automated, the system would need to know something about what was studied last time, how it was received, what the goals and methods of the current session are to be and how they are likely to be received. Considerations of how best to conclude a lesson may well mirror those around how best to start one, as indicated above. This requires both careful logging by the system of what happens as well as modelling derived from those logs.

In terms of ordering concepts and finding the right balance of activities (examples *vs* problems, say) there are various theories that can be applied; for

example there are some based around learner motivational characteristics (master vs perfromance: see for example, Dweck, et al., 1995) or learning style (active vs reflective: see for example, Graf, Liu, Kinshuk, Chen, & Yang, 2009), or around learner cognitive capacity limitations (see for example, De Jong, 2010).

Which affective states are to be distinguished and how are they to be identified

There is general agreement that the "basic" emotional states developed e.g by Ekman et al. (1972) are not a useful set with which to design educational interactions. For example they include anger and disgust, and neither of these tends to occur, though other more nuanced negative feelings are important in education such as disappointment, frustration, shame and anxiety. In the search for a more useful set, some research has observed students in educational settings via a mixture of observation, self-report, interviews and questionnaires and has identified a space of affective states: "enjoyment, hope, pride, relief, anger, anxiety, shame, hopelessness, and boredom" (Pekrun, Goetz, Titz, & Perry, 2002). This space is often portrayed in a two dimensional form with the degree of arousal (how strong the feeling is) along one dimension, and the valence (negative or positive) along another. Some systems operate simply on valence and distinguish and react to whether the learner is in a broadly positive or broadly negative frame of mind (Zakharov, et al., 2008). A set of affective distinctions, commonly used by micro-adaptive system designers, is between "boredom, flow (engagement), frustration, confusion, delight, surprise, and neutral" (see for example, Graesser, et al., 2007). The main design issue is whether the system is able to differentiate its reactions between all the affective states that can be identified (see for example, du Boulay, 2011).

The methods and technology for identifying the affective states of learners fall into four categories. First there are various forms of self-report where learners are prompted to indicate their affective state (see for example, Balaam, et al., 2010; Beal & Lee, 2005). Second there are methods using cameras to identify facial expression and from thence affective state (Craig, D'Mello, Witherspoon, & Graesser, 2008). Third there are various kinds of sensor to identify body posture, skin conductance, heart rate, brain waves, and grip on the mouse. As yet the jury is still out as to which kind of technology works best (for a comparative analysis, see for example, Arroyo et al., 2009). Fourth are methods based on observing learner behaviour, either from what they say (D'Mello, Craig, Witherspoon, McDaniel, & Graesser, 2008) or from the balance of off-task and on-task behaviour (Walonoski & Heffernan, 2006).

Conclusions

This chapter has delineated some of the issues that must be considered by a designer of educational systems which react to affect. The order of description has been top-down from considerations of which affective pedagogical theory to embody in the system, which educational interactions are to be catered for, which affective states are to be identified and distinguished, and what methods are to be used to identify those states in the learner.

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