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Abstract. We analyze the relationship between a variety of affective constructs that have been published, as it is not clear what the relationship between these is, which are redundant or the same, and which ones are different, when it comes to automatically predicting affect in tutoring systems. A deep analysis allows to understand how affect, motivation and emotions relate to each other, and how we could potentially design interventions to address them.

Keywords: affect, assessment, modeling of emotions

1 Motivation

Several research groups have used Artificial Intelligence Techniques to model and recognize student affect in Interactive Learning Environments, and started exploring mechanisms to repair or cope with negative emotions.

However, there are several different theories and constructs for student affect, so much of the work is hard to compare and divergent in approaches. Some of them relate to emotions, others to affective predispositions, other to attitudes, and yet others to motivation. There is a general lack of clarity between of the difference between engagement, attitudes, motivation and emotions, for instance, and which constructs would be best to use or more important when talking about “affect” in learning software.

It is particularly unclear how exactly these constructs overlap, which ones are redundant, and how they relate to each other. When creating a survey or a model for an emotion, which one should be taken into account? This article presents the results of a correlation research study to quantitatively validate and establish the relationship between a variety of affective constructs. The hope is that this will bring more clarity to the relationship among these, the possibility to eliminate redundant items, and make clear which constructs are better to use for which situation, particularly for those who are modeling student affect.

Theories of Affect and Affective Constructs

Many research groups have used minimally invasive sensors to help predict a large percentage of variance in student self-reports of (“How [confident/anxious, bored/interested, excited/not-enjoying, frustrated/not-frustrated] do you feel right now?” (e.g. [9]). Sensors provide data about posture, movement, grip tension, arousal, and facially expressed mental states [1]. Additionally, these constructs are modeled from behaviors and inferred automatically with a high degree of accuracy using students’ recent performance and styles of use of the software. While sensors improve the accuracy of emotional diagnosis, tutor-context variables (e.g., number of hints requested, effort excerpted) are also important in emotion detection.

However, it is unclear what affective variables are of interest to an intelligent tutoring system. Affect is a general term that refers to all emotion, motivation, and attitudes and maybe even engagement. Each of these constructs are very different from each other. For instance, attitudes are affective predispositions that students bring to the educational context, grounded in beliefs about themselves and the task. Motivation as related to students’ goals, and for instance their desire to learn versus desire to perform. Emotions are fluctuating affective personal experiences. Several theories of emotion, attitudes and motivation have been proposed [3][4][5], though only a few of the affective theories are related to education.

One of the few emotional theories grounded in education is the **control-value theory of emotions** in education by Pekrun and colleagues [5], which describes several emotions related to achievement in learning situations, and instruments for measurement. Achievement emotions may be classified according to their valence (positive/negative), and their arousal (activating/deactivating), and their focus (activity/outcome). Positive activating achievement emotions (enjoyment of the activity, hopeful/confident to achieve the outcome) exert a positive impact on achievement, while negative deactivating emotions (e.g. boredom, hopelessness) have negative impact. However, given that these emotions have been studied via surveys, and not at the moment they occur, we cannot call them ‘emotions’ per se, but “affective predispositions”. We thus considered the following achievement emotions, and two items for each different construct from the Achievement Emotions Questionnaire for Math in [6], the most reliable items:

JOY_P	JO1CD	I enjoy my math class.
	JO5LD	When doing my math homework, I am in a good mood.
PRIDE_P	PR2CA	I am proud of my contributions to math class.
	PR1CA	I am proud of how much math I know.
ANGER_P	AG7LD	I get so angry when doing math homework that I would like to throw it into the trash.

	AG2CD	I am so angry during math class that I would like to leave.
SHAME_P	SH2CD	I am ashamed that I cannot answer my math teacher's questions well.
	SH3CD	When I say something in my math class, I feel embarrassed.
	AX3CB	When thinking of my math class, I get queasy.
ANXIETY_P	AX2CD	I worry when the math material is too difficult for me.
	AX12TB	Even before I take a math test I worry I could fail.
HOPELESS_P	HL1TB	I feel down before starting my math work.
	HL5TD	When solving math problems, I would prefer to give up.
BOREDOM_P	BO3CD	I am so bored I can't stay awake.
	BO5LD	My math homework bores me to death.

The **affective predisposition constructs** by Arroyo, Woolf, Burlison and colleagues [9] built from data from hundreds of students in real classrooms, were rooted in [4], then grounded in an educational context and names changed, to classify four ranges of emotional self-concept including frustration, interest, confidence and enjoyment with over 78% accuracy and a similar accuracy when validating across student populations, with students in new schools and classes (Cooper et al, 2010). These can be considered emotions when asked inside of the tutoring system (e.g. "how frustrated do you feel right now?") and 'affective predispositions' when asked in a pre/post survey (we modified the emotion question to ask "how frustrated do you get when solving math problems?").

INT_A	How interested do you feel when solving math problems, in general?
EXC_A	In general, how exciting is it to solve math problems?
CON_A	How confident do you feel while solving math problems, in general?
ANG_A	How angry do you get when solving math problems?
FRUS_A	How frustrated do you get when solving math problems, overall?
ANX_A	How anxious do you get while solving math problems?
SHAME_A	How embarrassed (ashamed) do you get while solving math problems?
BOR_A	Do you get bored when solving math problems?
JOY_A	Do you enjoy solving math problems?
HOPL_A	Do you feel hopeless when you solve math problems? (reverse scale, Very...Not at all)
PRIDE_A	Do you feel proud when you solve math problems?

Motivational constructs by Mueller and Dweck [8], attempt to discern students' deeply rooted goals when carrying out a task. These goals may be related to affective predispositions, their perceptions about themselves, and their perception of learning in general and of the domain to be learned. The construct tries to discern true interest in learning versus goals of performance. This construct has been used in surveys by other members of the ITS community, so it is important to understand. This is a categorical assessment with several distractors, so that students don't figure out which one is the "right one" to choose. Each LOR1 and LOR2 are coded 1 or 0 if the learning orientation option was chosen or not. LOR_M is the average of these two binary variables. Thus, possible values for LOR_M are 0, 0.5, or 1.

LOR1 Dweck	Some math classes have extra-credit projects. If you had your choice, what kind of extra projects would you most like to do? (Circle one option) a. An extra-credit project that is easy, so I can get a better grade b. An extra-credit project where I could learn about things that interested me c. An extra-credit project in an area I'm pretty good at, so I can show my teacher what I know d. An extra-credit project that isn't very difficult, so I don't have to work too hard
LOR_M	We are considering adding a new feature to our math practice software, to give you more control over the problems the software gives you. If you had your choice, what kind of problems would you like best? (Circle one option) a. Problems that aren't too hard, so I don't get many wrong b. Problems that are pretty easy, so I'll do well c. Problems that I'm pretty good at, so I can show that I'm smart d. Problems that I'll learn a lot from, even if I won't look so smart

Attitude constructs by Eccles and Wigfield [7] attempt to understand students' concept of themselves as capable to carry out the task, the value of pursuing the task, and the appreciation for the task. These come from developmental psychology, and there is an apparent overlap with other affective constructs from other fields.

SC_E	SC1	Some people are better in one subject than in another. For example, you might be better in Math than in English. Compared to most of your other school subjects, how good are you in math?
	SC2	How good would you be at learning something new in math?
ML_E	ML1_E	In general, I find working on math activities... (Very Boring ... Very interesting)
	ML2_E	How much do you like doing math? (Not at all Very Interesting)
MV_E	MV1_E	Some things that you learn in school help you to do things better outside of class, that is, they are useful. For example, learning about plants might help you to grow a garden. In general, how useful is what you learn in math?
	MV2_E	For me, being good in math is... (Not at all important ... Very Important)

All of the items mentioned above assess affective predispositions and not true emotions, as emotions are fluctuating and depend on the context or situation, and the interaction with those subjective predispositions. In the Intelligent Tutoring Systems

community we are for the first time talking about true **emotional constructs**, as we can stop the student and ask about how they are feeling ‘right now’, or how were you feeling in ‘that specific moment’ if asking students to look back.

We believe the difference lies in what is clearly expressed in Figure 1. Affective predispositions constitute the baggage students bring to the situation, and emotions are a result of affective predispositions + the context the student is in + recent history, as shown in figure x. An emotion is a short-term experience, and the assessment of emotion is different from the assessment of predispositions in how we ask the question --pointing to an adjective and asking about the awareness of the feeling or experience in the present time.

INT_A _{em}	How interested do you feel right now?
EXC_A _{em}	How excited do you feel right now?
CON_A _{em}	How confident do you feel right now?
ANG_A _{em}	How angry do you feel right now?
FRUS_A _{em}	How frustrated do you feel right now?
ANX_A _{em}	How anxious do you feel right now?
SHAME_A _{em}	How embarrassed (ashamed) do you feel right now?
BOR_A _{em}	How bored do you feel right now?
JOY_A _{em}	How much are you enjoying this right now?
HOPL_A _{em}	How hopeless do you feel right now?
PRIDE_A _{em}	How proud do you feel right now?

4 Method and Results

Two hundred and forty students (N=240) took a survey before using a mathematics tutoring system. Students were enrolled in math classes in public schools, 7th, 8th and 9th grades from various levels, rural and urban schools. One of the purposes was to analyze all of these affective constructs, see how they relate to each other, and how they relate to emotional self-reports inside of the tutoring system.

The first step would be to measure the extent of the correlation, and consider some constructs basically the same and redundant if the correlation is greater to a certain threshold. We establish that if the correlation is $R \geq 0.75$, then the constructs are basically *equivalent*, and can probably one of them can be omitted in any further assessment. The other possibility is that the two constructs being considered are *related* to each other, but not exactly the same. In that case, those constructs might affect students and their behaviors in the tutoring system in a different way. This is the case for affective constructs of a correlation with an upper and a lower threshold.

Value Oriented

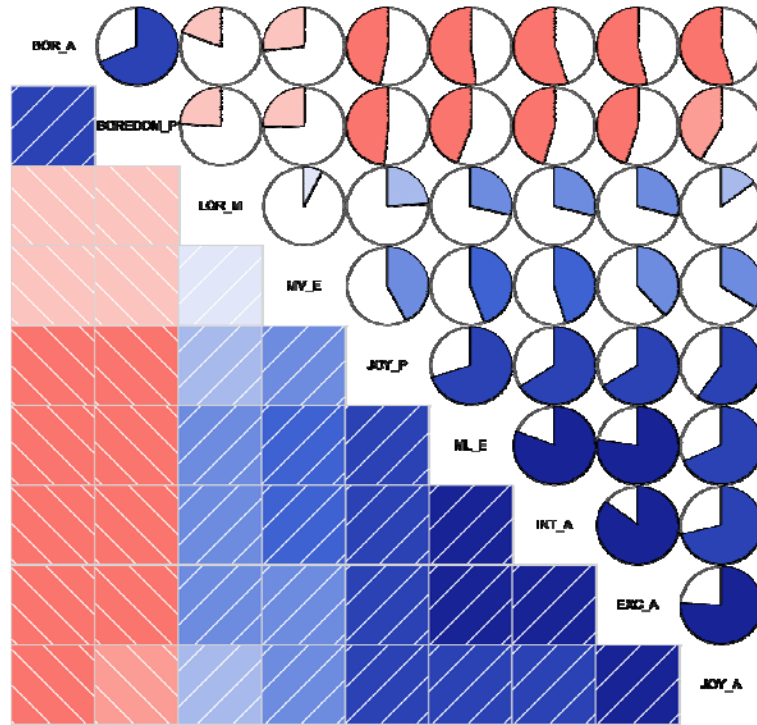


Fig 2. Correlation between control-oriented affective constructs

We consider two constructs to be *highly related* when $R \geq 0.5$ and $R < 0.75$. We consider two constructs to be *moderately related* when $R \geq 0.25$ and $R < 0.5$. The last possibility is that the constructs are *unrelated*, completely different ($R < 0.25$). Note that the significance level for this amount of students is significant at $p < 0.001$ for *moderately significant* correlations. However, this seems fair due to the large number of comparisons.

As we have 21 constructs, we start by separating two different sets of variables that are fairly different from each other. This classification in two sets is based on Pekrun and colleagues [5] control-value theory. The theory assumes that students experience emotions when they feel in control of, or out of control of, activities and outcomes that are subjectively important to them, which suggests that control appraisals and value appraisals are the proximal determinants of their emotions. Occurrence and intensity of achievement emotions are seen as a joint product of these two kinds of appraisals (control and value). For example, anxiety is seen to be induced when the outcome of an exam is perceived as not being sufficiently controllable, but

subjectively important. Conversely, if a student feels in control and does not expect failure or does not care about the exam, there is no need to be anxious. Similarly,

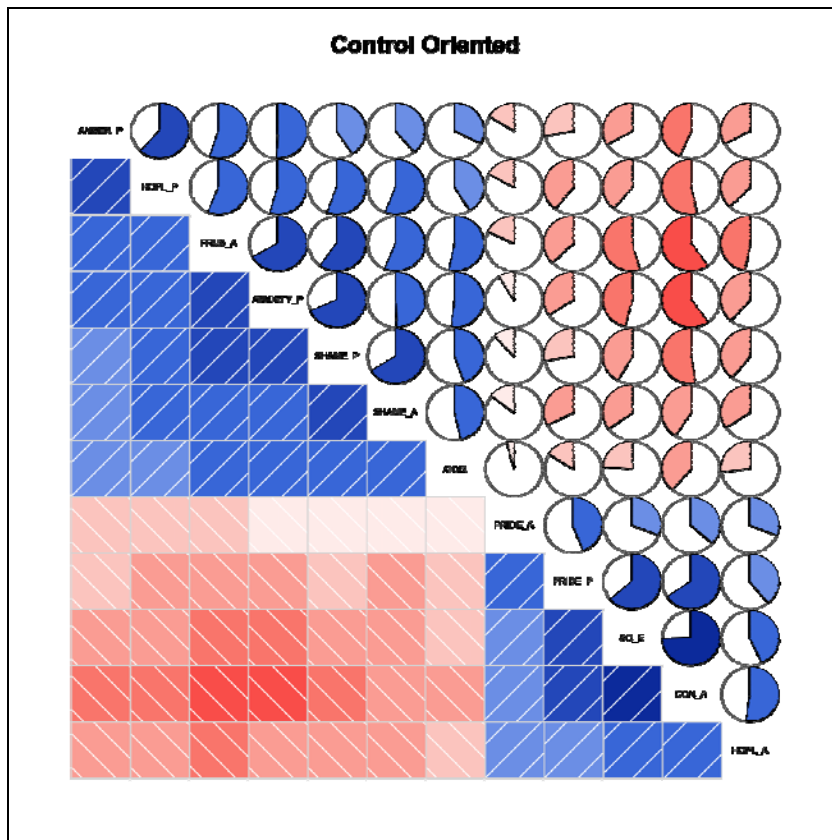


Fig 3. Correlation between value-oriented affective constructs

enjoyment of learning is seen to be instigated if a student feels competent to master the material and values the material. If the student feels incompetent or is disinterested, negative activity emotions such as boredom are induced rather than enjoyment.

Thus we classify the set of *control-oriented* constructs (high or low control), composed of PRIDE_P, PRIDE_A, ANGER_P, ANXIETY_P, ANX_A, SHAME_P, SHAME_A, HOPL_P, FRUS_A, HOPL_A, SC_E, CON_A. The other set is *value-oriented* variables (high or low value), regardless of control, or: JOY_P, JOY_A, EXC_A, BOREDOM_P, BOR_A, INT_A, ML_E, MV_E, LOR_M. The next section presents correlations between and across categories.

5 Results

Value-Oriented Affective Constructs. Figure 2 shows the results of correlating *value-oriented* affective constructs. Several of these constructs are basically *equivalent*. For instance, ML_E (Eccle's Math Liking) is equivalent to Arroyo's Interest (INT_A). This is not surprising as both of the items in ML_E talk about interest of math. What is not so obvious and important to know is that ML_E is equivalent to EXC_A (excitement). These three constructs, math liking, interest, and excitement are redundant and two of them can be eliminated. However, EXC_A is *equivalent* to JOY_A, while JOY_A is only *highly related* to math liking and interest. Thus, reducing those 4 constructs to 2 (one for joy and one for liking/interest) would be the best approach.

Surprisingly, constructs that were expected to be *equivalent* but were not, are BOREDOM_P and BOR_A, as they are only highly related, as well as JOY_A and JOY_P. The suggested way to proceed in this case is to aggregate items to make a richer boredom and joy construct.

Control-Oriented Affective Constructs. Figure 3 shows the results of correlating *control-oriented* affective constructs. We found only two constructs that are basically *equivalent* (see pies with painted section $> \frac{3}{4}$). These are Eccle's SC_E (Math Self-Concept) and Arroyo's CON_A ("How confident do you feel when solving math problems?"). We then discard SC_E as CON_A is simpler, involving a single item.

Surprisingly, constructs that were expected to be *equivalent* but were not, are ANXIETY_P and ANX_A, or PRIDE_A and PRIDE_P. The suggested way to proceed in this case is to aggregate those items to make a richer anxiety and pride construct. Meanwhile, Constructs that are *highly related* in a non-obvious way regard pride and confidence. PRIDE_P is highly related to both SC_E and CON_A. In turn confidence highly relates to anxiety --CON_A in particular is highly related (negatively) to one of the anxiety constructs, ANXIETY_P. CON_A also highly relates to FRUS_A, HOPL_P, HOPL_A, SHAME_P. This suggests talking with students about their "confidence" which is a construct related to attitudes, students are talking about a complex summary of a variety of emotional experiences related to hope, anxiety, frustration, shame and pride. A variety of control-based constructs of negative valence are highly related too. Anger, hopelessness, frustration, anxiety and shame are all highly correlated among themselves.

Rare cases across categories. Figure 4 shows correlations across all variables. This is interesting in particular to see extremely *unrelated* cases and relationships across control and value constructs. If an item is completely unrelated to all others, it is possible that there is a problem with that specific item. One of such cases is ANX_A (written as ANX2 by mistake in the charts). This item in particular talks about being anxious, and may be simply too explicit for students. Instead, the other anxiety construct (ANXIETY_P) is more subtle by talking about worries and physiological discomfort during testing, but not explicitly mentioning the word 'anxiety'.

All Questions

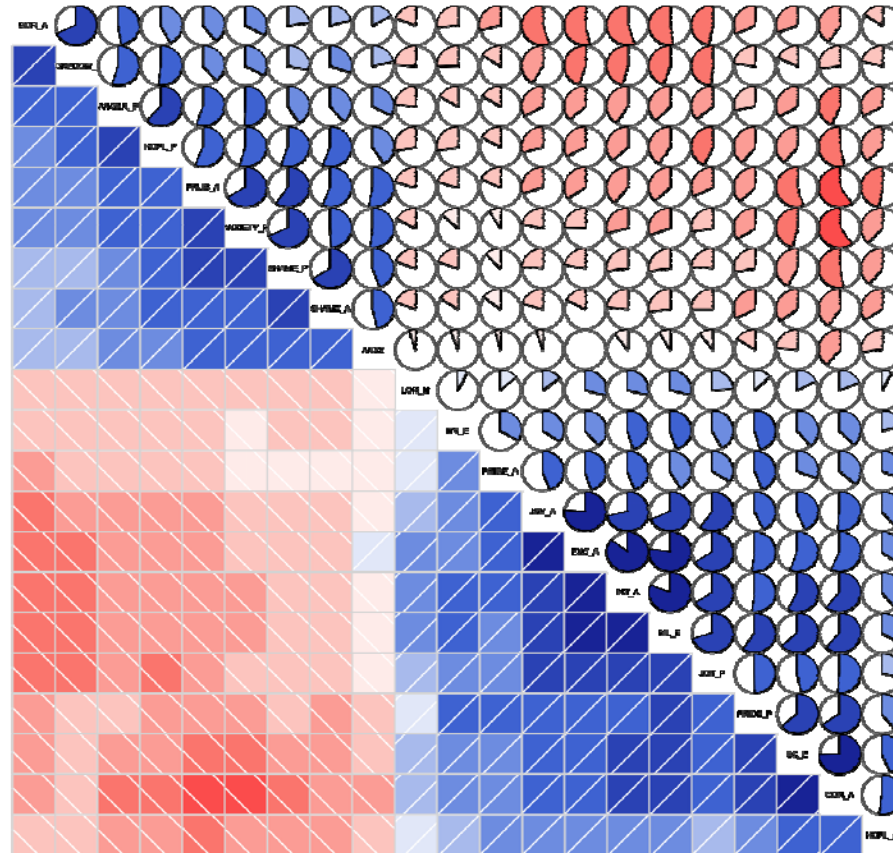


Fig. 4 Correlation of all variables

The other rare construct regards the motivation construct by Mueller and Dweck (LOR_M) regarding learning or performance orientation. This one is only *moderately related* to interest/liking and to one of the hopeless constructs (HOPL_P). This means that either motivation is a completely different construct from other affective variables, or the items are just not well designed to assess motivation. It seems reasonable that students' learning or performance orientation would be related for instance to shame, particularly when students have mastery orientation (LOR_M=low value). Another similar case is Eccle's math value (MV_E), which is only moderately related to the interest/liking variables and PRIDE_P.

The next step is to evaluate if these constructs is related to any other variables in the system (emotions within the system? Mastery? Learning measurements?), or if we simply want to optimize those variables by themselves, setting them as a new educational goal (having students feel that mathematics is valuable, or that learning for the sake of learning is valid). In such a case, we need more constructs that relate to these ones, as a single assessment item gives a very partial grasp of the construct.

6 Discussion

We have uncovered important relationships between affective constructs coming from a variety of fields and theories, that suggest that several affective constructs are basically equivalent, and can be simplified. Others are related but not the same, and others completely unrelated. Some are extremely rare and might not be useful for any assessment.

What were considered general math attitudes [7] are related to students' emotional predispositions: we found that students' pre-tutor attitudes about mathematics highly correlate with their reported feelings regarding solving problems [9], including the reported confidence or anxiety reported while solving math problems, or students' worries and shame, frustrations and sense of pride.

Past research has shown how self-reports of simple emotional states within a tutoring system are related to what has recently happened in the software interaction - characteristics of the context and level of success in the last problem can impact students' reports of emotions such as frustration and anxiety. The next step consists of understanding these emotions and affective constructs with a higher level of detail, after removing redundant ones, and creating specific interventions to address very specific emotions and situations. The vision is to shape the context within the tutor and its pedagogical moves (support, problem difficulty, affective talk, etc.) to impact a large breadth of students' emotions.

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