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Students' Emotions in the High School Mathematical Class: Appraisals in Terms of a Structure of Goals

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Abstract Little research in the field of Mathematics Education is directed towards emotions of students beyond their emotions in problem-solving. In particular, the daily emotions of students in a mathematics class have been sparsely studied in the field of mathematics education. In order to fill this gap, this qualitative research aims to identify high school students' emotional experiences in the mathematics classroom and identify the appraisal structures that support such emotional experiences. Focus group interviews were carried out until theoretical saturation of the data was achieved (N = 53 in nine focus groups interviews). Data analysis is based on the theory of cognitive structure of emotions, which specifies eliciting situations for each emotion and the variables that affect intensity. The emotional experiences in this structure are as follows: satisfaction, disappointment, hope, fear, joy, distress, boredom, interest, pride, reproach, self-reproach, like and dislike. These results show that the emotional experiences of students are based on their appraisals of events, objects and agents in terms of a structure of goals.

Keywords Appraisal structures · Emotions in mathematics classroom · Emotions in mathematics education · Goals · Students' emotions · Theory of cognitive structure of emotions

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Introduction

Students' Emotions in Mathematics Education

Most of the research on students' emotions in the field of mathematics education focuses on their role in mathematical *problem-solving* (e.g. Adams & McLeod, 1989; DeBellis & Goldin, 2006; Goldin, 2000; Op' T Eynde, De Corte & Verschaffel, 2006, 2007; Schoenfeld, 1985) and *mathematics anxiety* (e.g. Ashcraft & Krause, 2007; Bekdemir, 2010; Hembree, 1990). Research also focuses, to a lesser extent, on students' emotions in mathematical engagement (Goldin, Epstein, Schorr & Warner, 2011; Schorr & Goldin, 2008) and in the mathematics classroom (Frenzel, Pekrun & Goetz, 2007; Larkin & Jorgensen, 2015; Lewis, 2013; Op' T Eynde et al., 2006).

Emotions in Problem-Solving

Op' T Eynde et al. (2006, 2007) find that students experience different emotions while solving problems. For example, a student can be *worried* at the beginning of the process while finding a strategy to solve a problem (as evidenced by descriptions such as "brow lowering" and "not feeling well"). If the solution does not appear after 10 s, then the student becomes *frustrated* ("I don't want to use the calculator", "it does not help me", "but I still want to reach the goal"). Finally, emotions such as *panic* or *anger* may appear ("come on, what is this all about?"). This research concludes that students experience negative emotions if they are not able to solve a problem as easily as expected and that emotional experience triggers them to redirect their behaviour to look for alternative cognitive strategies to find a solution to the problem.

Mathematics Anxiety

Mathematics anxiety refers to the negative reaction that many people experience when placed in situations that require mathematical problem-solving (Richardson & Siunn, 1972); it manifest as feelings of apprehension, dislike, tension, worry, frustration and fear (Goldin, 2014; Wigfield & Meece, 1988). Research shows that mathematics anxiety has been associated with negative feelings surrounding mathematics and has adverse outcomes on both mathematics performance and the confidence to learn mathematics (Bekdemir, 2010; Hembree, 1990; Ma, Xu, & Xu, 2004).

Emotions in Mathematical Engagement

In mathematics education, Schorr and Goldin (2008) describe the roles of dignity and respect in creating an emotionally safe environment for mathematical engagement. They also identify several recurring patterns—"behavioral/affective/social constellations"—of in-the-moment desires, emotions, behaviours and social interactions, which they term engagement structures (Goldin et al., 2011). As in cognitive structures, these engagement structures are present in individuals and become active in certain social-mathematical situations. Each situation includes as many as 10 interwoven, mutually interacting strands, 4 of which are related to emotions and affect: (1) a

sequence of emotional states (affective pathway), (2) expressions of affect by the person, (3) meanings that the emotional feelings encode and (4) meta-affect.

Emotions in the Mathematics Classroom

Research into emotions of students in the mathematics classroom has been studied to a lesser extent (Frenzel et al., 2007; Larkin & Jorgensen, 2015; Lewis, 2013; Op' T Eynde et al., 2006). Frenzel et al. (2007) find that enjoyment, anxiety, anger and boredom are among the most frequently experienced emotions during mathematics classroom instruction. Lewis (2013) found that the most frequently chosen positive emotions among students of two further education colleges were pride and relaxation. Pride was usually associated with being able to understand or do something, or with the achievement of test or exam results. Relaxation was related to the experience of being able to cope, to do what was being asked. Mischievous or playful and excitement and curiosity were chosen by approximately a quarter of the interviewees. Larkin and Jorgensen (2015) find that some positive emotions emerge: (1) when the mathematics is related to the world beyond schools and the students can see some purpose in doing the mathematics, (2) where mathematics is activity-based and (3) students are positive about the support they receive from their teachers. Some of the negative themes are as follows: (1) generic difficulty of mathematics as a subject, (2) specific difficulties with content areas, (2) hatred (including the associated language of dislike and anger), (3) frustration or confusion and (4) sadness or boredom as a result of the feelings described above.

Rationale

The above literature review shows that not much is known about daily emotions in the classroom. Research on emotions in mathematics education has pointed out the necessity to move beyond the view of distinguishing between positive and negative emotions in problem-solving to focus on emotions during routine mathematical experiences (Hannula, Pantziara, Wæge & Schlöglmann, 2010). In the same way, Goldin (2014) indicates that the qualitative work focusing on state emotions suggests the "desirability of far more complex descriptions of affective architecture in the study of emotion in mathematics education" (p. 405).

Considering this, we assumed the task of identifying students' emotional experiences in the mathematics classroom. In order to go beyond a consideration of positive and negative emotions, we used the cognitive structure of emotions theory (Ortony, Clore & Collins, 1988). Martínez-Sierra and García González (2014, 2015) have shown the utility of the cognitive structure of emotions theory in identifying and explaining *emotional experiences* (past experienced emotions as narrated by people) in a mathematics classroom.

Research Questions

Consequently, we look for the students' emotions in routine activities in a mathematics class and go further than merely distinguishing between positive and negative emotions through the theoretical framework of the cognitive structure of emotions. The research questions were as follows:

RQ1. What are the emotional experiences of high school students in mathematics class?

According to the cognitive structure of emotions theory, emotions are supported by appraisal structures. The second question of this research is a consequence of this hypothesis:

RQ2. What are the appraisal structures that support the students' emotional experiences?

Theoretical Framework

The Appraisal Theories of Emotion

Appraisal theories of emotion propose that people experience emotions according to their appraisals of the specific situation. In other words, individual differences in emotional experiences suggest different interpretations of the situation. Appraisal is a process that detects and assesses the "significance of the environment for well-being"; it is conceptualized as the satisfaction or obstruction of "concerns". Appraisal includes the individual's needs, attachments, values, current goals and beliefs and everything that an individual cares about (Frijda, 2007; Lazarus, 1991; Moors, Ellsworth, Scherer, & Frijda, 2013). For example, "the Law of Situational Meaning" from Frijda (2007, p. 4) considers that "emotions arise in response to the meaning structure of a situation; different emotions arise in response to different meaning structures". It follows that appraisal is inherently transactional: it involves an interaction between the event and the appraiser (Lazarus, 1991).

In general, the appraisal theories of emotion include hypotheses about individual, cultural and developmental differences that other theories do not (Moors et al., 2013). Appraisal theories can account for differences in individuals' emotional responses to the same situation. If two people differ in their appraisal of the event's novelty, goal congruence, controllability or any of the other appraisal variables, their emotions will differ correspondingly. If they have different concerns, one person might appraise the event as furthering those concerns, while the other may see it as obstructing them.

The Theory of the Cognitive Structure of Emotions

The *theory of the cognitive structure of emotions*—known as "OCC theory" for the initials of the surnames of the authors—is structured as a three-branch typology, corresponding to three kinds of stimuli: consequences of events, actions of agents and aspects of objects. Each kind of stimulus is appraised with respect to one central criterion, called the central appraisal variable. An individual judges the following: (1) the *desirability of an event*, that is, the congruence of its consequences with the individual's goals (an event is pleasant if it helps the individual to reach his goal, and unpleasant if it prevents him from reaching his goal), (2) the *approbation of an action*, that is, its conformity to norms and standards, and (3) the *attraction of an object*, that is,

the correspondence of its aspects with the individual's likes. In terms of the distinction between reactions to events, agents and objects, we have three basic classes of emotions: "being *pleased* vs. *displeased* (reaction to events), *approving* vs. *disapproving* (reactions to agents) and *liking* vs. *disliking* (reactions to objects)" (Ortony et al., 1988, p. 33).

The OCC theory contains 22 emotions types that are grouped into three classes and six groups. Different types of situations that elicit emotions are classified according to a word or phrase corresponding to a relatively neutral example that fits the type of emotion. For example, OCC theory uses the emotional word *satisfaction* (a *sample name*) to refer to the emotional situation "pleased about the confirmation of the prospect of a desirable event", because it represents an emotion of relatively neutral valence among all those that express that you are happy about the confirmation of something expected. Similarly, for the emotional situation "displeased about the disconfirmation of the prospect of a desirable event", OCC theory uses the emotional word *disappointment* (another *sample name*) because it represents an emotion of relatively neutral valence among other emotional words or phrases that express that you are displeased, such as hopelessness, frustration or heartbreak. The classification of emotions in OCC theory is independent of the words that refer to emotions, as it is a theory about the things that concern denotative words of emotions and not a theory of the words themselves.

Emotion Types in Reaction to Events (Plus Boredom and Interest Emotions)

The first emotion class (Table 1) contains three groups of emotions triggered by the appraisal of the consequences of an event and its desirability: (1) well-being emotions (joy, distress) arise when an individual appraises an event that has just occurred focusing only on the desirability of its consequences for himself, (2) fortunes-of-others emotions (happy for, sorry for, resentment, gloating) arise when an individual appraises an event focusing on its desirability for another individual and (3) prospect-based emotions such as hope or fear arise when an individual appraises the consequences of a prospected event (namely an event that has not occurred yet but is expected to do so) focusing on the desirability of its consequences for himself. Other prospect-based emotions such as disappointment, relief, fears confirmed and satisfaction arise when an individual appraises an event that has just occurred and was expected, focusing on its desirability for himself.

Boredom and Interest Emotions. We added two types of emotions to the prospect-based group of emotions in OCC theory to interpret emotional experiences in the mathematics class. We called them *boredom* and *interest*. Our definition of boredom and interest (grounded in the students' narratives collected in the present study) emphasizes the individual experience and perception of a cognitive state interpreted as an obstacle or a facilitator for achieving the goals of the students. This attribution feature makes boredom and interest emotions different from disappointment and satisfaction emotions.

Boredom and interest emotional experiences are elicited by the students' appraisal of their own cognitive state: (1) states of *alertness* and *concentration*, which produce understanding and learning, in the case of *interest*, and (2) states of *distraction* and *lack*

Table 1 Emotion types in reaction to events (plus boredom and interest emotions)

Group	*Sample name*: Appraisal
FORTUNES-OF-OTHERS	*Happy for*: Pleased about an event desirable for someone else *Gloating*: Pleased about an event undesirable for someone else *Resentment*: Displeased about an event desirable for someone else *Sorry for*: Displeased about an event undesirable for someone else
PROSPECT-BASED	*Hope*: Pleased about the prospect of a desirable event *Satisfaction*: Pleased about the confirmation of the prospect of a desirable event *Interest*: Pleased about a desirable cognitive state of attention *Relief*: Pleased about the disconfirmation of the prospect of an undesirable event *Disappointment*: Displeased about the disconfirmation of the prospect of a desirable event *Boredom*: Displeased about an undesirable cognitive state of distraction *Fear*: Displeased about the prospect of an undesirable event *Fears confirmed*: Displeased about the confirmation of the prospect of an undesirable event
WELL-BEING	*Joy*: Pleased about a desirable event *Distress*: Displeased about an undesirable event

of concentration, which prevent understanding and learning, in the case of *boredom*. Thus, we consider *boredom* emotions arise when one is "displeased about an undesirable cognitive state of distraction" and *interest* emotions arise when one is "pleased about a desirable cognitive state of attention".

Other appraisal theories have also considered emotions similar to those defined here as boredom. For example, the Control-value theory of emotions (Pekrun, 2006) establishes that *boredom* is induced when the achievement activity lacks any incentive value (positive or negative) and when the activity is perceived to be insufficiently controllable. Our definition of boredom is more related to the phenomenological characteristics of boredom that can be found in the corresponding studies in school settings (Belton & Priyadharshini, 2007; Nett, Goetz, & Hall, 2011), which state that boredom has several components: (1) feeling as if time has slowed down, (2) a state of under-stimulation, (3) a lack of psychological involvement associated with dissatisfaction in the task situation and (4) an unpleasant, transient affective state in which the individual finds it hard to concentrate and displays a persistent lack of interest in the current activity.

Similarly, there are appraisal theories that also consider emotions similar to those defined here as interest. For example, Silvia (2005) considers that two appraisals trigger the emotion of interest: (1) the first appraisal is an evaluation of an event's novelty–complexity, which refers to evaluating an event as new, unexpected, complex, hard to process, surprising, mysterious or obscure, and (2) the second, less obvious appraisal is an evaluation of an event's comprehensibility. Interest's function is to motivate learning and exploration (Silvia, 2008). Our definition of interest is consistent with these phenomenological descriptions of interest, where it is considered a motivational variable for learning (Hidi, 2006). When considered as an emotion, interest is a psychological state in which persons are "concentrated, alert, absorbed or exited" (Ainley, 2007) and "attention is focused on a particular object or event" (Ainley, 2010).

Emotion Types in Reaction to Agents

The second class of emotions (Table 2) contains only one group of emotion types (Attribution emotions), triggered by the appraisal of an action in terms of its approval, that is, its accordance to norms and standards. Thus, pride and shame arise when an individual appraises their own actions, focusing only on its approval ("does this action conform to the standards?") and not on its consequences. Admiration and reproach arise when an individual appraises an action of another individual while focusing only on its approval.

Emotion Types in Reaction to Events and Agents Simultaneously

Another class, common both to Well-being emotions (first class of the typology) and Attribution emotions (second class of the typology) is Compounds emotions (attribution–well-being) (remorse, gratification, gratitude, anger) that arise when an individual appraises an action, focusing both on its approval and on the desirability of its consequences (Table 3).

Emotion Types in Reaction to Objects

Finally, the third class (Table 4) contains one group of emotions: attraction emotions (love, hate), triggered by the appraisal of the aspects of objects with respect to the individual's likes.

Variables Affecting the Intensity of Emotions

A person's appraisal of an emotion-inducing situation is based on three central variables: *desirability*, *praiseworthiness* and *appealingness. Desirability* applies to event-based emotions, *praiseworthiness* to agent-based emotions and *appealingness* to object-based emotions. The desirability of an event is appraised in terms of how it facilitates or interferes with the focal goal and the sub-goals that support it. Praiseworthiness of an agent's actions is evaluated against a hierarchy of standards and appealingness of an object is evaluated with respect to a person's attitudes.

Among the different variables that affect the intensity of emotions, we considered both global and local variables. The global variables affect all emotions and include the followinh: (1) *sense of reality*, which depends on how much one believes the emotion-inducing situation is real, (2) *proximity*, which depends on how close in psychological space one feels to the situation, (3) *unexpectedness*, which depends on how surprised

Table 2 Emotion types in reaction to agents

Group	*Sample name*: Appraisal
ATTRIBUTION	*Pride*: Approving of one's own praiseworthy action *Appreciation*: Approving of someone else's praiseworthy action *Self-reproach*: Disapproving of one's own blameworthy action *Reproach*: Disapproving of someone else's blameworthy action

Table 3 Emotion types in reaction to events and agents simultaneously

Group	*Sample name*: Appraisal
WELL-BEING/ATTRIBUTION	*Gratitude*: Approving of someone else's praiseworthy action and being pleased about the related desirable event *Anger*: Disapproving of someone else's blameworthy action and being displeased about the related undesirable event *Gratification*: Approving of one's own praiseworthy action and being pleased about the related desirable event *Remorse*: Disapproving of one's own blameworthy action and being displeased about the related undesirable event

one is by the situation, and (4) *arousal*, which depends on how much one's emotions are aroused prior to the situation. Increases in these variables intensify the experienced emotions.

Local variables are tied to particular groups of emotions. The *desirability* variable affects all event-based emotions. This variable focuses on the representation of the goal in the assessment structure. The value attributed to each goal depends on how and where it is placed in the structure of goals. All states in this structure are desired states because they represent goals. The *degree of desirability* associated with the achievement of a goal will depend on the expected level of beneficial consequences. The *degree of undesirability* associated with the achievement of a goal will depend on the value attributed to higher-level goals that obstruct the actual goal and its level of obstruction. This is a measure of the expected level of harmful consequences of the event.

Prospect-based emotions are affected by (1) *likelihood*, which reflects the degree of belief that an anticipated event will occur, (2) *effort*, which reflects the degree to which resources were expended to achieve or avoid an anticipated event, and (3) *realization*, which depends on the degree to which an anticipated event actually occurs.

Appraisals Structures

The OCC theory (Ortony et al., 1988, p. 35) conceptualizes three support appraisals structures for changes in the world: (1) *structure of goals* to support appraisals of the desirability of events, (2) *structure of attitudes* to support appraisals of the appeal of objects and (3) *structure of standards* to support appraisals of the praiseworthiness of actions.

The OCC theory defines *goals* as what one wants to achieve. There are three kinds of goals: active-pursuit goals (A-goals), interest goals (I-goals) and replenishment goals (R-goals). We reformulated the definition of these types of goals to adapt them to our data: A-goals represent the kind of things one wants to get done; a long period of time

Table 4 Emotion types in reaction to objects

Group	*Sample name*: Appraisal
ATTRACTION	*Liking*: Liking an appealing object *Disliking*: Disliking an unappealing object

is needed to achieve these goals. Some examples are finishing high school or studying at university. I-goals are more routine goals and are necessary to achieve or support A-goals; they require a shorter time of period than A-goals. Some examples of I-goals are "understanding", "solving a problem" or "passing a course". R-goals are the basic and necessary goals to accomplish all other types of goals. Some times they are so natural in the classroom that the subjects do not perceive them as goals. R-goals can be behavior such as attending a class or bringing materials to work with (notebooks, books, notes).

Standards represent the beliefs in terms of which decision assessments are made. We are concerned with *moral* or *quasi-moral* standards, standards of *behavior* and standards of *performance. Moral* or *quasi-moral* standards are the guidelines to approve or disapprove of the things someone is doing or did. *Behavior* standards are conventions, norms and other kinds of accepted regularities governing or characterizing social interactions. *Performance* standards are specific role-based norms; we understand them as the roles of being a teacher or student.

Emotions and Goals

The appraisal theories, like the functional approaches to emotion, consider that emotions help people manage goals (Lazarus, 1991). Mathematics education research has already highlighted the fundamental role of goals in emotional experience. Hannula (2006) connects emotion and goal concepts to define motivation in mathematics as "goals reflected in emotions" because it is possible to direct behaviour through the mechanisms that control emotions. In this regard, some motivational research in mathematics education has highlighted "fear of failure" as an important antecedent variable to direct students towards specific achievement goals (Pantziara & Philippou, 2015). Op' T Eynde et al. (2006, 2007) consider that students' appraisal processes play a crucial role in the emotional process and they also consider the fundamental role of goals in the emotional process: "students' appraisals of their on going goal-directed interactions with the world initiate and direct the emotional process" (Op' T Eynde et al., 2007, p. 187). For them "students' emotional reactions toward mathematics are thought to be the outcome of consciously or subconsciously activated personal *evaluative* cognitions" (Op' T Eynde et al., 2007, p. 188).

Methodology

Context

The Centres for Science and Technology Studies (CSTS high school hereafter) are one of the options the National Polytechnic Institute offers at high school level. The CSTS high schools are dedicated to the training of technicians. The National Polytechnic Institute has 17 CSTSs distributed throughout Mexico City. The CSTS high school where the study was carried out lies in the west of Mexico City and, compared to other CSTSs, it requires the lowest score in the standardized test for entry. Most of the students live in municipalities bordering the metropolitan area of Mexico City; they come from low economic households and most of their parents did not attend college. Most students' mothers are housewives.

Due to the inflexibility of the curriculum, all students follow the same mathematics schooling path composed of six courses (one per semester) with five hours in each class per week: (1) Algebra, (2) Geometry and Trigonometry, (3) Analytical Geometry, (4) Differential Calculus, (5) Integral Calculus and (6) Probability and Statistics. Generally, there is a traditional process of teaching and learning mathematics in the CSTS in that mathematical classes focus primarily on the teacher explaining and the subsequent resolution of problems and exercises by students.

Participants

We selected 53 regular students for the study (aged between 16 and 18 years, 29 men and 24 women). As we had no gender distribution control, it was not taken into account in the data analysis. The participants were officially registered in their fourth semester in the Differential Calculus course, which focuses on developing algebraic skills to study elementary Differential Calculus. The topics of this course are as follows: (1) functions, limits and continuity, (2) algebraic functions derivatives and (3) transcendental functions derivatives.

Data Gathering Procedure

We decided to determine students' emotions from their reports of experienced emotions because this research is focused on students' subjective experiences of emotions. We decided to use focus group interviews because we observed, during previous research at the same school (Martínez-Sierra & García González, 2014, 2015), that students feel more confident and comfortable in expressing their thoughts, feelings and emotions about various topics. This is consistent with previous works that considered focus group methodology to be an "ideal" approach for examining the stories, experiences, points of view, beliefs, needs and concerns of individuals; the method is especially valuable for permitting the participants to develop their own questions and frameworks as well as to seek their own needs and concerns in their own words and on their own terms (Kitzinger, 1995; Krueger, 1994; Morgan, 1997).

In focus groups, the key is to watch for patterns in the participants' responses and samples until *theoretical saturation* has been achieved (Morgan, 1997). Thus, focus group sessions should continue to be conducted until information provided by the sessions appears redundant and additional data collection no longer generates new understandings or information. In this study, theoretical saturation was reached with nine focus group interviews.

During mathematics classes, the Differential Calculus teacher (our key informant) agreed to allow a group of five or six students to go to another classroom to participate in a focus group interview. We worked with nine groups of students (seven groups of six participants, two groups of five participants), each with one interviewer. The interviews were conducted in May 2013, 1 month before the course was to end. The second author of this paper and one collaborator conducted the interviews. The collaborator is a research assistant with experience in conducting individual interviews and focus group interviews. Both interviewers were outside the participants' everyday context. Most of the participants knew each other.

Following OCC theory, our questions intend to provoke students to talk about their emotional experiences in terms of the eliciting situations. This is the main reason to

keep asking, "Why do you feel this way?" The questions asked in the focus groups were as follows: (1) what feelings or emotions do you experience about mathematics? Why do you feel this way? (2) What feelings or emotions do you experience in the mathematics classroom? Why do you feel this way? (3) What feelings or emotions do you experience just before a mathematical class? And what feelings or emotions do you experience after the mathematical class? Why do you feel this way? (4) What feelings or emotions do you experience when you learn mathematics? And when do you learn? Why do you feel this way? (5) What feelings or emotions do you experience when you solve a mathematical problem? And when you cannot? Why do you feel this way? (6) What feelings or emotions do you experience in a good mathematical class? And what feelings or emotions do you experience in a bad class? Why do you feel this way? (7) What feelings or emotions do you experience when a mathematics teacher is explaining? Why do you feel this way? (8) What feelings or emotions do you experience for a good mathematics teacher? And for a teacher that is not good? (9) What feelings or emotions do you experience in a mathematics assessment? Why do you feel this way? (10) What feelings or emotions do you experience in a mathematics test? Why do you feel this way?

Description of the Interview Situation

The interviews were conducted in a classroom. The interviewer sat in front of the participants who were spread out in a semi-circle in no particular order. The video camera was set up to the right or to left of the interviewer so that all participants would be captured on film. The recording time was one and a half hours on average. At the beginning, the interviewer informed the participants about the purpose of the research and the confidentiality of their identities and data; they were also informed that their teacher would not have access to the interviews. They were also asked for their consent to be videotaped; no participant refused to be videotaped.

In general, the role of the interviewer was to elicit deeper explanation of the use and meaning of words and phrases used by the students to answer the questions. During the interviews, interaction between the students was fostered. The interviewers generated auxiliary questions to prompt the students to deepen in their explanations or to give opinions on the answers of the other participants (e.g. "What else can you say about that?" "Can you give me an example?"). However, the students gave their opinions without the intervention of the interviewer in most cases and seemed comfortable during the interviews. In any case, a very good rapport was evident in each interview because all the participants know one another through their mathematics course or previous courses.

The interviewer verified that all participants answered the main question to avoid any discrimination based on race, ethnicity, personality or gender. The interviewer directly asked any participant who did not answer a specific question if they wanted to respond. After listening to all the participants, the interviewer asked if anyone had anything to add.

Data Analysis

All the interviews were videotaped and transcribed in Spanish. The data analysis was performed completely in Spanish and then translated to English for this paper. It was

necessary to ensure the equivalence of the English translation to write the final version of the paper. Two people contributed to this. The first translated all the data analysis into English. The second person is a professional proofreader; she reviewed the translation and discussed the meanings of specific testimonies with the translator to ensure equivalence and consistency.

Students were identified as M*n*-G*k* or F*n*-G*k*: M and F indicate that the participant is male or female, *n* (1 to 5 or 6) is the participant identification number and G*k* (1 to 9) indicates the focus group number. We used the following typographical conventions for the data analysis and presentation of results: (1) *concise phrases* that express the eliciting situations of the emotional experiences are in bold italics, (2) *emotion words* that express emotional experience are in italics, (3) *variables* that affect intensity of emotions are underlined phrases, with the name of the intensity variable in curly brackets (e.g. {effort}), and (4) explanations that clarify some of the students' expressions are included in square brackets ([in classes]).

Due to the daily use of words to express emotions, it may happen that one word refers to a number of different types of emotions. To identify evoked emotions we took into account the eliciting situations, just as the OCC theory suggests. For example:

> **M1-G1:** *I feel fine and motivated* ***when I am doing problems, when I am solving problems***.

In this testimony, **M1-G1** used the emotional phrase "*I feel fine and motivated*" to express his emotional experience triggered by the success of solving of a problem. We identified "*doing problems*" as a desirable event for **M1-G1.** Therefore, this is an eliciting situation that triggers in the student an emotional experience of satisfaction (pleased about the confirmation of the prospect of a desirable event). We labelled this eliciting situation as "Being able to solve a problem". We assumed that solving problems is a goal in the mathematical class for the student, so the appraisal of the eliciting situation is made in terms of this goal.

Methodological Limitations

We are aware that the analysis of narratives of emotional experiences is quite different from the direct analysis of emotions but, like Ortony et al. (1988, pp. 8–9), we are willing

> To treat people's reports of their emotions as valid, also because emotions are not themselves linguistic things, but the most readily available non-phenomenal access we have to them is through language […] Because emotions are subjective experiences, like the sensation of color or pain, people have direct access to them, so that if a person is experiencing fear, for example, that person cannot be mistaken about the fact that he or she is experiencing fear. (pp. 8–9)

Thus, our acceptance of the validity of verbal self-reports of their emotional experiences—past experienced emotions as narrated by people—leads us to offer a way of coding emotional narratives in relation to mathematics. Like other researchers in emotions, we believe that emotional phenomena are multidimensional with cognitive,

verbal, motivational, physiological, behavioural and social components. Our position is that research on emotions in mathematics education should deal with all possible dimensions of emotional phenomena; for our particular investigation, we consider the verbal dimension. This is why we consider it necessary to make inquiries from other perspectives and take into account other dimensions of emotional phenomena.

Results

Research Question 1

We identified 12 different types of students' emotional experiences in the mathematics classroom (Table 5). We found that the same eliciting situations trigger different emotional experiences according to the structure of appraisal of the students (RQ2). For example, if a student considers the eliciting situation "Being able to solve a problem" as a goal to achieve then emotions of satisfaction or disappointment are triggered, whether the goal is achieved or not.

On the other hand, the student may consider the eliciting situation "Being able to solve a problem" as an agent, meaning that solving problems is a norm set to be followed in the classroom. In this case, if the norm is considered plausible then pride emotions are triggered, and if "Not being able to solve a problem" is considered not plausible then self-reproach emotions are triggered.

Some students are attracted to "Being able to solve a problem"; therefore, liking emotions are triggered. In this case the eliciting situation is interpreted as an attractive object.

Research Question 2

Our analysis identified emotions from all groups in the OCC theory; this means that it is possible to find three appraisal structures that support the emotions: a structure of goals that supports appraisals of the desirability, a structure of attitudes to support appraisals of the appealing and a structure of standards to support appraisals of the praiseworthiness. We found that goals trigger all students' emotional experiences, even when the OCC theory states different appraisal structures for each group of emotion. So, our analysis indicates that the structure of norms and the structure of attitudes are subordinate to the structure of goals, since norms and attitudes are organized to enable the achievement of goals. Each appraisal of a specific eliciting situation involves an implicit or explicit goal that triggers an emotional experience, which will be positive or negative valence depending on whether the goal is achieved or not. This is the reason to propose an appraisal of the specific eliciting conditions in terms of goals (Fig. 1).

Three types of goals form this structure: active-pursuit goals (A-goals), interest goals (I-goals) and replenishment goals (R-goals). In this structure, the types of goals follow a hierarchy in terms of the achievement of goals: R-goals are at the bottom, followed by I-goals, and finally A-goals. In Fig. 1, we denote with a letter N the I-goals that are needed to achieve other I-goals or A-goals, and with a letter F when the I-goals facilitate them. For example, the I-goal to "understand" facilitates the achievement of other I-goals like to "solve a problem" or "go to the blackboard". However, the I-goal

Table 5 Students' emotional experiences in the mathematics classroom

Group	Type of emotion	Eliciting situations	Variables that affect intensity
PROSPECT-BASED (Reaction to events)	Satisfaction	+Being able to solve a problem	
	Disappointment	+Being able to solve a problem	Effort, Likelihood
	Fear	+Not learning or not understanding a mathematics class +Not passing a test	Desirability
	Boredom	+Not understanding the teacher's explanation +Non-dynamic class	Desirability
	Interest	+Understanding teachers' explanations +Teacher caring +Being motivated to pay attention	Desirability
WELL-BEING (Reaction to events)	Joy	+End of class +Being able to solve a problem at the blackboard	Desirability
	Distress	+Not being able to solve a problem in class +Not being able to solve a problem in a test +Going to the blackboard	Undesirability
ATTRIBUTION (Reaction to agents)	Pride	+Passing a course +Being able to solve a problem	
	Reproach	+Reproaching the teacher	
	Self-reproach	+Not being able to solve a problem	Expectation-deviation
ATTRACTION (Reaction to objects)	Liking	+Understanding mathematics +Being able to solve a problem	
	Disliking	+Not being able to solve a problem	

to "understand" is necessary to both "pass a test" and "graduate from high school", but is not necessarily sufficient to achieve the A-goal to "get a job".

We also show in Fig. 1 the two types of variable that affect the intensity of the identified emotions. The *desirability* of an event is appraised in terms of how it facilitates or interferes with the goal and the sub-goals that support it. *Expectation-deviation* reflects how much the agent's action deviates from expected norms. We illustrate this in the next section by showing in detail the types of emotional experiences identified: satisfaction, disappointment, fear and boredom.

Satisfaction and Disappointment Emotions

Satisfaction and disappointment emotions are consequences of the students' appraisal of the desirability to achieve the I-goal to "solve a problem". One emotion will appear depending on whether the goal is achieved or not. For example, M1-G1 experienced satisfaction—pleased about the confirmation of the prospect of a desirable event—when he managed to achieve the I-goal to "solve a problem".

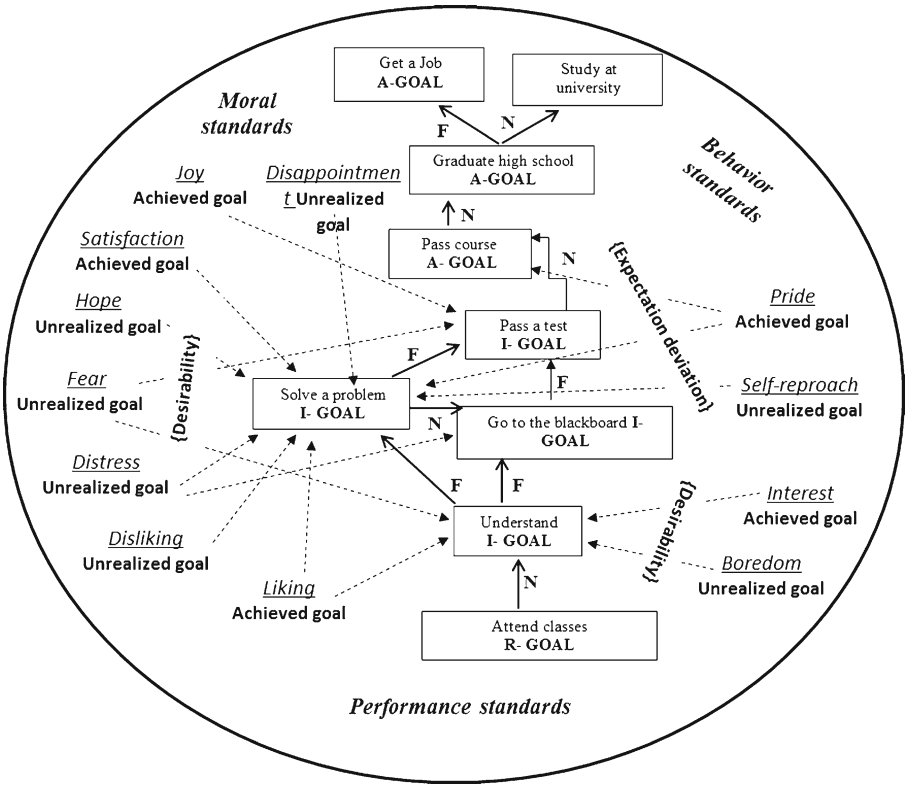

Fig. 1 Students' structure of goals

M1-G1: *I feel fine and motivated* ***when I am doing problems, when I am solving problems [in class].***

The intensity variable desirability affects the intensity of the prospect-based emotions, the group to which satisfaction and disappointment emotions belong. We identify this variable in the testimony of M1-G1: he said that solving a problem in class (I-goal) motivates him but he felt better if the problem was solved in a test. The desirability to solve a problem in a test is stronger because it facilitates the I-goal to "pass a test". In his goal structure, the degree of desirability associated with the achievement of the I-goal to "solve a problem in a test" depends on the degree of desirability of the achievement of the I-goal to "pass a test".

M1-G1: *I feel better* **if the problem is in a test,** because the result really counts {desirability}.

On the other hand, M4-G8 experienced disappointment—displeased about the disconfirmation of the prospect of a desirable event—when he did not achieve the I-goal to "solve a problem". The consequence of this experience was even physiological because he recounted getting a headache for not reaching a solution. This is the result of

the *arousal* variable because it depends on how much his emotions are aroused prior to the I-goal to "solve a problem".

M4-G8: *I get angry, stress and with a headache* {arousal} ***if I am not able to solve a problem, because I cannot reach a solution***.

F2-G8 also experienced disappointment when she was not able to achieve the I-goal to "solve a problem":

F2-G8: ***When I am not able to solve a problem*** then I ask myself *what to do because I don't understand anything*, I leave it that way and ask my teacher or a classmate for help {effort}.

F2-G8 and M4-G8 experienced disappointment when they were not able to solve a problem. The intensity of the disappointment emotion increased as a result of the *arousal* variable in the case of M4-G8, but in the case of F2-G8 it was as a result of the *effort* variable because she left the problem unsolved until she asked her teacher and classmates for help to achieve the I-goal to "solve a problem"; she did not give up. This means that she used additional resources such as asking for help to solve the problem.

Another variable identified in the disappointment emotions is the likelihood variable. It reflects the degree of belief that an anticipated event will occur. Some examples are the testimonies of M1-G4 and M1-G8. They experienced disappointment for not being able to solve a problem.

M1-G4: *I feel bad* ***when I cannot solve a problem in a test,*** and I will be constantly thinking I will fail the test until I get the result {likelihood}. *I get angry and depressed.*

We identified the *likelihood* variable in his belief that he would fail the test because he was not able to solve the problem during the test. The disappointment emotion was stronger because this belief made him feel angry and depressed.

On the other hand, M1-G8 expressed how he feels when he is not able to solve a problem in class or during a test:

M1-G8: *I am disappointed of myself* **when I don't understand anything and I cannot solve it** [the problem in class], *I get a bit depressed* because I don't know anything {desirability}.

E-1: And what if the problem is in a test?

M1-G8: *Well, I am screwed because I will go to the extraordinary test* and as I don't know anything then I am already fail {likelihood}.

The desirability variable increased the intensity of the disappointment emotion. This is because he desired to understand the lesson (I-goal "understand") and not achieving it interferes with his goal structure in the pursuit of the I-goal to "solve a problem". Moreover, if the problem is in a test, then he expressed "I am screwed" to show that

there was nothing else he could do. He believed that failing was a consequence of not solving the problem. This belief is the cause of the higher intensity of the disappointment emotion.

Fear Emotions

We identified two undesirable events that unleashed fear emotions—displeased about the prospect of an undesirable event: (1) "not learning or not understanding a mathematical class" and (2) "not passing a test". We will show these triggering situations in the next section.

Not Understanding or Not Understanding a Mathematical Class

One of the eliciting situations for fear emotions is the difficulty attributed by students to mathematics classes. The experienced fear is increased by the desire to learn or understand mathematics despite its difficulty; this happens when a student highly values mathematics (e.g. "they are important", "necessary", "interest"). F3-G7 and M5-G3 experienced fear emotions associated with the I-goals to "understand" and "learn", respectively. They both used the expression "feel really nervous", which we interpreted as a sign of fear.

> **F3-G7:** *I feel really nervous* ***if I don't understand mathematical class.***

> **M5-G3:** *I feel really nervous* before a Calculus class ***because I think I must learn everything*** {desirability}.

We observed more intense fear emotions in M5-G3 because he expressed a stronger desire to understand things. He said, "I think I must learn everything". He experienced a more intense fear than F3-G7 because of the desirability to learn (I-goal "learn").

Not Passing a Test

Fear emotions are caused by the prospect of not achieving the I-goal to "pass a test" because of the importance attributed to tests in the assessment system and the value of mathematics in the CSTS's curriculum. This was clearly expressed by M1-G1.

> **M1-G1:** *I fear to make a mistake in a formula or that I cannot reach the solution* ***in the tests. The tests are 8 points worthy*** [8 of 10 that represents 80 % of the numerical assessment] so I am pressed to pass the test.

Boredom Emotions

Not Understanding Teachers' Explanations

Being bored was a reaction to teachers' explanations. A good explanation makes the student understand and pay attention. In contrast, they do not pay attention and get bored if they do not understand the explanation.

F6-G6: My opinion is that mathematics is not boring, but it really depends on teachers and their explanations. Because *if* ***the class is not dynamic and the topics are not quite clear*** *then it becomes boring* and you won't understand and fail. … I understand my actual teacher well because she explains quite well.

Boredom had consequences for the students. This was the case for M10; he stated that not passing a class is a consequence of being bored.

M4-G2: *I do like mathematics,* but *it bores me* sometimes. … A boring class depends on the teacher; I stay and distract myself ***in a boring class.*** This affects me because this is why I failed Analytic Geometry.

Non-dynamic Class

For students, a dynamic class is one that is not boring. They considered that a class where the teacher does not interact with them is a boring class.

H5-G2: *I feel fine* ***in the mathematical class*** *and I understand it* because my Calculus teacher makes us participate and explains to us. … I believe that a good teacher generates good classes, and a bad teacher generates boring [classes].

F1-G7: *Boring* is the first thing I feel at class. ***The way the teacher explains*** *bores me*, he almost puts me to sleep with his voice.

Discussion, Conclusions and Future Research

Discussion

Altogether the students' structure of goals may be considered an inherent part of the high school context. Goals can be explicit or implicit. The structure of goals can be taken as part of the "didactic contract" (understood as "the set of specific behaviours of the teacher which are expected by the student and the set of behaviours of the students which are expected", Brousseau, 1997, p. 31), because it influences, along with the emotional reactions, the expected behaviour of students and teachers in class. So, students direct their emotions in order to stimulate and guide their conduct to achieve goals that are implicitly or explicitly established in the mathematics classroom. This is consistent with the perspectives that highlight the complementary relationship between emotion and motivation in learning and performance (e.g. Kim & Pekrun, 2014; Meyer & Turner, 2006).

As in appraisal theories, our results give evidence of emotions as a sociocultural and contextual phenomenon because even though emotion is an innate psychological capacity, an individual experience, the appraisal structures associated with emotions have social and contextual origins. This assertion is consistent with the idea that emotions cannot be reduced to singular and subjective moments (Radford, 2015); they are dynamic processes,

socially organized and historically constituted. Therefore, the individual appraisal structures reflect the collective appraisal structures of desirability in class.

Limitations and Future Research

About Methodology

The goal of our research is to identify the participants' emotional experiences and appraisal structures as a whole. We did not intend to identify the emotional experiences separately for each of the participants. Therefore, it was the right option to collect data of emotional experiences from focal group interviews. In addition, it would be appropriate to conduct future investigations to identify individual emotional experiences. We believe they will be supported with specific appraisal structures for each person but, at the same time, they will be consistent with our results because they might have common aspects with their pairs in the same context. It is also important to deepen research into the *emotional states* (emotions at the moment) of the students. This means that it will be necessary to collect data using a different methodology, such as individual interviews, diary methods, experience sampling methods or stimulated recall methods.

About Theory

Research on students' emotions shows that all students engaged in the process of problem-solving have the same emotions (Hannula, 2012). The empirical results on emotional experience in mathematics show the same, even if this type research is still quite sparse. The results of this research and those found by Martínez-Sierra and García González (2014, 2015) show that the students have the same experienced emotions, but the appraisal structures change. This idea is consistent with the principles of the appraisal theories of emotion, which account for differences in people's emotional responses to the same situation. Therefore, we consider that it is necessary to keep investigating students' (and teachers') emotions in different academic settings and at different school levels. Appraisal theories could help to identify the specific appraisal structure for each academic setting, school level and individual. Derived from the principles of appraisal theories, we consider that the emotional experience depends largely on the student's academic setting. In general, we believe that the emotional experience is a socio-cognitive phenomenon, since the individual appraisal structures are situated in institutional and cultural contexts.

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