Mathemagic or Mathetragic: A Thematic Analysis of Student-reported Antecedents of Academic Emotions in Middle-school Mathematics

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ABSTRACT

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Understanding students' academic emotions and their influencers and implications has been a challenge and growing interest in educational research (Martínez-Sierra & García-González, 2014; Larkin & Jorgensen, 2015; etc.). The purpose of this qualitative study is to examine positive, negative and mixed emotional experiences involved in general, non-test engagement with mathematics towards understanding the variety and dynamics of emotions and their antecedents.

The data collected comprised of reflections on emotional experiences associated with math-learning and achievement maintained in journals by thirty middle-school students from Delhi, India. Thematic analysis of the data led to the identification of three main categories of emotion-influencing factors and of the collective and mitigating influences of key antecedents across the three categories: lesson planning and implementation, classroom culture and expectations, and cognition and motivation.

The findings are consistent with the Control-Value Theory of Achievement Emotions (Pekrun, 2006) and offer insights on classroom practices, conditions and environment that are likely to foster emotions that enhance math-learning and outcomes. The central message of the conclusion is that an overall positively perceived experience can be created by mitigating negative influences through an understanding of the collective contribution of antecedents towards the nature of emotional experiences.

Keywords: academic emotions, learning environment, antecedents, cognition, motivation

CONTENTS

1 INTRODUCTION

Mathematics is an essential academic subject across most school years and disciplines, if not all (Kim, Park, & Cozart, 2012). The Urban Ward Survey, part of the Annual Status of Education Report (2014) carried out across 20 schools in a municipality in Delhi found that only 31.9% of students in grades 6-8 could divide triple digit numbers by a single digit number. Math anxiety has been recognized and legitimized as a learning difficulty faced by many children (Wilson, 2015). Hudson, Henderson, & Hudson (2014) highlight the significance of emotions in mathematics learning and achievement. Emotions associated with mathematics influence students' learning experience and outcomes related to the subject, how they perceive math, their competence regarding the same, and the extent to which students pursue math-related academic and professional pathways (Hannula, 2002). Academic achievement emotions are related to engagement, motivation, cognition, academic achievement, as well as physical and mental well-being (Putwain, Pekrun, Nicholson, Symes, Becker, & Marsh, 2018).

The focus on understanding and managing negative emotions like anxiety, which were correlated with undesired learning experiences and outcomes, has thus far overshadowed the investigation of positive academic emotional experiences towards enhancing cognitive and behavioral outcomes. Villavicencio & Bernardo (2015) support the need for further research regarding positive emotions and report a direct relationship between positive emotions (enjoyment and pride in particular) and students' final grade, self-efficacy and self-regulation. While research interest in academic emotions and discussions on the importance of affective (related to moods and emotions) considerations have been gaining momentum since the 2000s, there is still a perceived dearth of descriptive, qualitative studies among mathematics education researchers (Schukajlow, Rakoczy, & Pekrun, 2017). The present study aims to explore the relationship between emotional experiences (both positive and negative) and

their antecedents and contribute to the recently growing literature on learning environment and positive emotions in math education.

Academic achievement emotions, or simply achievement emotions are those that are associated with learning, pedagogy and achievement (Ahmed, van der Werf, Kuyper, & Minnaert, 2013). The present study adopts the Control-Value Theory (CVT) (Pekrun, 2006), which has offered a robust theoretical perspective to several studies on the role of emotions in the learning process (Peixoto et al., 2016). Pekrun's theory regards emotions as multidimensional with affective, cognitive, motivational, expressive and physiological components. In the CVT, the emotions considered are those related directly to achievement tasks or outcomes that stand to be evaluated against a standard of performance or expectation and are thereby referred to as achievement emotions. As the name suggests, control and value appraisals are considered the main determinants of emotions according to the CVT. Control appraisals may be understood as mental voices that create a certain image of self-efficacy, self-concept or the perception of one's own competence. Value appraisals are the internal or external voices that afford value or worth to the time and effort dedicated to an achievement task, to the outcome of the task, to the main learning outcome of a series of tasks or to the overall purpose of a learning goal.

While the dynamics of the primary antecedents of emotions (based on the CVT) - control and value appraisals (essentially cognitive-motivational in nature) have received growing attention in recent years, relatively lesser effort has gone into investigating secondary antecedents (influencers) of cognitive-motivational aspects such as students' learning environment. According to the CVT, the learning environmental factors are crucial secondary antecedents of emotional experiences. The main objectives of this study are to examine key learning environmental antecedents and factors that influence students' emotional experiences while engaging with mathematics and better understand the relationship and dynamics between environmental and cognitive-motivational antecedents and achievement emotions. The study aims to meet its objectives

through qualitative, thematic analysis of descriptive reflections of mathematics-related emotions maintained by students in reflection journals.

1.1 Academic Achievement Emotions: The Control-Value Theory

Research on the affective domain of learning has focussed more on attitudes and beliefs compared to emotions owing to the fluctuating nature of emotions that adds complexity to its study (Martínez-Sierra & García-González, 2014). In recent times, exploration and investigation of antecedents and effects of emotions related to academic engagement, performance, goals and outcomes has gained prominence (Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015). Emotional experiences that occur during engagement with mathematics can have a long-lasting impact on students' motivation and achievement concerning the subject (Goldin, 2014). Perceptions of failure and negative emotional experiences with assessments in the early secondary grades or at the start of the academic year can have enduring negative implications for future engagement with mathematics at an emotional level (Lewis, 2013). Kim, Park, & Cozart (2012) found emotions to be the overriding predictors of achievement in an online mathematics course, affecting other predictors of achievement such as motivation and self-efficacy. Goetz, Pekrun, Hall, & Haag (2006) stress the significance of emotions in the learning process and their role in determining learning outcomes and achievement.

Mathematics related emotions have been examined vastly in test situations, creating the need for studying emotions in everyday learning experiences as during lessons, homework or independent learning (Hannula, Pantziara, Wæge, & Schloeglmann, 2010). Hannula (2006) highlights the importance of investigating emotions associated with non-test, low stakes, regular environments and tasks, with holistic data collection and analysis including cognitive (strategies for problem-solving, self-regulated learning, etc.), affective (feelings and emotions) and motivational (perceptions of value, self-efficacy, etc.)

aspects of the learning experience. The study by Peixoto et al. (2016) further recommends exploration of emotions in non-test, regular learning contexts for new, relevant and important perspectives and insights, having identified that the relationship between cognitive appraisals and achievement emotions differs between general lesson work and test situations. Additionally, within the study of emotions, anxiety in particular has received a disproportionate share of attention in educational research, with new studies indicating that other emotions (including positive ones) play a significant role in learning experiences and outcomes (Pinxten, Marsh, Fraine, Noortgate, & Damme, 2013; Valiente, Swanson, & Eisenberg, 2012). For example, in the investigation of positive emotional experiences during learning activities, Pinxten et al. (2013) found enjoyment to be directly and cyclically related to achievement and competence beliefs in math classrooms across grades three to seven. The present study analyses data involving both negative and positive emotional experiences during general, non-test achievement activities like solving problems in regular math lessons.

In order to scientifically and structurally conceptualize emotional experiences (involving antecedents of the emotion and the emotion itself), this study employs the Control-Value Theory, or CVT (Pekrun, 2006). Control and value are the two main conceptual pillars that the CVT stands on. The mental processes or thoughts that trigger a feeling of being in or out of control of the outcomes of an activity or the necessary inputs that an activity demands are regarded as control appraisals. Control appraisals stem from a juxtaposition of task demand and self-concept. In other words, the perception of control emerges from the mental confrontation between the demands of an achievement task and the beliefs regarding one's competence in relation to the task. Moving on to value appraisals, if an activity is perceived to be of value by virtue of the nature of engagement and internally recognizable benefit it offers (interesting, stimulating, etc.), then the perceived value is deemed intrinsic. If the value of performance or engagement with an activity is tied to external recognition, praise or a socially

(or externally) recognizable benefit (e.g. career goals), then the thoughts and motivations associated with that value are termed extrinsic.

While achievement emotions pertain to achievement tasks (Pekrun, 2006), emotions experienced during regular, every day academic activities or tasks (such as solving math problems in class) are categorized as activity emotions. Additionally, there are outcome emotions that involve emotional experiences associated with the outcome of academic engagement (e.g. test performance). Outcome emotions can be further classified into prospective and retrospective outcome emotions. Prospective outcome emotions are those experienced in anticipation of an outcome (e.g. test scores). Retrospective outcome emotions are experienced whilst revisiting, reflecting on or thinking about past outcomes. The three categories of emotions- achievement, activity and outcome emotions are collectively referred to as academic emotions (Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015).

Control and value appraisals in the CVT can be viewed as a combination of cognitive and motivational components of a learning experience which are claimed to affect the affective aspect of the learning process. The cognitive precedence of an affective response is supported by other theories of emotion, 'the theory of the cognitive structure of emotions' (OCC) being one such that has been adopted across a significant number of studies (Martínez-Sierra & González, 2014). OCC and CVT both attribute interpretations of events, situations or stimuli to emotions. The choice of CVT over other interpretation or cognition based emotional theories is that the CVT narrows the matter of interpretations down to a robust control-value structure. Studies on learning related emotions in general have also employed the CVT in exploring every day academic emotions, their antecedents and outcomes in addition to investigating achievement emotions.

Muis et al. (2015) have demonstrated how the control-value antecedents of achievement emotions extend and apply to emotions experienced during mathematics problem-solving in the classroom. In the original article by Pekrun

(2006), the author also includes within the CVT, activity and outcome achievement emotions associated with general, day-to-day classwork, learning, instruction and academic activities, tasks and their outcomes. Another reason for the preference of the CVT is that it integrates assumptions from other theories of emotions in an academic context including the attributional theories of achievement emotions and theories of perceived control. Furthermore, the CVT is a result of improvements on Pekrun's preceding work on expectancy-value approaches to emotions and on the effects of emotions on learning.

While anxiety, frustration, anger, shame, etc. are generally regarded as negative emotions that deter interest and motivation, and restrict cognitive flexibility with demotivating and distracting thoughts, in some cases, they may generate increased effort with raised stakes of performance and achievement. In such cases, the emotions may be classified as negative activating emotions. On the other hand, experiences of relief, satisfaction, relaxation, etc., generally regarded to bear positive effects on cognitive flexibility, long-term persistence and achievement, may act as deactivating agents that lead to a reduction in short-term effort (Lam, Chen, Zhang, & Liang, 2015). Under such conditions, emotions such as relaxation get classified as positive deactivating emotions. Emotions such as enjoyment, pride, hope, etc. have been found to promote self-regulated learning, flexibility in use of problem-solving and learning strategies (cognitive flexibility) and increased interest, motivation and effort (Pekrun et al., 2011). Such emotions are labelled as positive activating emotions under the CVT. Conversely, hopelessness, sadness and boredom are classified as negative deactivating emotions and have been observed to reduce interest, motivation and effort.

Empirical studies have found levels of perceived control over and value assigned to an academic activity and its outcome to bear a direct relationship with emotions (Pekrun et al., 2011; Putwain, Becker, Symes, & Pekrun, 2018). A key argument under the CVT is that emotions resulting from control and value appraisals determine the degree of utilization of resources in a learner's motivational and cognitive repertoire. Positive emotions like enjoyment and

pride are associated with enhanced and extended effort, and flexible and comprehensive usage of cognitive and motivational resources like self-regulation, learning strategies, technical memory (content-specific knowledge, skills and strategies), interdisciplinary skills like problem solving and critical thinking, etc. Predictably, negative emotions like boredom and hopelessness lead to reduced task-persistence, interest, and trigger rigid, limited or misaligned usage of motivational and cognitive resources (Pekrun et al., 2011).

1.2 Learning Environment and Learner Emotions

The CVT identifies three main categories of determinants of emotional experiences- the learning environment, the situation at hand and individual factors (Pekrun, Frenzel, Goetz, & Perry, 2007). The perceived learning environment and interactions, learning and teaching strategies and resources, and the general culture and expectations of learning and achievement are regarded as important antecedents (Pekrun, 2006). The learning environmental factors influence emotion and the learning experience through effects on control and value constructs, which are aspects that have a direct influence on emotions (Pekrun et al., 2007). In addition to the learning environment, experiences of success and failure and their internally generated or externally influenced interpretations (performance appraisals) produce a cyclical relationship between psychological constructs of control-value and performance (Peixoto et al., 2016; Pinxten et al., 2014). Since the perceived learning environment has a significant impact on emotions and the overall learning process, experience and outcomes (Pekrun et al., 2011), the study of the perceived learning environment and its impact on achievement emotions, albeit via the control-value intermediary, gathers legitimacy and importance.

Learning environmental factors such as learning and teaching materials, classroom management systems and structures, and teacher pedagogy, instructions, beliefs, expectations and guidance have an influence on students'

attitudes and emotions regarding mathematics (Mohamed & Waheed, 2011). A positive perception of teacher support is linked directly with feelings of control and confidence and positive emotional experiences in mathematics lessons (Akey, 2006). Support with respect to mathematical competence, independent learning, and goal-setting and feedback has been strongly linked with cognitive appraisals that determine emotional dispositions towards math (Mata, Monteiro, & Peixoto, 2012). Social interactions in the classroom have the potential of triggering emotions that may either encourage or hinder engagement with cognitively demanding tasks (Goldin, 2014). Teachers' approach towards goals and communication of the same- for instance, whether goals revolve around understanding the material (mastery based) or around comparative performance in tests (performance based) impact students' affective responses in the classroom (Pekrun, 2006).

In the present study, since all data is obtained through students' written reflections on their emotional experiences, the learning environment is conceptualized as a perception to be interpreted in the context of emotional experiences rather than an environment that has been observed first-hand (Frenzel, Pekrun, & Goetz, 2007). Furthermore, emotional experiences have been conceptualized as a collection of emotions, emotional responses and antecedents of emotions.

1.3 Research Problem, Task and Questions

The aim of this study is to explore the relationship between students' perceived learning environment and their emotional experiences and identify environmental antecedents of positive and negative emotional experiences. The study also entails examination of antecedents of emotions (environmental and non-environmental) towards better understanding the dynamics of the influence that antecedents have on emotions.

Negative emotional experiences during engagement with mathematics in early and middle-school years can fix a negative attitude towards math as a subject in higher education and in adult life as well that becomes very hard to mitigate, let alone reverse (Larkin & Jorgensen, 2015). Low self-esteem, self-doubt, a negative perception of one's ability to develop mathematical competence and a general repulsive attitude towards math as a result of negative emotional experiences can deter students immensely from pursuing studies and professional fields involving math (Hascher, 2010). On the other hand, positive emotional experiences with mathematics at school have been linked positively with math achievement, perception of mathematical competence, development of a mathematical perspective towards understanding the world around and problem-solving, and the confidence to engage with a wider range of academic and professional avenues without being deterred by a crippling fear of math (Attard, 2011).

There are several factors that contribute to students' emotional experiences, among which are included performance and related expectations, instruction and pedagogy, and peer interaction and influence (Tulis & Ainley, 2011). As the aforementioned factors are part of the learning environment, it can be claimed that students' experience and perception of their learning environment affect their learning and achievement related emotions. Given that emotions are connected with matters of math-image, self-image, engagement and achievement, and in context of the connection between learning environment and emotions, the present study deals with a relevant and significant problem and hopes to offer insights that can be used to develop effective solutions.

With the purpose of understanding the link between learning environment and emotions, the study involves qualitative, thematic analysis of students' descriptions of their learning environment and emotions mentioned in their reflections on emotional experiences during engagement with mathematics. The main research questions that the analysis aims to answer are:

1. Which factors of the learning environment do students associate with their emotional experiences?
2. How do environmental and non-environmental factors interact in relation to the nature (positive or negative) of emotional experiences?

2 RESEARCH METHODS

The phenomena under consideration in the present study includes middle-school students' academic emotions and related antecedents during engagement with everyday mathematical activities. The theoretical lens adopted for the conceptualization of emotions and their determinants relies on the Control-Value Theory of Achievement Emotions postulated by Reinhard Pekrun in 2006. The data comprises students' reflections on emotional experiences related to mathematics learning and achievement. The causes of emotions as articulated by the participants in their reflection journals have been regarded as interactions between forces/ events/ conditions (secondary antecedents) and the learners' control-value constructs (primary antecedents). This is a positivist approach that chooses to view causality as a continuous and collective influence of events that determines the nature of an outcome (emotional experience in this case) (Maxwell, 2012). Both, events and their effects, have been considered as participants' subjective perceptions (experience of a thing rather than the thing itself) which have been interpretively viewed and analysed by the researcher (Zittoun & Gillespie, 2017). With a focus on participants' lived experiences and perceptions of events, the present study follows a phenomenological epistemology and a contextualist method (Braun & Clarke, 2006).

2.1 Research Context

The present study explores the dynamics of emotion-related antecedents and their interactions with and influences on students' emotional experiences. Within

the limited but growing space of research on academic emotions, the focus on negative emotions and mitigating their occurrence and adverse effects far outweighs effort in the direction of amplifying positive emotions and leveraging their impact on attitudes, learning and achievement (Holm, Hannula, & Björn, 2016). Furthermore, there exist very few studies that rely on direct student voice or narratives regarding their emotional experiences, with many studies being based on inferring emotions, their antecedents and effects from lesson videos and observations (Wilkie & Sullivan, 2017). While interviews and focus group discussions have been employed in research on emotions, and provide the opportunity to hear from the horse's mouth, the power dynamics between the researcher and the student participants abates the authenticity and honesty of responses (Di Martino & Zan, 2009). Additionally, data collection modes that entail the presence of the researcher(s) allow for the possibility of researcher bias to interfere with objective data collection through interviews and interactions (Larkin & Jorgensen, 2015). Considering the points stated above, in the present study, the data collected on students' emotional experiences comprised of students' self-written reflections on their emotional experiences during engagement with mathematics related activities.

The study was conducted across six classrooms in Delhi, India (three grade 7 and three grade 8) with thirty participating students (five from each classroom). It was decided that the participants be from middle school based on the following assumptions:

a. Students from higher grades would be too caught up with preparations for high-stakes, competitive examinations. Furthermore, it was assumed that students' guardians would not be welcoming of additional tasks disconnected from their children's regular academic work during crucial school years. In many parts of India, Delhi included, high-stakes examinations are held after grades 10 and 12. The exams are considered high-stakes as students get to choose their stream of study in grades 11 and 12 based on their performance in the exams at

the end of grade 10, and their college and study program based on the results of their end-of-grade 12 exams.

b. Students from lower grades might not be as competent as students in higher grades with reflection and writing abilities.

Every class of students belonged to a different school: one co-educational low-income private school, one co-educational government school, two all-boys government schools and two all-girls government schools. Different school types were chosen to include students with diverse educational experiences. The choice of schools was based on ease of access and cooperation of the school principal and class teachers. Convenience and cooperation were both a result of the researcher having worked with a non-governmental organization that works in partnership with the selected schools, among several others in the city. However, the researcher did not work with the chosen schools during his time at the partner organization and had not interacted with the participating students or any of the concerned stakeholders prior to the study. The medium of instruction in all the chosen classrooms was English, as was the language used in the reflection journals.

2.2 Research Participants and Research Data

Thirty students participated in the study- fifteen from grade 7 (aged 12-13) and fifteen from grade 8 (aged 13-14). The female-male ratio in the sample set was 1:1. The participants were chosen via a self-selection process (described in the next section) based on self-assessment of the experience, competence (reflection and writing) and attitude (discipline, dedication and intrinsic motivation) that self-regulated journal maintenance demands. All participating students were from socio-economically neglected communities. No other considerations (such as math achievement) were made in the participant selection process. However, data on the students' average math scores in the standardized school tests

administered in the current academic year (2019-20) was collected. Gender considerations were not made in the present study. The data collected comprised of participants' reflections on their emotional experiences during engagement with any and all types of mathematics-related activities engaged with throughout the reflection period of two weeks.

The researcher had no interaction or relationship with the participating students prior to the first interaction regarding the study. It is worth noting though that the students had a trusting and appreciative attitude towards the partner NGO, its involvement with students' families and community, influence on personal and academic issues and educational interventions. The researcher introduced himself as a former teacher, program manager and instructional leader with the NGO, and a current student of a master's in educational sciences program in Finland. The students responded with enthusiasm and a promise of dedicated and authentic participation to the researcher's description of his background, the personal significance the study holds for the researcher and its potential with regards to contributions to educational research and practice. The students were told that they were expected, for two weeks (with specific start and end dates) to be specially and deliberately aware of their emotions during engagement with mathematics and note down key points as and when the emotions were being experienced. Further reflection and elaboration were expected to be done in their free time as soon after the experience and with as much detail as possible. The noting down of key points as well as further detailing were facilitated through prompts and guiding questions provided to the students. The prompt provided to the students for real-time note taking was as follows:

Time	
Topic	
Task	
Teacher actions and words	
Peer actions and words	

The guiding questions for later reflection and detailing were as follows:

1. What was the topic and task you were involved with?
2. What was the emotion you experienced? What caused the emotion?
3. How were you engaging with the task? What were you thinking, doing and feeling?
4. What was your interaction with others (teacher and peers) during the emotional experience? What were the teacher and your classmates saying and doing?

Students were provided with the prompt in addition to the guiding questions so that they could write down key points in brief without being too distracted from the classroom-task at hand. The prompt and questions were aimed at eliciting information from students about their learning environment and mental processes without leading them to focus on specific emotion-related antecedents and factors based on extant research. This decision was made to offer participants the freedom to describe their emotional experiences without influencing their choice of words or areas of focus during reflection (Larkin & Jorgensen, 2015).

2.3 Data Collection

The students in each of the classrooms were self-nominated. The self-nomination process is mentioned further down the section. The researcher had met with the math teachers of the students prior to interacting with the students in order to explain and clarify the purpose and process of the study, and to seek permission and an appropriate time slot to interact with the students towards the same. The initial interaction with the students entailed an introduction to the researcher and the study. The involvement expected of the students (maintaining a 'math emotion journal') was explained to them and clarifying questions were received and answered by the researcher. The journals, provided to the students by the researcher, were to be maintained for two weeks. The stipulated time-period was decided upon in order to ensure the following:

a. There were no high-stakes tests or exams during and at least a week after the last day of the two-week period. This was to minimize, if not completely avoid the occurrence and recording of test-specific emotions, and maximize reflections pertaining to everyday math activity emotions- the focus of the study.
b. The duration was long enough to accommodate emotional experiences.
c. Motivation to remain independently regular and sincere with the task would sustain over the time-period and the task would seem feasible and manageable.

After the students were informed of the study and the task, as a check for understanding, the researcher asked some students to repeat key points regarding the purpose of the study and the task demand. The students were then given five minutes to consider their ability and willingness to engage with the task diligently and meet the task expectations without worrying concerns. Once the students contemplated their participation and indicated their readiness with their decision, those that were confident to participate sincerely were requested to write their full name down on a chit of paper. In each of the all-boys and all-girls classrooms, of all the chits collected, five were picked randomly. In the co-educational classrooms, the students were requested to indicate their sex (M for

male and F for female). Three chits labelled F and two labelled M were picked in one classroom and the reverse was followed in the other. This is how a 1:1 female-male ratio was ensured in the sample set. The math teachers of the participating students were requested to provide daily gentle reminders over the reflection period at the end of which the journals were collected by the researcher.

2.4 Data Analysis

Students' reflections on their emotional experiences were qualitatively analysed using the method of thematic analysis (Braun & Clarke, 2006). The data entailed rich descriptions of emotions and associated antecedents. The first step of analysis involved reading through all the journal entries to get a sense and idea of the information provided (Tracy, 2012). The initial reading revealed that the students had described with fair detail the emotions that arose while engaging with mathematics along with descriptions of associated learning and teaching-related interactions, learning tasks and outcomes, social interactions, and motivational and cognitive elements such as attitudes, beliefs, learning and problem-solving strategies. This validated the choice of providing students with prompts and guiding questions for notetaking and reflection respectively.

In the next step, all the sentences relevant to emotions and their influencers were isolated and summarized for every journal entry (Tracy, 2012). Then, open coding was used to reduce the emotion related utterances to emotions (Tracy, 2012). The summaries of antecedents were then collapsed into codes and eventual themes through open primary and secondary cycle coding (Tracy, 2012), while maintaining definitions of all the codes towards ensuring trustworthiness of the analysis (Elo, Kääriäinen, Kanste, Pölkki, Utriainen, & Kyngäs, 2014). All journal entries, utterances and codes were labelled with numbers such that any code could easily be traced back to the original utterance, which in turn could be traced back to its respective journal entry (Tracy, 2012).

The primary coding condensed 148 journal entries (with 210 utterances pertaining to emotions and their antecedents) to 59 primary codes which further

collapsed into 10 sub-themes. Finally, the ten sub-themes were categorized into the final three main themes of factors that were found to be associated with students' emotional experiences of engagement with mathematics. While open coding was adopted throughout the analysis, the primary codes were based on the meanings that emerged from the journal utterances pertaining to antecedents while the codes for emotion, the secondary codes or sub-themes and the final themes were theory-informed but not entirely theory-based. The purpose of the primary and secondary cycles of coding was to collapse rich descriptions of antecedents (events) into themes which could be recognized as determinant factors associated with emotions. Of the ten factors (sub-themes) that were identified, six were related to the learning environment and four were cognitive-motivational in nature. Thus, the learning-environmental factors associated with students' emotions were identified in response to the first research question.

The next problem to be addressed was the examination of positive and negative emotional experiences to explore the dynamics of the antecedents in relationship with the nature of emotions (positive or negative). Now, the analysis was focused on experiences with both positive and negative emotions, but an overall positive or negative perception. Since the summaries of antecedents were too descriptive and cluttered with a lot of nuanced information, and the codes (sub-themes) obtained from secondary cycle coding were too broad and non-descriptive, the first set of codes, which were condensed yet descriptive enough, were juxtaposed for comparison. On juxtaposition of the two sets (positive and negative) of emotion influencing antecedents, those that were associated with both positive and negative emotional experiences were identified. These were a collection of influencers generally associated with positive emotions that had a presence in negative experiences and vice-versa.

Every common antecedent identified was then traced back to all the journal entries in which it was present to locate the set of antecedents (primary codes) among which it was present in every journal entry. All the antecedents linked with each common antecedent across all journal entries (emotional experiences)

were collated for each common antecedent, separately for positive and negative emotional outcomes. The positive and negative accompanying antecedents associated with every common antecedent were organized separately based on the frequency with which an accompanying antecedent occurred together with a common antecedent. The frequency of accompaniment of an antecedent across common antecedents was considered as an indication of the mitigating potential of the accompanying antecedent. Thus, the interaction of emotion influencing factors in relation to the nature of the emotional experience was examined in response to the second research question. Since the analysis involved moving from instances to broad themes and back from themes to instances for focused examination towards conclusions based on relationships between primary codes, the reasoning employed could be considered as abductive in nature (Tracy, 2012).

2.5 Ethical Solutions

The journals were used in the study with informed consent from the participating students' guardians. A note in Hindi outlining the students' involvement and anonymity, and the purpose of the study was sent home with the students and collected along with the journals with a parent/guardian signature. As participant names were not collected at any stage and only pseudonyms and number labels were used throughout the study, the anonymity of the participants was guaranteed. The journals were kept in the sole possession of the researcher and shared with a supervisor on one occasion to discuss analysis possibilities. The students were provided with the journals by the researcher to avoid any cost incurred by the participants. No teaching time was disturbed during the data collection process and the students wrote in their journals in a time and location of their choosing (presumably at school or home during free time). The identities of the teachers and schools were not referenced at any point in the study. Finally, the journal writing process itself was aimed to be mutually beneficial to the students and the researcher. Three of the thirty students even mentioned in the journals how the whole reflective exercise had been a productive experience in

terms of building awareness of their strengths, limitations, opportunities and emotions with respect to mathematics learning.

3 FINDINGS

The thematic analysis of participants' emotional experiences during engagement with mathematical tasks in general, non-test situations led to the identification of a comprehensive list of math emotions. The emotional experiences were broken down into emotions and their attributed antecedents. Based on the predictions of the CVT, cognition and motivation emerged as a clear theme of antecedents, which were assumed to be the primary antecedents of math emotions. Other antecedents fell into the category of learning environment, which were assumed to be secondary antecedents, affecting emotions via the cognitive-motivational control-value mental construct. The examination of antecedents in mixed emotional experiences resulted in better understanding of the dynamics of antecedents in relation to the nature (positive or negative) of emotional experiences. It was found that a collective contribution of antecedents seemed to determine the nature of emotional experiences, and mitigating factors with respect to both positive and negative emotional outcomes were identified.

3.1 Achievement Emotions

Enjoyment, pride, sadness and boredom were the most frequently referenced emotions in students' reflections on engagement with mathematics. The other emotions that featured are outlined in Table 1.

Table 1

Academic emotions referenced in reflection journals

Positive emotions	Negative emotions
Enjoyment	Sadness
Curiosity	Boredom
Confidence	Anxiety/ Fear
Pride	Shame/ Guilt
Relaxation/ Comfort	Stress
Satisfaction	Disappointment/ Dissatisfaction
Relief	Anger/ Frustration
Hope	Hopelessness

3.2 Emotion-influencing Antecedents and Factors

The themes that emerged from the analysis are represented in Table 2. The student reported antecedents were classified into three broad categories- Lesson Planning and Implementation, Classroom Culture and Expectations, and Cognition and Motivation.

Table 2

Main Themes and Determinants of Academic Emotions (Math)

Main Themes	Sub-themes (secondary codes for antecedents)
Lesson Planning and Implementation	Content
	Instruction
Classroom Culture and Expectations	Validation
	Student-teacher interaction
	Student-student interaction
	Measure of success/ failure
Cognition and Motivation	Attitude
	Self-regulation
	Self-efficacy
	Task persistence

3.2.1 Lesson Planning and Implementation

Lesson Planning and Implementation (LPI) and Classroom Culture and Expectations (CCE) have several common elements entailing, but not limited to, teacher involvement and student-teacher interaction (a factor that has been categorized in the present study under CCE, the justification for which will be provided further). The separation of the two big themes is based on the nature of teacher and student involvement. The choices and actions under LPI are more teacher-owned while those under CCE are more interactional and mutually determined between the teacher and students. Lesson Planning and Implementation includes the following:

a. Content: This factor refers to the concepts, topics, information and related material chosen by the teacher based on past experiences, education, training, research (self or external), curriculum or recommendations from stakeholders such as students, parents, educators or the school team. Content includes texts, problems, activity/task descriptions and demands and learning and teaching materials accessed by the students visually, auditorily, or possibly kinaesthetically (for example, the description of a kinaesthetic learning activity). Here's an extract from a journal related to content:

> Whenever a new chapter starts so, in my mind there's curiosity coming about, what's about the chapter? What type of property will we use to solve and we need to put them our daily life…a new chapter was started cubes and cube roots. That chapter based on previous square root chapter so, from thar I found maths is nothing but it based on its basic features (Ram, entry 1).

b. Instruction: It includes the choices and moves made by the teacher to deliver content to students to impart learning in the form of knowledge, skills and mindsets. Instruction, however, is not attached solely to content-based learning but also experiential or reflective learning (which would have its own "content" associated with it). Motivational support-based interactions with students could also be classified under instructional choices and moves but they also fit aptly under the broader umbrella of pedagogy. Responses to behavioural situations could be another example of interaction that fall outside the 'instruction' category. Following is an instruction related excerpt:

> Ma'am (was) doing number talk then I tell instruction of number talk (and) ma'am said great…I feel good then and I tell answer then ma'am (said) great and (another teacher) said what a nice strategy (and) then I also feel good (and) then my reaction is very happy and I wish it is done with me every day (Mohit, entry 2).

The perception of learning being new, the topic interesting, the content relevant, the task comfortable and the concept having meaningful, practical application were associated with positive emotions. The perception of the topic being familiar or unfamiliar and the task being cognitively challenging are two

content related antecedents that were associated with both positive and negative experiences. The examination of this commonality will be addressed in the next section (pertaining to the second research question). So, cognitively challenging task demand and topical familiarity were two content-related factors that were associated with mixed emotional experiences. The topic being perceived as boring was linked with negative emotions.

Furthermore, in the context of collective influence, it must be noted that no overall experience, positive or negative was associated with a single, isolated antecedent or factor. This is because an emotional "experience" has been considered as a collection of events and emotions, and not a single event or emotion. Single, isolated emotions have been associated with single, isolated antecedents and factors. For example, a positively perceived instructional strategy (like "number talk") or the use of an instructional resource (like a video shown via a projector) has been linked one-one with a positive emotion. Similarly, a negatively perceived instructional input ("boring lesson") for example has been single-handedly associated with the negative emotion of boredom.

Topical familiarity has been associated with positive emotions. Interestingly, unfamiliarity has not been associated with an overall negative experience but with single, isolated emotions like stress and anxiety. In fact, unfamiliarity has been associated with positive emotions (like curiosity) in some cases. In the present study, familiarity has to do with there being a similarity or explicit connection between presently exercised and previously acquired knowledge and skills.

Reflections on instruction that entailed factors associated with positive emotions included: the use of good teaching and learning (T&L) strategies or resources, on-going feedback and cognitive support from the teacher provided individually or in small groups and the teacher addressing the notion of "how to learn". The factors pertaining to adequate preparation time and whole-class teacher explanation, and positive student self-perception of pre-task readiness

were linked with positive emotions but also featured substantially in experiences that were perceived as negative overall.

3.2.2 Classroom Culture and Expectations

The "feeling" or "vibe" that appears to be characteristic of ways of being, doing, responding and interacting in a classroom may be called classroom culture. Behavioural expectations, teaching, demonstration and appraisal of values, definitions of or approaches to effort, success and failure, and interactions that reflect the classroom's culture, rules, expectations and values have also been classified under this category. Three factors have been outlined within classroom culture and expectations. They include:

a. Validation: This theme or factor entails students' and teachers' intentions and interactions pertaining to validating ideas, strategies, approaches, actions, choices, effort, outcomes and results (academic and holistic).

Students' demonstration of competence (sharing perspectives, ideas, approaches, methods or solutions) to the teacher, to a partner, a peer group or to the whole classroom was associated with both positive and negative emotions. The lack of opportunities to demonstrate competence has been associated with negative emotions. Below is an extract related to validation:

> Today my answer(s) were right and wrong too but the right answer(s) were in the majority which makes me feel very good about it and the wrong answer makes me to demotivate but today's class was the most wonderful class of this year because in this class I enjoyed participating (in) that chapter (in) which last year I was just not able to solve some really easy questions so it makes me feel proud on myself. But today for my wrong answers many children tease me and it really hurt me and makes me feel bad about my mistakes (Aniket, entry 2).

b. Interaction: Interactions pertaining to direct curricular, cognitive support have been classified as teaching and learning (T&L) strategy, under instruction (lesson planning and implementation). Interactions associated with setting, maintaining or appraising behavioural, academic or moral expectations and those (like way

of greeting or responding to a mistake) that stand out as indicative of the classroom's culture more than instructional knowledge or practice have been included in this category. This factor includes both student-student as well as student-teacher interactions. Peer interaction regarding cognitive support in the form of peer feedback and group work are also considered under culture and expectations as its quality, consistency and authenticity is largely owing to values, habits and culture built over time as opposed to being the result of an instructional strategy. Here's an interaction related excerpt:

> I don't know why not only me but everyone in the class is distracted and sleepy…Today our class did not had that good old energy! No one wanted (including me) to answer in the class because nothing was entering our brain when the teacher asked a thinking question but when she explained it we got it and few people answered!...Today my teacher scolded me because of sign mistakes I did in Integers. I felt bad and guilty at the same time because I did not revise it before. I should actually do a revision (Jacqueline, entry 3)

Teachers exhibiting a positive emotional state (for example: enthusiasm, joy), teachers appreciating/praising student work, and teachers expressing empathy were identified as factors associated with positive emotions. Teachers scolding was associated with negative emotions.

Students contributing to each other's learning, peer feedback and cognitive support, positive emotional state of peers (for example: "energetic", "enthusiastic", "interested"), appreciation from peers, and healthy competition among peers were interactional factors linked with positive emotions. Working in groups as a more general factor however has been associated with mixed emotions. Inadequate peer interaction, low peer participation and bullying were factors linked with negative emotions.

c. Success/Failure: A factor found to be significantly influencing emotions is the perception and understanding of, and attitude towards success and failure in achievement tasks. In this study, it was found that the extent to which the focus was around whether the final answer was correct or wrong, student thinking, strategizing, collective learning or the approach being adopted and its

justification, was a significant antecedent. Following is an excerpt regarding the pace of solving questions:

> Today, the teacher was giving same type of question again and again…I was thinking why…But after some time I understood why because after some time we become the master of that type of question. I was able to do that very confidently with focus…We all were trying to do that question quickly comparatively to each other. After some time that concept was really clear to me. I was able to do any question just like that. If teacher did not gave those questions for practising so may be now we are not able to do that question so quickly (Yogita, entry 4).

Reflections on task-success or failure that entailed a focus on approach as a factor with frequent use of phrases such as "multiple approaches to a problem", "different strategies and methods", "my strategy", "our strategy", "discussing approaches and strategies", "sharing strategies", "thinking aloud", "that was a good approach", "that was a unique way" and "mistakes are good", were associated with positive emotions. The journal entries communicating a focus on (in)correctness of the solution, with the choice of language and concern leaning towards "the correct answer", "how many correct answers", "how many wrong answers", "that is correct", "that is wrong", "solved quickly", "I was fast" and "I took a long time", were associated with mixed emotions.

3.2.3 Cognition and Motivation

Antecedents that pertain to self-image, math-image, learning processes and habits, mental strategies towards learning and problem solving, tracking and appraising math-related and interdisciplinary knowledge, skills, abilities and mindsets (self-efficacy), and personal goal setting were categorized under cognition and motivation. A positive math-attitude or image was found to be associated with positive emotions. Viewpoints of math being "like a game or puzzle", "logical", "interconnected", "all about problem solving", "fun", "useful", and "easy" were linked with positive emotions. Attitudes towards math learning and learning in general that were connected to positive emotions

include notions of "practice makes perfect" and "learning something new is interesting". Positive emotions were also linked with high task-persistence, engagement and a positive self-image communicated by phrases such as "I am very intelligent" and "when I have a problem, I think fast". Here is an excerpt related to attitude towards math:

> I did all the questions easily and those questions were hard for many students. I really felt happy. Today in house I actually studied maths because I heard the more I will practice the more I will improve in maths. Everyone wants to be good in maths because maths is very important part of life (Pushkar, entry 3).

A negative self-image, characterised by thoughts like "I am not able to do anything" and a negative math-image represented by phrases such as "I can't study math", "math lessons are bad for me" and "what is math, why is it a subject, who made this subject, I want to kill him or her" were associated with negative emotions. Low task persistence and engagement also featured in reflections on negative emotions. Self-regulation, which entails reflective and deliberate decision, and choice-making around effort, performance, learning practices and avenues for feedback and self-improvement elicited positive emotions but also featured in overall negative experiences.

3.3 Collective Contribution of Antecedents

This section pertains to findings from the analysis of antecedents that were associated with both positive and negative emotions and those experiences that had both types of emotions but an overall experience that was of either type. These antecedents are outlined in Table 3.

Table 3

Antecedents Associated with Mixed Emotional Experiences

Antecedent	Definition (all in relation to students)
Cognitively challenging task demand	Mathematical tasks reported by to be difficult and demanding extra attention and effort
Task readiness	Perception of having acquired the necessary knowledge, skills and resources to attempt the task with adequate confidence
Focus on (in)correctness	The stress on accuracy of the solution over the thinking employed
Topical unfamiliarity	Inexperience with the kind of knowledge and skills entailed in the topic of study
Personal learning approach	Having knowledge of one's learning style, preference or strategy
Demonstration of competence	Sharing perspectives, ideas, approaches, methods or solutions to an audience
Participation in group work	Involvement in group learning activities
Negative self-image	Having a poor perception of one's competences and abilities

Cognitively challenging task demand, focus on (in)correctness, demonstration of competence, topical unfamiliarity and participation in group work were factors that were linked with positive emotions in some reflections and negative in some others. The factors of task readiness and self-regulated learning were associated with positive emotions but featured in many overall negative experiences despite positive emotions. Negative self-image was the only factor that was associated with negative emotions but was still referred to in several experiences with an overall positive perception.

The antecedents present in over 75% of the cases where negative emotional effects were mitigated and the overall experience turned out positive are outlined in Table 4. The following excerpt is an example of how participating in group work and contributing to other's learning led to an overall positive experience despite the presence of negative emotions.

> When ma'am (was) teaching the concept of multiplication questions so that time I got (a) little confused because everyone has understand except me. So everyone then explain (to) me that how to do it and then I understand. All my groupmates explain (to) me and said that (now) you try more questions. Then that time some questions I do it on (the) board and after all of this doing I get more confidence and I can now make everyone understand questions like that (Parnish, entry 1).

On the other hand, focus on (in)correctness (Table 4) was the only factor that contributed to an overall negative experience despite the presence of positive emotions in more than 75% of such instances. Below is an excerpt that conveys how focus on accuracy of the solution mitigates the positive influences of other antecedents:

> I am doing homework of school maths. I can do so easily (those) questions (and) I think I can do anything. I am very intelligent. But in class I do it but not very goodly…So I am very sad that how (I have) wrong answers (Rohan, entry 4).

Table 4

High-frequency Mitigating Antecedents

Antecedent	Definition
Participation in group work	Involvement in group learning activities
Contributing to other's learning	Students offering cognitive support and feedback to other students
Focus on approach	The stress on the thinking employed over the accuracy of the solution
Demonstration of competence	Sharing perspectives, ideas, approaches, methods or solutions to an audience
Task persistence	Sticking to a task despite negativity or failure.
Personal learning approach	Having knowledge of one's learning style, preference or strategy
Effective teaching practices and resources	Teacher's instructional repertoire and use of learning aids and tools towards enhancement of student learning
Focus on (in)correctness	The stress on accuracy of the solution over the thinking employed

4 DISCUSSION

The purpose of this study was to identify learning environmental antecedents of learners' academic (math) emotions and examine the dynamics of all types of antecedents (in addition to environmental) in relation to the nature (positive or negative) of emotional experiences. In this final section, the findings will be discussed considering extant research and implications for future research and the practical field of learning and teaching of mathematics.

4.1 Connections with Extant Research and Insights for the Classroom

First and foremost, the emergence of cognition and motivation, and the learning environment (lesson planning and implementation, and classroom culture and expectations) as the two major themes of emotion influencing factors aligns with the CVT (Pekrun, 2006) which states that control and value constructs (a cognitive-motivational domain) mediate the influence of environmental factors in the determination of academic emotions. With respect to emotions, despite anxiety being the single most widely reported and studied academic emotion in mathematics education (Villavicencio & Bernardo, 2015), in the present study, its frequency of utterance was significantly lower compared to the big four emotions of enjoyment, pride, boredom and sadness (Putwain et al., 2018), and comparable with the remaining emotions. The reason for this may be attributed to the fact that math emotions have been studied primarily in test situations (Hannula et al., 2010), which haven't featured at all in this study as the experiences reflected upon by the participants entailed regular, everyday mathematical engagement. So, boredom and sadness appear to be the most commonly and frequently experienced negative, deactivating emotions associated with math in general situations, which possibly translate into stress and anxiety in test situations.

While the significantly higher frequency of enjoyment-related utterances may be interpreted as positive and optimistic information, it is to be considered with caution given that the participant-selection was based on self-nomination. Since the research task demanded appreciable effort from the participants, it could be assumed that the participant-pool consisted of students with relatively higher levels of enthusiasm, ownership, discipline and reflection. The positive correlation between self-regulation of values and achievement has been supported by Corte, Depaepe, Eynde, & Verschaffel (2011). Furthermore, with respect to average performance in school standardized tests administered in the academic year 2019-20, the ratio of students in the top:second:third quartile was 2:1:1. No participant's performance was from the bottom quartile. The skewed frequency of utterances in favour of positive emotions could be explained by the presence of more students with high math achievement scores than those with

average or low scores. Support for this explanation can be found in the study by Pinxten et al. (2013), who found a positive correlation between enjoyment, task persistence and achievement (along with a reciprocal relationship between enjoyment and perceived effort).

Within the category of lesson planning and implementation, content and instruction were the key learning environmental factors found to be related to students' emotions. Topics and lessons that built on students' existing knowledge and skills and afforded interactional and practical tasks like data collection, statistics and measurement were regarded to be interesting and enjoyable. Explicit mention of effective routines and strategies aimed at enhancing the quality of mathematical thinking and discussion among peers was common to many reflections related to instruction. There exists a direct link between student-centric, group based learning and positive emotions, as well as between direct, teacher-centric instruction and boredom (Bieg et al., 2017). The use of alternate teacher explanations, and structures that afford multiple avenues to demonstrate competence and seek clarification and feedback were often associated with positive emotional experiences. A direct relationship has been found between effective and responsive cognitive support from teachers and students' positive emotional experiences (Gamlem, Kvinge, Smith, & Engelsen, 2019; Lazarides & Buchholz, 2019). Students teaching each other, discussing problem-solving approaches and methods in peer groups, and perceiving their peers as a regular source for cognitive and motivational support were also commonly stated antecedents of positive emotions. This is consistent with the findings of Alegre Ansuategui & Moliner Miravet (2017).

Moving on to the interactions between antecedents towards the determination of the nature of emotional experiences, it was found that the antecedents outlined in Table 3 were associated with mixed emotional experiences. Except for students' recognizing their personal learning approach and task persistence (which belong to the cognitive-motivational theme), the antecedents with the highest frequency of mitigation towards overall positivity belonged to the learning environment category (participation in group work,

contributing to other's learning, demonstration of competence, focus on learning and problem-solving approach, and effective teaching and learning strategies and resources). These findings suggest that environmental factors related to effective and adaptive instructional, feedback and coaching practices, and multi-avenue cognitive support and feedback through effective group learning activities hold the potential to mitigate negative emotions associated with mental factors such as self-image and math-attitude. This has been supported in the studies conducted by Vandecandelaere, Speybroeck, Vanlaar, De Fraine, & Van Damme (2012) and Gilbert, Musu-Gillette, Woolley, Karabenick, Strutchens, & Martin (2013).

The antecedents with the highest frequency of mitigation towards overall negativity were related to focus on accuracy of the final answer (learning environment). These findings indicate that while some factors mitigate negative influences, some others have the capacity of mitigating the positive influence of mental and external antecedents (Attard, 2012; Taylor & Fraser, 2013). The idea of mitigation is also akin to the concept of negative and positive emotions being activating or deactivating in nature based on the context of mental and external factors (Pekrun, 2006).

4.2 Strengths and limitations of the study

The diversity and randomness of participant selection contributes to the generalisability of the findings (Tracy, 2012). The diversity of participants is owed to the variation in school type, gender and math achievement but limited by the context of all the participating students coming from socio-economically neglected communities. The only limitation with respect to randomness of participant selection rests in the assumption that the participants share traits that are associated with voluntary participation in a reflection and writing-heavy extended task. However, the variation in quality of reflection and linguistic skills (in English) as well as in math achievement scores indicates that the participating group was cognitively and experientially diverse.

The reliability of the study lends itself to the rich data set collected from relevant sources (direct student voice), through a validated method (reflection journals) (Zittoun & Gillespie, 2017). The open-ended reflection prompts and absence of researcher-influence contribute to the objectivity in data collection. The trustworthiness of the analysis stems from the clear and explicit justification of analytical choices, descriptions of analytical codes and the methodical, systematic and structured thematic analysis employed in the study (Elo et al., 2014). Furthermore, three students stated in their reflections that the journal writing experience expanded their awareness of their learning choices, preferences, limitations and opportunities. This information enhances the value of the data collection method as a beneficial process for the participants and product for the researcher.

4.3 Scope for further research and closing words

The present study falls in the category of extant qualitative research related to the examination of links between the learning environment, individual and social factors, emotions, and math learning and achievement. The findings from this study and others are aimed to be inputs for further quantitative and qualitative analysis of the dynamics of a myriad of factors that influence learning and teaching experiences and outcomes.

A big challenge before the mathematics education research community would be to further the vision of what strong learning and teaching of mathematics looks, sounds and feels like, while identifying and prioritizing key conditions and practices towards that vision, all in the context of influencing factors that are numerous and vary with the context and goals of learning and teaching. While the challenge for educators lies in the multivariate and highly contextual nature of the learning and teaching process, the hope is that teachers across mathematics classrooms gradually and collaboratively develop the pedagogy, resources and mindset to make students' learning experiences 'mathemagical' and not 'mathetragical'.

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