

AFFECT IN MATHEMATICS EDUCATION: STATE-OF-THE-ART AND NEW DEVELOPMENTS

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Students' emotions, beliefs, motivations, values, and attitudes, summarized under the term affect, are crucial for learning mathematics, educational choices, and future life trajectories. Over the past decade, research on affective constructs and their relations to other educational outcomes has increased in mathematics education. This research forum will present current developments and future directions in research on affect in mathematics education. Contributions addressing overarching perspectives will synthesize research from measurement, situational, and sociocultural perspectives. Contributions focusing on specific contexts will address affect in problem solving and problem posing, mathematical modelling and applications, and gender. The forum will include audience discussion and invited commentary to advance research on affect.

INTRODUCTION TO THE RESEARCH FORUM

Stanislaw Schukajlow and Pietro Di Martino

Research on affect has reached a phase in which its centrality is widely acknowledged in the field of mathematics education. However, questions of theoretical integration, conceptual clarity, and methodological coherence remain still open. Scholars have since emphasized the intertwined nature of affective, cognitive, and sociocultural dimensions in mathematical activities, students' learning, and teachers' development. Several studies have shown how affective constructs (e.g., emotions, beliefs, motivations, values, attitudes) influence the way people interpret tasks, persist through challenges, and construct meaning in mathematics. In sum, studies have shown how affect is a crucial component of the quality of teaching and learning.

Perspectives in research on affect have progressively expanded, for example, by recognizing how affective issues emerge through interactions in classrooms, communities, and broader cultural contexts (Hannula et al., 2019). Investigations of affect provide key insights into identity, quality, and equity in mathematics education. “Affective considerations” that are used to interpret research findings have also emerged from studies whose focus and paradigms differ from those on affect. Studies on problem posing, problem solving, modelling, and applications are of special interest. These developments point to a growing convergence of research strands that still need to be fully and systematically connected. The RF will foster dialogue across researchers, theoretical frameworks, and methodologies, with the aim of articulating new conceptual connections and research directions on the topic of affect.

The portion of research papers addressing affective constructs in leading journals is considerable (Schukajlow et al., 2023). Recent reviews on specific aspects of affect, such as attitudes or self-efficacy in mathematics, have further illustrated both the progress that has been made and the complexity of the field by offering comprehensive overviews of current developments (Aquilina et al., 2025; Street et al., 2024). At the same time, this growth highlights the need to move beyond isolated constructs and local findings. Building on these insights, we consider two broader perspectives to be crucial: (a) overarching perspectives in research on affect and (b) perspectives embedded in research in contexts that are relevant for mathematics education.

Within the overarching perspectives, one of the most pressing challenges concerns the conceptual clarity of affective constructs. As discussed in the working group “Conceptual overlap in approaches to affect: Attitude, emotion, motivation, and what else?” in 2023, substantial overlap across definitions continues to cause confusion, and jingle–jangle fallacies (e.g., the distinction between self-concept and self-efficacy) represent major barriers to theoretical progress and to dialogue among researchers. This issue is closely connected to another long-standing challenge: the assessment or observation of affect. Although most studies have relied on self-reports, such as questionnaires or interviews, researchers have repeatedly argued that other methods should also be included depending on the type of approach: quantitative, qualitative, or mixed. In addition, a shift in research has emerged in recent years. Whereas earlier research primarily conceptualized affective outcomes as stable dispositions, the situational perspective highlights how specific situations shape affective experiences. A systematic review of research within the situative perspective on motivation revealed that prior research has typically addressed temporal and contextual aspects separately (Radišić et al., 2026). Studies have predominantly focused on motivation related to specific activities and classroom contexts. In the situational perspective, the sociocultural perspective plays a particularly crucial role, as it emphasizes how social norms and classroom practices influence affect. Understanding how dispositional and situational perspectives can be theoretically and methodologically integrated has thus become a key emerging challenge for the field.

Although some progress has been made in this area, most findings currently considered robust stem from Western countries. Consequently, the extent to which these results are generalizable across different cultures remains unclear.

Beyond overarching perspectives, affect research is also increasingly reconceptualized through significant mathematical contexts. Two particularly important areas in this perspective include research on problem solving and problem posing (Cai & Leikin, 2020) and research on mathematical modelling and applications (Krawitz et al., 2025). The research in these areas includes affect as an integral component of mathematical activity itself. Moreover, research on gender has been integral to affect research from the outset. For instance, Eccles' expectancy–value theory (Eccles & Wigfield, 2020) was shaped by the observation that women in the 1980s rarely chose STEM subjects or professions that required strong mathematical skills. Despite several decades of research, these issues persist, as gender differences continue to appear in central constructs such as self-efficacy expectations.

Goals and key questions of the research forum

This research forum is intended to address the two broader perspectives in research on affect—the overarching perspectives and perspectives in research in important contexts—by focusing on different aspects and involving several researchers with different approaches and from different areas of the world. The RF aims to identify conceptual tensions, methodological challenges, and promising new openings that characterize the current state of the field. This organization aims to offer participants the opportunity to engage in a well-structured, informed discussion that can help identify and share meaningful future research in the study of affect in mathematics education. A RF on affect in Helsinki carries profound symbolic significance, given the substantial contribution of the Finnish school to the genesis and development of research on affect in mathematics education. At the same time, the RF is intended as a space of critical exchange among researchers investigating affect from different perspectives, supporting reflection on emerging directions for future research.

Overarching perspectives in research on affect

- Perspectives on the assessment of affect across methodological approaches: C. Coppola (Italy), M. del Socorro García González (Mexico), Ç. Haser (Finland).
- Dispositional and situational perspectives on affect and their theoretical integration: S. Rach (Germany), J. Skott (Norway), K. Street (Norway).
- Sociocultural perspective on affect: T. Evans (New Zealand), K.-L. Yang (Taiwan).

Perspectives embedded in research in important contexts

- Affect, problem solving, and problem posing: J. Cai (USA), R. Leikin (Israel).
- Affect in mathematical modelling and applications: J. Krawitz (Germany), I. Ferrando (Spain), W. Van Dooren (Belgium).

- Affect and gender: C. Giberti (Italy), L. Gildehaus (Austria), L. Sumpter (Sweden)

Discussant: Markku S. Hannula (Finland)

PERSPECTIVES ON THE ASSESSMENT OF AFFECT ACROSS METHODOLOGICAL APPROACHES

Cristina Coppola, María del Socorro García González, Çiğdem Haser

Affect in mathematics education has been assessed in different ways, presenting advantages and limitations. While the predominant trend to assess it with quantitative instruments at a single time-point, there are new approaches that may be more effective in addressing its cognitive, emotional, situational and dynamic nature across different cultures; in tracking it over time; and for different age groups. Below, we present a brief overview of major methods, trends, and alternatives in assessing mathematics-related affect with illustrative studies.

Introduction

Mathematics education field started to explore the relationship between students' affect and their success in mathematics in the 1960s by measuring the relationship between attitude towards mathematics and students' achievement, typically operationalised through school grades (e.g., Aiken & Dreger, 1961). Despite several reports of positive correlations between mathematical affect and achievement, the direction of causality was not clear, addressing the inadequacy of the attitude instruments (Ma & Kishor, 1997) and a major persisting methodological issue: the difficulty of constructing appropriate tools for the assessment of affect. Meanwhile, the study of mathematics-related affect has evolved from relatively bounded conceptualizations toward more complex and multidimensional theoretical frameworks. Hannula (2012) proposed a multidimensional model distinguishing among types of affect, degrees of stability, and theoretical traditions. This model has led to methodological consequences: the more affect is conceived as dynamic and relational, the greater the demands placed on its empirical assessment.

Methods of assessment of affect

Researchers have been developing instruments to assess mathematics-related affect with different approaches. Quantitative approaches are typically based on standardized questionnaires and Likert-type scales, allowing the analysis of large samples through statistical techniques. Qualitative approaches focus on smaller samples and aim to provide in-depth interpretative accounts of affective phenomena through interviews, observations, and narrative data. Mixed methods designs have been adopted to combine the strengths of both approaches and mitigate their respective limitations.

Despite this diversification, research on attitude towards mathematics mostly aimed to measure attitudes through scales and correlating them with other variables, typically students' mathematical performance as Di Martino and Zan (2001) reported. The multidimensional nature of attitude also raises questions about the suitability of

common traditional instruments, such as questionnaires and Likert scales, which are not capable of capturing the interaction among the various components of attitude, a crucial aspect in models that attempt to integrate both cognitive and emotional factors (Di Martino & Zan, 2011). A recent review by Aquilina et al. (2025) confirms the persistence of this trend where reviewed empirical studies predominantly (about 81%) adopted quantitative approaches mostly using Likert-type scales.

Traditional measurement instruments limit assessing affect constructs by reducing complex and multidimensional nature to single indicators or bipolar scales; and may not fully capture the interplay between their cognitive and emotional components or the situated character. Therefore, they should be complemented with other approaches to support a more comprehensive understanding of affect.

Cross-cultural and longitudinal assessment of affect

Cross-cultural and longitudinal trends respond to the need to overcome historical limitations associated with cross-sectional and culturally restricted studies. They reflect a significant shift from static, localized, and unidimensional approaches toward a contextualized, dynamic, and structurally complex understanding of affect.

A cross-cultural investigation of differences in mathematics anxiety among engineering students in the U.S. and Colombia revealed significant differences in learning-related anxiety but not in test anxiety (Brown et al., 2020), suggesting that certain affective components may be more culturally permeable than others. Yet, there is a need to widen cultural diversity because the geographical representativeness of the field is limited despite the methodological advances (Pekrun, 2023). A longitudinal study of a cohort of students from grade 4 to 8 by using international comparison study data indicated an increase in negative emotions toward mathematics by age, and gender differences in intrinsic motivation (Sumpter & Sollerman, 2023), capturing transformations that cross-sectional studies cannot reveal. An analysis of National Assessment of Educational Progress data showed a sustained decline from 2017 to 2024 in interest, enjoyment, and confidence in mathematics among U.S. students (Campbell et al., 2025) stressing the value of longitudinal research for detecting trends that might be unnoticed in isolated analyses.

Alternative methods in assessing affect

Existing methods assessing affect assume that the respondents are aware of, willing and ready to express their affect clearly (Satyam et al., 2022) and they may not be suitable for younger participants (Hannula, 2019). Therefore, alternative ways of assessing affect have been devised, yet presenting their own limitations.

Drawing has revealed students' attitudes and beliefs when they drew a picture of, for example, themselves when doing mathematics (Quane et al., 2023) or a mathematician while working (Picker & Berry, 2000). However, drawings should be combined with additional data because students' reasons for drawing a certain object and/or its size can be misinterpreted (Quane et al., 2023).

Affect graphing enables tracking affect over time by illustrating experiences and the reasons for the changes and stability in affect when combined with autobiographies (Guillaume & Kirtman, 2010), written explanations (Andrà & Scalvini, 2023) and interviews (Satyam et al., 2022). Drawing multiple dimensions of experiences, such as motivations, emotions and perceived competence, on the same graph offers exploring how these dimensions covariate (Andrà & Scalvini, 2023). Yet, graphing has limitations of the level of structuring, respondents' subjective scaling of affect and the extent they can remember their past affect and experiences (Satyam et al., 2022).

Video diaries provide particularly younger students with the autonomy in expressing their mathematics experiences and enable access to their affect (Larkin & Jorgensen, 2016; Noyes, 2004). Stimulated recall interviews of videos can reduce the limitations and provide a deeper understanding of students' affect (Noyes, 2004).

Conclusion

The convergence of cross-cultural comparability, longitudinal analysis, integrative approaches and alternative methods outlines a promising horizon for assessing mathematical affect. Nevertheless, a key challenge remains: articulating methodological rigor, cultural sensitivity, and theoretical coherence within diverse research designs—quantitative, qualitative, and mixed—in order to understand affect as a constitutive component of mathematical experiences in specific contexts.

DISPOSITIONAL AND SITUATIONAL PERSPECTIVES ON AFFECT AND THEIR THEORETICAL INTEGRATION

Stefanie Rach, Jeppe Skott, Karin Street

Affect is an important factor in mathematics education. Whereas earlier research primarily conceptualized affective outcomes as stable dispositions, different versions of the situational perspective highlight how specific contexts and time shape affective experiences. It is an important challenge for the field to understand whether these perspectives may be theoretically and methodologically integrated, or if tensions between them may be productive even if unresolved. We refer to theoretical frameworks that address both perspectives, discuss methodological implications, and illustrate differences by presenting concrete studies from different subfields.

Theoretical frameworks on dispositional and situational perspectives

Students' and teachers' affect, for example, their beliefs, emotions, motivations, and identities, are assumed to be crucial for their educational engagement and learning. Research on affect is well established, but theoretical and methodological problems persist, particularly regarding the dispositional and situational perspectives on affect.

Different subfields of the affective domain relate differently to the question of whether their respective key constructs are most productively considered dispositional or situational. Mapping the conceptual space of this research is an important future task (Pekrun & Marsh, 2022). Key phenomena (e.g., self-efficacy, teacher identity, interest)

are not considered dispositions, but fluctuate according to situations. Even so, there is broad variation in terms of how these constructs have been operationalised, and whether theoretical assumptions are treated explicitly and with precision. We describe how conceptual developments have served to clarify theoretical underpinnings of some affective subdomains, before moving on to methodological considerations.

Inspired by constructivism, belief research was initially based on the premise that teachers' and students' *beliefs* – understood as relatively stable mental constructs residing within the individual – serve as an explanatory principle for practice (e.g., Schoenfeld, 1992). This dispositional perspective is to some extent maintained, where beliefs are still considered the default explanation for practice, but dynamic perspectives between beliefs and practice have become more prominent (cf. Pepin & Roesken-Winter, 2015).

Concerning *motivation*, recent research in mathematics education and educational psychology highlights that it arises from participation in mathematical activities rather than being an innate characteristic. This shift towards a more nuanced analysis of the situated nature is, for example, evident in the decision of Eccles and Wigfield (2020), who added the word “situated” to their “expectancy-value theory”. With this relabelling, they highlight that all processes that involve the emergence and impact of expectancies and values depend on the situations in which they occur.

Identity research in mathematics education was from the outset concerned with how identities relate to social and cultural contexts. Drawing, for instance, on social practice theory (e.g., Lave, 2019; Wenger, 1998), it suggests that any response to the question who are you must be made with reference to practices, relations, and activity systems. Identities, then, are considered situated in the fundamental sense that they are constituted in cultural-historical and social circumstances.

Affective constructs can exist as trait-like (dispositions) and state-like (situational) variables. Renninger et al. (2024) show how these two manifestations interact and propose a process model of interest development that goes from situational interest occasions to the development of individual interest. On the one hand, they suggest that the interest development stages are consistent across contexts, content, and individuals. On the other hand, they emphasise that the sociocultural context plays a vital role in fostering the development of interest along these development stages. In identity research, Skott (2024) defines identity as experiences of being, becoming, and belonging. Drawing, for instance, on Dewey (1997/1938), he distinguishes between experiencing (the situated aspect) and experiences had (the more dispositional perspective) and discusses the relations between them.

The discussion above suggests that the affective domain has generally moved away from purely dispositional perspectives towards more dynamic ones that acknowledge the significance of some form of situatedness. However, different subfields of affective research attach different significance to situatedness, e.g., to what degree it is

considered a constituting element of the affective construct in question. Furthermore, theoretical underpinnings that include situational perspectives are not always adequately considered through research designs or through the way affective constructs have been operationalized methodologically speaking.

Methodological considerations on dispositional and situational perspectives

Emphasising dispositional aspects, studies may rely on methods such as cross-sectional surveys or interviews. Explicitly or implicitly, such studies may locate affect within the individual and fail to address how people relate affectively, for instance, to mathematical activity in schools and classrooms. Such methods have been challenged by researchers who call for approaches that better capture situational perspectives.

Schukajlow et al. (2023) conclude that the often-applied methodological approach of focusing on between-learners' differences in affect conflicts with the conceptual view of motivation as emergent, relational, and responsive to mathematical activity. A situational perspective is needed to account for the significance of time and context (Pekrun & Marsh, 2022).

With respect to time, researchers often use experience-sampling methods, including longitudinal designs, to capture how affect changes in the short or long term. Different conceptualizations of context are reflected in large-scale studies such as PISA; in micro-level studies that address the impact of culture, classrooms, and tasks on affect; and in techniques that enable in-depth analysis, such as case-based ethnography or microgenetic interaction analysis (e.g., Nolen, 2020).

Insights into perspectives on affect in mathematics

To illustrate the progress made in clarifying the dispositional and situational perspectives, we present exemplary studies. Addressing the context perspective, Krawitz et al. (2022) used modelling in mathematics and compared the educational systems in Germany and Taiwan. They examined whether providing students with reading comprehension prompts would improve modelling competencies needed to construct a model of a real-world situation and increase students' interest in modelling.

Combining the context and the time perspective, Parrisius et al. (2022) used a multilevel approach and data from ninth graders in 78 classrooms. They investigated whether individual students and entire classrooms differ substantially in their levels of competence and value beliefs regarding mathematics, and whether individual students' competence and value beliefs fluctuate substantially from lesson to lesson.

Heyd-Metzuyanim and Nachlieli (2024) study professional identities in the case of leaders and participants in professional development initiatives. The authors use positioning theory to document changes in how the research participants implicitly identify themselves and each other when faced with an explorative task. The study demonstrates the potential of a dynamic and situated perspective focusing on immediate interactions when seeking to understand identity-practice relationships.

In summary, while a dispositional perspective has dominated much empirical research, many educational theories already encompass situational perspectives (Pekrun & Marsh, 2022). This indicates that there is a need for greater conceptual awareness and more careful operationalisations, where methodological advances might enable enhanced investigations of existing theories by better incorporating and accounting for situational variations. At the same time, others may argue that differences in conceptual understandings of the notion of “situatedness” lead to incompatible perspectives, in which incorporating factors such as “time” and “context” is insufficient to wholly capture the situational perspective.

SOCIOCULTURAL PERSPECTIVE ON AFFECT

Tanya Evans, Kai-Lin Yang

This forum contribution advances a sociocultural perspective on affect in mathematics education, drawing on a review of 286 cross-national studies (2014–2023). We synthesise four recurring patterns: persistent between-country differences (including the East Asian learner paradox), developmental declines in positive affect and strengthening Big-Fish-Little-Pond effects, contextually patterned affect–achievement relations, and multilevel influences shaped by classroom and institutional structures. We contend that affect is constituted through participation in culturally organised practices, making cross-national research essential for theory building and for refining accounts of how affect and achievement become linked.

Affect in Mathematics Education: Insights from Cross-National Comparative Studies (2014–2023)

The past decade has witnessed a global shift toward competency-based mathematics curricula, which has increased attention to affect—students’ emotions, beliefs, motivations, and attitudes—as both an outcome and a mediator of learning. Drawing on a scoping review of 286 cross-national comparative studies (Yang et al., 2025), we first synthesise key empirical findings. Across the period 2014–2023, this body of research reveals several coherent patterns regarding students’ affect in mathematics.

First, systematic between-country differences persist: the “East Asian learner paradox” remains evident—students from Confucian-heritage systems often attain higher cognitive achievement yet report lower mathematics self-concept, self-efficacy, and enjoyment compared with many Western peers (Leung, 2017), although exceptions and contextual nuances (e.g., Singapore) are documented.

Second, developmental trajectories are consistent across contexts: positive affect declines from late primary to lower secondary (e.g., marked drops in high-level confidence between grades 4 and 8 across multiple jurisdictions), and the Big-Fish-Little-Pond Effect (BFLPE) strengthens with age, indicating increasing sensitivity of self-perceptions to classroom composition (Ker, 2017; Marsh et al., 2015).

Third, the affect–achievement relationship is contextually patterned and multifaceted: (a) within-country (student-level) correlations between affective indicators and achievement are typically positive, whereas between-country (aggregate) correlations can be weak, null, or even negative (Chen & Hastedt, 2022); (b) different affective constructs play distinct roles—domain self-confidence/self-concept is frequently the strongest predictor of achievement, while utility value and related measures often show weaker or inconsistent associations; (c) cultural and institutional contexts moderate effect sizes and directions (e.g., the reciprocal impact of achievement on self-concept varies across Western, Asian, and some Islamic contexts; Marsh et al., 2015) and (d) substantial within-region heterogeneity means that affect–achievement associations vary even within a specific cultural tradition.

Fourth, multilevel determinants of affective outcomes are evident. Classroom-level factors—most notably the BFLPE—fundamentally shape self-concept, though the magnitude of classroom effects varies by cultural and institutional setting. Developmental factors amplify these dynamics over time.

Achievement and Affect in Tension: Performative Participation in High-Performing Systems

Duty orientation and dual pressure as sociocultural mechanisms

A sociocultural lens clarifies the mechanisms underlying this tension. In collectivist-oriented East Asian contexts, mathematics learning is often organized around role obligation and ‘vertical’ academic striving, sustained by long-term, duty-bound effort and delayed gratification (Chen, 2023; Meng & Liu, 2022). Academic success serves as a primary pathway to educational mobility and social recognition, grounding motivation more in obligation and instrumental goals than in intrinsic enjoyment. Simultaneously, examination-based admission systems institutionalize dual evaluative pressures, self-referential comparison with prior performance, and norm-referenced comparison through peer competition and parental expectations, which may intensify students’ sensitivity to academic judgment.

This interpretation is further supported by cross-cultural evidence. Yang et al. (2024) showed that Taiwanese students’ mathematical modelling task value profiles significantly predicted modelling performance even after controlling for intra-mathematical knowledge, whereas such associations were not observed among German students. Notably, intrinsic-related task values—rather than examination-driven utility—were most strongly associated with modelling success in Taiwan. These findings suggest that the motivation–achievement link is culturally mediated and institutionally structured rather than universal.

Rethinking success and affect through performative participation

From a sociocultural perspective, learning is participation in historically organized practices (Lave & Wenger, 1991). For example, within Taiwan’s performative-oriented educational culture, mathematics is structured around speed, accuracy,

ranking, and public evaluation, shaping not only what students learn but also how success is socially defined (Yang et al., 2022). Effort is celebrated, failure is attributed to insufficient diligence, and external evaluation carries moral weight. These participation structures sustain achievement while generating pressure and anxiety.

Affect, therefore, is not an internal deficit but a socioculturally constructed outcome of performative participation. Evidence from the Just-Do-Math program shows that when participation structures are redesigned, affective outcomes shift accordingly (Wang et al., 2021). Addressing the East Asian learner paradox thus requires not merely individual-level interventions, but a reconfiguration of the cultural meanings and evaluative norms through which students experience mathematics.

Beyond the Paradox: Reframing Affect–Achievement Through Sociocultural Integration

Recent cross-national evidence complicates deficit interpretations of the so-called East Asian paradox by demonstrating that sociocultural configurations may generate adaptive pathways linking affect and achievement (Gao et al., 2026). A latent profile analysis of TIMSS 2023 data across Chinese Taipei, Hong Kong, Singapore, Australia, and New Zealand revealed both convergent and divergent motivation profiles. Notably, a value-oriented inconsistent profile—characterised by low confidence alongside relatively higher attainment and utility values—was prevalent in the East Asian jurisdictions yet rare in the Western-influenced Pacific systems. While confidence remained the strongest predictor of achievement in Australia and New Zealand, attainment and utility values in the East Asian contexts appeared to compensate for lower confidence in predicting mathematics performance. Taken together, these patterns illustrate how culturally embedded valuing of mathematics can operate as a compensatory motivational resource: within East Asian collectivist traditions, strong instrumental and attainment-oriented commitments appear to sustain high performance even in the presence of comparatively low self-evaluative confidence.

Gendered distributions further highlight contextual differences: maladaptive profiles were overrepresented by girls in the Western-influenced Pacific jurisdictions, unlike in the East Asian systems, suggesting that sociocultural contexts shape both affect–achievement links and the gendered distribution of motivational risk (Gao et al., 2026).

In conclusion, we contend that, given that the sociocultural research programme now constitutes the dominant research programme in our field of mathematics education—as evidenced by the seminal work of (Inglis & Foster, 2018)—affect can no longer be treated as an isolated psychological attribute located within the individual. Rather, it must be theorised as constituted through participation in culturally and institutionally structured practices. The comparative evidence we presented makes this case difficult to ignore: affective patterns do not merely vary incidentally across contexts, but are systematically organised by local norms, values, and institutional arrangements. If affect is patterned by culture in these ways, then cross-national research is not

supplementary but indispensable to theory building. It provides the analytic leverage required to refine construct boundaries, surface culturally specific mechanisms, and develop more robust, globally responsive accounts of how affect and achievement become linked in practice.

At the same time, advancing a sociocultural perspective on affect calls for continued methodological development. Comparative research has already established affect as culturally embedded and multilevel, drawing productively on large-scale studies such as TIMSS and PISA. Future work could extend this foundation through more theory-driven cross-national designs, culturally attuned instruments, and careful attention to measurement comparability, alongside increased use of longitudinal and mixed-method approaches and broader regional sampling. Such developments could enhance theoretical clarity and contribute to the continued advancement of our field of mathematics education.

AFFECT IN PROBLEM SOLVING AND PROBLEM POSING: A COMPARATIVE AND CONNECTING PERSPECTIVE

Jinfa Cai and Roza Leikin

This article examines affective factors in mathematical problem solving (PS) and problem posing (PP) through comparative and connecting perspectives. We argue that affective experiences in PS depend on whether tasks are creativity-directed, while PP is inherently creative in nature. Using expectancy-value theory, self-determination theory, and flow theory, we argue that routine PS can generate evaluative anxiety, whereas creativity-directed PS (e.g., multiple solution tasks, insight problems) open opportunities for affect linked to interest and aesthetic pleasure. At the same time, PP, being inherently creativity-directed, extends autonomy to task definition itself, reducing anxiety while enabling competence through meaningful question generation. The PS-PP cycle creates affective regulation: posing transforms frustration into curiosity, while invested effort in self-generated problems enhances solving motivation and producing self-regulating affective-cognitive cycle.

Introduction

Problem solving (PS) and problem posing (PP) are two interconnected mathematical activities considered central to the field of mathematics education since Pólya (1945/1973), Silver (1994), and Cai (1995). Both activities involve cognitive and affective processes, yet affect has received comparatively less attention. In this article, we focus on the affective factors associated with PS and PP in mathematics.

“Affect” encompasses emotions, feelings, and character traits that influence thoughts and actions. Affect is categorized as global or local, differing in intensity and stability (Goldin, 2009): Global affect comprises moderately stable beliefs, attitudes, and values (McLeod & Adams, 2012), whereas local affect includes rapidly changing and context-dependent emotions. Consequently, Schukajlow et al. (2017) distinguished task-

specific emotions from domain-level attitudes. Importantly, affect in the context of mathematical PS can be positive (e.g., enjoyment and satisfaction) or negative (anxiety and frustration; McLeod & Adams, 2012). Cai and Leikin (2020) identified affect in PP as an area needing conceptual clarification, noting that the emotional processes accompanying problem generation remain insufficiently understood.

Both PS and PP generate local affect and influence global affective conceptions but in different ways. Our analysis of affective differences and connections between PS and PP centers on their creativity-directed nature (Leikin, 2018). Conventional PS, which involves analyzing conditions, selecting tools and strategies, and implementing them to attain the solution outcome, differs from open PS (Silver, 1995). Multiple Solution Tasks (Leikin, 2013, 2018; Silver, 1997) and insight problems (Leikin & Guberman, 2023) exemplify creative approaches within PS. PP, which comprises generating new mathematical questions from situations, is inherently creativity-directed allowing diverse question generation (Cai et al., 2013; Leikin, 2018; Silver, 1994, 1997).

We analyze the affective components of PS and PP from two perspectives. The first is comparative: How do emotions, self-efficacy beliefs, and motivational orientations manifest differently across the two activities? The second is connective: How does affect link posing and solving within their cyclic relationship?

Comparative perspectives on affect FOR PS and PP

We employ three theoretical frameworks to illuminate the affective dimensions of PS and PP: (a) Eccles and Wigfield's (2002) expectancy-value theory posits that engagement depends on expectation of success and task value; (b) Deci and Ryan's (2000) self-determination theory holds that intrinsic motivation requires three basic needs: autonomy, competence, and relatedness; and (c) Csikszentmihalyi's (1990) flow concept describes absorption arising when challenge and skill balance and individuals self-regulate task difficulty. We integrate these frameworks as complementary lenses for examining affect across mathematical activities.

In routine PS, success expectancy connects to procedural proficiency, and value is often instrumental. When PS is creativity-directed, value shifts toward intrinsic interest: Solvers experience aesthetic pleasure in elegant solutions or surprise at unexpected connections (Leikin, 2009, 2013). In PP, expectancy is more diffuse because no single correct answer exists, and intrinsic value tends to be higher because the activity involves personal expression and creative choice. In routine PP, self-efficacy builds through accumulated success but erodes quickly with failure. In creativity-directed solving, it rests on a broader base: Even when one strategy fails, success through another sustains competence beliefs (Leikin, 2018). In PP, students experience competence through creating meaningful questions regardless of whether they can solve them. Cai and Hwang (2023) noted that PP tasks have a "low floor and high ceiling," a characterization also applying to well-designed Multiple Solution Tasks. In a recent study, Cai et al. (2026) found significant differences between

reported self-efficacy and self-evaluation. For PS, the Self-efficacy Group reported higher confidence about their ability to complete the task than the Self-evaluation Group reported retrospectively about their performance, but, for PP, the Self-efficacy Group reported lower confidence than did the Self-evaluation Group.

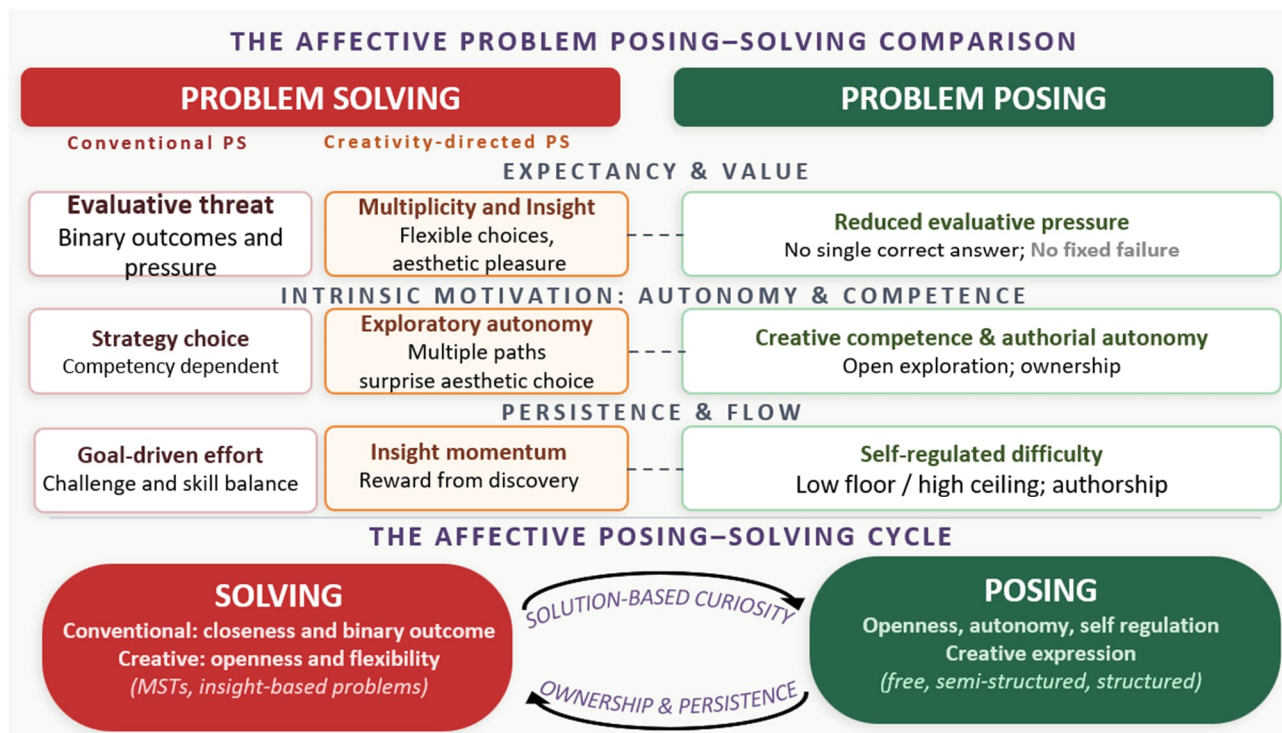
Mathematical anxiety is associated with binary outcomes, creating evaluative frames in PS (Schoenfeld, 1985). When solving involves insight-requiring tasks, frustration shifts toward enjoyment depending on PS success (Leikin, 2013; Leikin et al., 2023). PP is not associated with binary evaluation, thus reducing anxiety (Akay & Boz, 2009). However, posing is not anxiety-free. In fact, mathematicians pose problems with triggers (Kontorovich, 2020). Whereas PS addresses autonomy through strategy choice, PP extends autonomy to defining the task itself (Cai & Leikin, 2020).

The affective contrast between PS and PP does not follow a uniformly evaluative solving experience versus uniformly creative posing experience but connects to different configurations of PS and PP assignments. In closed problems, persistence depends on goal clarity and competence; in open tasks, complexity rises alongside autonomy, so motivation is not necessarily higher. Integration of PS and PP creates specific affective effects. Cai et al. (2013) found that affective investment in posing transferred to stronger solving performance. Liljedahl and Cai (2021) noted that posing embedded within solving creates conditions favourable to flow (Csikszentmihalyi, 1990) through self-regulation of difficulty.

The Connecting Perspective: Affect Across the Cycle

The comparative analysis above treats PS and PP separately. However, as Liljedahl and Cai (2021) emphasized, solutions generate new questions, and new questions reshape subsequent solving. The affective dimension of this cycle deserves attention because affect shapes and is shaped by cognition. Transitioning to posing shifts learners from convergent, evaluative modes to divergent, exploratory ones. This can transform frustration from incomplete solutions into curiosity about new questions. Conversely, satisfaction from complete solutions can fuel ambition to pose harder problems. The posing phase thus serves an affective regulatory function. The transition from posing to solving also carries affective significance. Students who invest creative effort in formulating problems are more motivated to solve them compared to externally assigned problems. Cai and Leikin (2020) described this as the affective signature of PP, involving pride, investment, curiosity, and anticipation. The posing-solving cycle, when functioning well, creates a self-regulating system: Posing calibrates challenge, solving provides feedback. Affective quality depends on classroom culture, teacher responsiveness, and learners' prior experiences. This bidirectional relationship suggests that integrating PS and PP enhances both cognitive and affective outcomes (Figure 1).

Figure 1: Affect in Problem Solving and Problem Posing



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AFFECT IN MATHEMATICAL MODELLING AND APPLICATIONS

Janina Krawitz, Irene Ferrando, Wim Van Dooren

This contribution synthesises research on affect in mathematical modelling and applications, treating affect both as an outcome and a condition for solvers' activity. We show how task characteristics and instructional designs shape emotions and motivation, often fostering competence and interest, but sometimes eliciting frustration. We also explain how beliefs and classroom culture influence the use of real-world knowledge instead of routine procedures. Individual differences modulate these dynamics. We end by outlining future research directions.

Introduction

Mathematical modelling—the capacity to solve real-world problems with mathematical methods—has become a central competence in mathematics education, equipping students to address complex challenges. Modelling tasks embed real-world contexts and require solvers to understand the situation, simplify and structure the given information, make assumptions, mathematise, interpret and validate the solution and, if needed, refine the result in iterative cycles (Niss & Blum, 2020). Teaching modelling in school pursues distinct goals, including psychological goals that highlight the motivational importance of real-world connections (Krawitz et al., 2025).

Achieving these goals depends on specific task characteristics. At the same time, these task characteristics can also heighten uncertainty and, in some cases, negotiation, which is why affective processes arise alongside metacognitive and cognitive activity (Chamberlin, 2019).

We discuss some key insights regarding affective aspects around modelling from various perspectives. Affect is an outcome of modelling activities, but pre-existing beliefs, attitudes and values are also brought to modelling tasks. We further consider individual differences in these matters.

Affect as an outcome of modelling

Engaging in mathematical modelling shapes learners' emotions and motivation during and after task work. This is largely due to distinctive task characteristics of modelling, and to instructional approaches. Regarding task characteristics, modelling tasks typically allow multiple solutions. Their openness may affect students' perceived autonomy and control, thereby affecting their self-efficacy beliefs and other motivational and emotional experiences during task engagement. However, modelling tasks pose specific challenges, such as the need to make plausible realistic assumptions. These challenges may elicit frustration or lower self-efficacy beliefs.

Further, the relationship of the task's context to reality and its proximity to solvers' lifeworld impacts students' affective outcomes. Real-world contexts can improve affective outcomes. When solvers have a greater personal interest in the task context, they show more frequent validation sequences and more explicit, justified assumptions (Kämmerer, 2025). However, real-world wrappers do not guarantee higher interest, as studies demonstrated that students report lower interest and task-values for modelling compared to intramathematical problems.

The instructional approach matters for these affective outcomes. Numerous studies have consistently shown that student-centred formats (e.g., collaborative work), explicit strategy instruction, and structured scaffolding to support the demands of modelling (e.g., providing solution plans) enhance students' motivation. Recent empirical work nuances this picture: prompting multiple solutions reliably increases students' experience of competence during modelling, although it does not always raise interest directly, suggesting indirect pathways from instruction to affect (Achmetli & Schukajlow, 2019).

Affect as a condition in modelling

Modelling behaviour is also strongly impacted by beliefs learners bring to modelling tasks. Convincing evidence comes from research on word problems. Word problems are assumed to bring (rather simplified) real-life situations in the classroom, where learners can then practice modelling. However, learners often do not engage with using real-life knowledge, but instead routinely execute arithmetical operations without seriously considering the problem context (Van Dooren et al., 2006).

In a series of studies, Verschaffel et al. (2000) gave “tricky” word problems to upper elementary and lower secondary students, for example: “Bruce and Alice go to the same school. Bruce lives at 17 km from school, and Alice at 8 km. How far do they live from each other?” Widely replicated studies indicate that learners massively tend to ignore their real-world knowledge (answering 9 km to this problem). Such superficial problem-solving behaviour is due in part to the beliefs that learners develop gradually, implicitly and tacitly through the immersion in the mathematics classroom culture. They acquire sociomathematical norms that determine implicitly or explicitly how to behave in the mathematics classroom, and part of these norms are that word problems require a single precise numerical answer, and that learners should not engage in real-life considerations or information from outside the word problem. Several studies have shown the impact of the classroom culture. When learners are involved in more authentic settings, they perform substantially better than when answering a written question (Van Dooren et al., 2006), and learners approach the same problem differently when embedded in a mathematical test versus in an ethics test (Dewolf et al., 2011).

Influence of individual differences

Individual differences also moderate the influence of affective constructs in modelling. In classroom modelling tasks, Lu et al. (2026) report that intrinsic value positively predicts enjoyment and curiosity, while situational success expectancy—students’ momentary belief that they can succeed in the ongoing modelling task—supports positive emotions and buffers against boredom and anxiety. Crucially, these affective patterns vary by learner profiles: boys report higher boredom but lower anxiety than girls, and higher prior achievement is linked to reduced negative emotions and increased curiosity, revealing heterogeneous affective dynamics across groups.

Regarding differences in students’ cognitive profiles, in modelling tasks, interest gaps between talented and regular students are similar as in intramathematical problems and significantly larger than in word problems with no authentic real-world connection; also, while interest related positively to performance across task types, this correlation is attenuated for talented students (Ferrando et al., 2026). Similarly, low-achieving students show higher situational interest for open modelling problems than for closed real-world problems, and the interest-performance link depends on both openness and achievement level (Schukajlow et al., 2022).

Future research directions

While research in affect in modelling and applications has made advances in the recent years, there are still important gaps that should be addressed. First, more systematic investigations of task characteristics are needed. Because modelling tasks integrate multiple characteristics at once, the affective impact of specific characteristics remains difficult to isolate. Future studies should disentangle the individual and interactive effects of task characteristics including openness, authenticity, and cognitive demand

on students' affect, while examining whether these effects are conditioned by modelling-specific beliefs and classroom norms, and whether they differ across learners' profiles. Second, longitudinal evidence is scarce. Follow-up studies are needed to differentiate situational emotions from enduring motivational development and to understand how modelling task design and modelling interventions influence affect over time, including how trajectories vary by beliefs profiles and individual differences.

AFFECT AND GENDER

Chiara Giberti, Lara Gildehaus, Lovisa Sumpter

Here, we present the results of a narrative review, where we identified three themes based on earlier research. The themes are: how gender differences evolve, gender differences and affect in the classroom, and finding a voice. These themes are deliberated using research picked purposely to represent different geographical contexts, methods, and epistemological and philosophical framings. We end the review by discussing the consequences of gender and affect.

Setting the scene

In many countries, there is a traditional view regarding boys' and girls' participation in mathematics, where gender stereotypes still exist (e.g., Liu et al., 2020). These stereotypes relate partly to what boys and girls are considered to 'be', and mathematics as a subject (e.g., Basma & Rubie-Davies, 2025). However, one major problem in research on mathematics and affect is the dominance of Western research: although people from Western cultural backgrounds make up just 12% of the global population, a disproportionately large portion of psychological research relies on samples from these societies (Picho & Schneider, 2018). For instance, a recent meta-analysis by Flore and Wicherts (2015) found a small effect of stereotype threat reducing female adolescents' mathematics performance. However, they note that 94% of the studies in their meta-analysis were conducted in just four countries: the United States, Italy, France, and Germany. The results should be compared with a study from Uganda signalling that men are not immune to stereotype threat in mathematics (Picho & Schneider, 2018). Given that gender stereotypes are culturally-defined constructs that show both consistency and variation across cultures (e.g., Ng et al., 2012), there is scope to both challenge and confirm many of the earlier studies on mathematics, affect, and gender to build a more informed research body.

How gender differences evolve

One important question in mathematics education and affect is how gender differences evolve over time, especially given that these differences are not linked to biological sex but can be influenced. For example, there are greater gender differences in participation and performance in competitive countries and environments (Steeh et al., 2019). France exemplifies such a country, and Martinot et al. (2025) recently documented gender disparities in mathematics achievement through a four-year

longitudinal study of all first and second-grade children in France, 2.5 million students. Initially, boys and girls showed similar results, but a notable gender gap in favour of boys emerged after just four months of schooling, widening further after a year. The findings are supported by a study of Australian kindergarten children: both girls and boys entered school confident in their mathematical capabilities, but after a year, not only did girls' confidence decrease relative to boys', but girls also showed a shift in their conceptions of mathematics, viewing it as less important for future careers (Davey et al., 2025). These results highlight the early formation of stereotypically gendered conceptions that can function as an explanation for other reported gender differences in affective constructs. As an example, a comparison of Swedish TIMSS data for grades 4 and 8 shows that girls' motivation declines more than boys' during this period (Sumpter & Sollerman, 2023). This is an international trend followed by most countries (von Davier et al., 2024). What is new is that more countries, which did not show any gender differences in TIMSS 2019 and earlier studies, are reporting significant differences in favour of boys in TIMSS 2023.

Gender differences and affect in the classroom

In the classroom, students who believe they can succeed persist in challenging mathematical tasks, whereas those with low self-efficacy withdraw when difficulties arise (Watson & Rubie-Davies, 2024). Even when girls earn higher grades, they often rate their abilities lower than boys, indicating a persistent mathematics confidence gap. Higher mathematics anxiety among females reduces participation and, by taxing working memory during tests, can lower performance (Ganley & Vasilyeva, 2014). Within classrooms, affect is socially constructed through students' and teachers' beliefs, expectations, and daily interactions, with students' motivation and confidence closely tied to perceived support, feedback, and encouragement from teachers (Rojo Robas et al., 2018). Teachers' gendered stereotypes and expectations can emerge in everyday classroom practices, shaping both students' self-beliefs and teachers' practices (Watson & Rubie-Davies, 2024). For instance, the idea that girls' success in mathematics is due to hard work while male success is due to innate ability or talent (Basma & Rubie-Davies, 2025), can reinforce gender biases and lower girls' self-beliefs. Moreover, classmates' stereotypical beliefs have been found to influence girls' mathematics self-concepts more strongly than boys', highlighting that peers also play a role in shaping affective factors in the classroom (Wolff, 2021). Understanding gender and affect means viewing the classroom as a system where teacher beliefs, practices, peer interactions, and classroom norms interact.

Finding a voice: the sense of belonging

The relevance of positive identities becomes evident when considering differences in students state and trait interest: girls often report similar levels of situational interest in specific mathematical tasks or lessons as boys. However, when asked about their general interest in mathematics, girls report lower levels (Høgheim & Reber, 2019). This suggests, that girls may struggle to see mathematics as something that fits with

who they are. Such a sense of belonging refers to students' feelings of being valued and recognised as participants in mathematical activity. Many girls experience a weaker sense of belonging in mathematics, often perceiving a misalignment between dominant images of "the mathematician" and their own identities (Good et al., 2012). At the same time, research highlights positive learner identities among girls in mathematics (Radovic et al., 2017). However, these identities can be fragile (Solomon et al., 2011). Success may be associated with effort rather than with competence, which can limit students' sense of agency. Within such framing, mistakes or uncertainty can be experienced as threats to identity, rather than as integral aspects of learning. This creates ground for experiences of shame in mathematics (Jenßen, 2023), where students perceive a discrepancy between who they feel they are expected to be and how they experience themselves. Shame can lead to self-silencing or avoidance of challenging tasks, even among students who are otherwise successful. Importantly, shame is not merely an individual emotional response but is socially produced and maintained. In this context, identity is not only about how students see themselves, but also about how they are seen and addressed by others in mathematical spaces. Conversely, learning environments that support dialogue, recognise diverse forms of participation, and legitimise uncertainty can foster agency and counteract shame.

The role of affect and consequences: future perspectives

While the achievement gap in mathematics has reduced, gendered differences in students' mathematics self-efficacy and future engagement in STEM fields persist. Even in countries where no gender differences in performance are observed, such as Singapore and Finland, gender gaps in mathematics self-efficacy and self-concept persist and strongly affect teaching and learning processes (Mejía-Rodríguez et al., 2021). These results suggest that deep-seated differences in self-beliefs remain, potentially affecting their future involvement in STEM. In addition, large-scale studies (e.g., Sumpter & Sumpter, 2021) show evidence of the so-called discrimination hypothesis, thereby refuting the lag hypothesis as an explanation for the continued underrepresentation of women in mathematics and engineering education, indicating that there is room for improvement at all levels.

NAVIGATING THE SPACE OF MATHEMATICS-RELATED AFFECT

Markku S. Hannula

Research on affect in mathematics education has evolved into a complex field examining emotions, motivation, and beliefs across varied contexts and activities. This forum highlights consistent findings, such as the reciprocal relationship between affect and achievement and the situated nature of affective experiences. Future work must continue refining affective constructs, apply stronger research designs, address intersectional factors, and develop interventions that foster positive mathematical experiences for all learners.

Introduction

Mathematics education research has acknowledged the importance of affect for teaching and learning. Early research on mathematics anxiety, attitude, self-efficacy, and beliefs addressed affect mostly as a factor explaining failure. Gradually the scope of mathematics-related factors has expanded in many directions. The current research forum collected important perspectives in the field to build a more holistic understanding of the area both theoretically and methodologically.

As an attempt to build a coherent picture of mathematics-related affect as a research domain, I have suggested a metatheory to map the different affective concepts (Hannula, 2012). That metatheory consists of three dimensions: 1) the level of theorizing affect (from physiological to sociological), 2) the state vs. trait type affect, and 3) the type of affect (emotional, motivational, or cognitive). These three dimensions can be used to map affective constructs in a tree-dimensional space.

However, neither my metatheory, this research forum, nor any other attempt to synthesize mathematics-related affect theories has captured all relevant aspects in one coherent framework. Such synthetic elaborations have to choose focus and ignore some peripheral issues or else they become too complex to meaningfully communicate ideas. In the current research forum, the focus is on psychological and to minor degree sociological theorizing of affect, often explicitly elaborating the state-trait distinction. Not trying to address every aspect of affect, the elaborations can be more thorough.

State-of-the-art

While the domain of affect is theoretically complex, some of the findings seem well established regardless of the specifics of the affective concept under scrutiny. Firstly, there is a well-established positive correlation between affect and achievement. Moreover, the typical mechanism behind the correlation is some kind of reciprocal feedback system where affect influences achievement and the achievement feeds back to affect development. Many contributions in this research forum review and discuss important aspects of such reciprocal affect-achievement dynamics.

Secondly, we know that the role that affect plays in learning is not universal but significantly influenced by the context where learning is situated. All contributions in

this research forum acknowledge some kind of situatedness of affect. Affect is situated in a dynamic process, in a specific type of activity, in the educational setting, and in the sociocultural context of the educational system. Comparing across the different contributions, it is apparent that the issue of situatedness is complex. Another layer of complexity is indicated by the well-established gender differences in mathematics-related affect. It is likely that the gender interacts with situatedness, so that gender differences are emphasized in some contexts and diminished in others.

Much of the interesting development in mathematics-related affect has stemmed from research on problem solving (e.g., Goldin, 2009; Schoenfeld, 1985). In this research forum Cai and Leikin review current research in the area and Krawitz and others extend this work into the area of mathematical modelling. Other specific areas where affect has been analysed are, for example, proving (Häsä et al. 2023) and working with technology (Gómez-Chacón, 2012). These examples point out the relevance of specific affective aspects of different mathematical activities.

Affect has typically been studied using either questionnaires or interviews. As it is a personal experience, it is understandable that methods often rely on self-reports. Both interviews and questionnaires are valid approaches, each for different purposes. As discussed by Coppola and others, longitudinal and comparative designs provide stronger foundation to analyse affective dynamics and impact of sociocultural context.

Future directions

Affect terminology is sometimes confusing. This research forum is aware of semantic pitfalls, and each author uses sufficiently detailed language to describe their ideas. There is growing awareness of the space of affective constructs and explicitly locating research in that space. Such practices in communication will make the field stronger.

The current research forum revisited the gender differences in affect. In addition to gender, student ethnicity (McGraw et al., 2006) and sexuality (Moore, 2021) interact with mathematics-related affect. While the role of ethnicity is well researched in some countries, the sexuality in relation to mathematics identity is less well known and the intersections of multiple group identities are largely unexplored areas.

Reading the contributions, it is obvious that no single theoretical or methodological solution suits all needs of affect research. Therefore, when beginning to plan a study, it is important to make a thorough analysis of the phenomenon under examination and choose the right constructs for the study. Is the focus on individual experience or group level patterns? Is it enough to measure the trait type disposition or is there need to follow the dynamics of an affective state? If affect is both an outcome and a condition (see Kravitz et al.), is it the same affect in both? Such questions determine what concepts and instruments are likely to allow answering to your research questions.

Overall, advancing mathematics affect research calls for stronger research designs (e.g. longitudinal or comparative) with large samples to allow for more complex analyses. Moreover, current research has mostly focused on understanding the current

mathematics education practices rather than trying to change them. There is great need for interventions aiming to develop a healthy and productive affective relation with mathematics for all students.

Self-reports will continue to be central methods in affect research, being feasible for even studying affective states as part of the process. Think-aloud protocols and stimulated recall interviews are already frequently used for revealing state type emotions as part of the process. Alternatively, facial expressions and body posture (e.g. Hannula 2015) can indicate emotions and be analysed in detail from a video. With machine learning methods, such analysis will become faster and more feasible for large samples. In addition, physiological measures (e.g. Ketonen et al., 2023) are becoming easier to use and analyse allowing stronger triangulation of different measures of affect.

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