Chapter 2
The Affective Domain, Mathematics, and Mathematics Education

Abstract The affective domain has been of interest to mathematics educators and researchers for many years. However, there has been a lack of clarity about the nature and make-up of the affective domain, and so in this chapter we begin by first discussing a conceptual background and framework of affect in relation to mathematics education. This is a contested space, and so we outline an understanding of mathematical affect as including beliefs, values, attitudes and emotions, and this will underpin the empirical and theoretical work reported in this book. The relationship between affect and mathematics and mathematics education is specifically discussed, to this end the concept of *mathematical identity* is posited as a way to include affective, cognitive and conative aspects of learning. Finally, all these aspects of learning mathematics are considered in the light of middle schooling and adolescent students.

Keywords Mathematics education · Affective domain · Beliefs · Attitudes · Emotions

There has been a great deal of interest in the affective domain and mathematics education over many years. Perhaps a critical moment in the attention and study of affect was associated with the investigation of issues related to gender—in particular girls, and mathematics starting in the 1970s (e.g., Fennema and Sherman 1976). More recently, the interest in affective factors in mathematics teaching and learning has focused on and been fuelled by issues of disengagement and diminishing participation. In this chapter we provide a discussion of the affective domain to give a conceptual background and framework for the book. The affective domain, and its constituent components, have been variously defined by a range of authors who come from a variety of disciplinary traditions, so we take some time to define the affective terms and concepts that we have used. In doing this we draw on a range of highly cited seminal authors (e.g., Green 1971; McLeod 1992; Pajares 1992; Rokeach 1968, 1973). Following this, affect is specifically discussed in relation to learning and teaching mathematics. At this point, we introduce the concept of *mathematical identity* as a term to include affective, cognitive and

P. Grootenboer and M. Marshman, *Mathematics, Affect and Learning*,
DOI 10.1007/978-981-287-679-9_2

conative aspects, and explore mathematics education as the development of mathematical identities. Finally, all these aspects of learning mathematics are considered in the light of middle schooling and adolescent students.

The Affective Domain

The affective domain has various inter-related dimensions that are defined in a variety of ways and the terms used to refer to the concepts are confused in their meaning (Lomas et al. 2012). In his seminal chapter, McLeod (1992) stated that "the affective domain refers to a wide range of beliefs, feelings, and moods that are beyond the domain of cognition" (p. 576), although even the distinction between the affective and cognitive domains is often unclear. Here the affective domain will include the following inter-related facets:

- beliefs;
- values;
- attitudes; and,
- emotions.

We are aware that there are a number of other facets that could have been included like motivation and engagement (see Attard 2014). It is also important to note that while we are interested in the various aspects of the affective domain, we are more concerned with analysing and discussing them as a complex, inter-related whole as indicated in the Fig. 2.1. Drawing on the theoretical work of McLeod (1992),

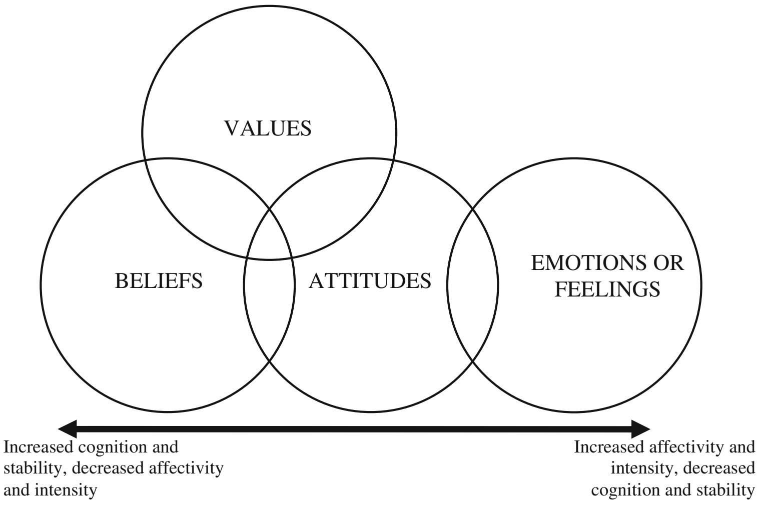

Fig. 2.1 A model of conceptions of the affective domain (Grootenboer 2003; Leder and Grootenboer 2005)

the figure highlights that in the literature, beliefs, values and attitudes are inter-related and defined in somewhat inter-changeable ways, and also shows emotions are generally conceptualised as distinct from beliefs and values, but related to attitudes. Furthermore, the continuums related to affectivity, cognition, intensity and stability are shown at the bottom of the diagram, highlighting, for example, the relative intensity, stability, affectivity and cognition of emotions vis-à-vis beliefs.

Whilst these aspects are often discussed and interrogated separately in this book, it is important to note that they are complexly inter-related and 'over-lapping' constructs. It is also important to be aware that there are a range of other constructs or dimensions that could have been specifically included including anxiety, confidence, efficacy and dispositions, and these have been, to a greater or lesser degree, been assimilated into the four key aspects employed. Indeed, there have been many studies that have addressed subsets of the affective domain in regard to mathematics education, but the richness and complexity of the domain as a whole can render this division as a simplification and therefore, problematic. Nevertheless, each aspect will now be outlined in turn.

Beliefs

There is a substantial and growing body of literature related to the significance of teachers' beliefs and their role in shaping teaching practice (e.g., Grootenboer 2008; McLeod 1992; Mosvold and Fauskanger 2014; Pajares 1992). There is also an emerging and growing interest in students' beliefs about mathematics and mathematics learning and teaching (e.g., McDonough and Sullivan 2014). However, what is not so clear is the meaning or definition of the concept of beliefs. In his foundational article, Pajares (1992) noted that "a variety of conceptions of educational beliefs has appeared in the literature" (p. 314). He stated;

> Defining beliefs is at best a game of player's choice. They travel in disguise and often under alias—attitudes, values, judgements, … perceptions, conceptions, … perspectives, repertoires of understanding, … to name but a few that can be found in the literature. (p. 309)

Richardson (1996) noted that, "there is considerable congruence of definition … in that beliefs are thought of as psychologically held understandings, premises, or propositions about the world that are felt to be true" (p. 103). Commonly, beliefs are seen as subjective personal assumptions of truth which act as predispositions to action (Rokeach 1968), and it also seems to be widely accepted that beliefs are structured and organised into some form of system (Green 1971; Rokeach 1968). More recently Philipp (2007) defined beliefs as "psychologically held understandings, premises, or propositions about the world that are thought to be true. … Beliefs might be thought of as lenses that affect one's view of some aspect of the world or as dispositions towards action" (p. 259).

In the widely cited text, Green (1971) suggested that there are three dimensions to belief systems.

1. There are primary beliefs and derivative beliefs.
2. Beliefs can be seen as being on a range from central to peripheral.
3. Beliefs are often held in groups or clusters.

Primary beliefs are developed from direct experience whereas derived beliefs are learned indirectly from significant others, and primary beliefs are considered to be more important and influential than derived beliefs (Rokeach 1968). Second, beliefs can be organised along a central-peripheral continuum, where central beliefs have greater significance and impact, and are more resistant to change. According to Rokeach (1968), a central belief is developed from direct experience of the object of the belief, and it is then reinforced by social group consensus. As such, central beliefs are often primary beliefs. The third dimension of a belief system is the clustering of beliefs into relatively independent groups (Green 1971), and it is inappropriate to consider single beliefs. This clustering of beliefs into more or less isolated groups can help explain why it is possible for people to hold apparently contradictory beliefs in different contexts (Jorgensen et al. 2010; Richardson 1996; Philipp 2007).

Of significance to researchers and educators is the relative inaccessibility of beliefs—beliefs must be inferred because they cannot be directly observed. Furthermore, there are often tacit and known compelling personal and social reasons that mean what individuals state *as a belief* may be quite different from their *actual* beliefs. Also, the contextual and clustered nature of beliefs may well mean that individuals can express different beliefs in different situations or contexts. In terms of individuals' behaviour, thinking and learning, beliefs are seen as playing a filtering role for new experiences and information, and as such they moderate what and how children learn mathematics (Pajares 1992). If the beliefs of students are not conducive to effective mathematics learning and mathematical practice, then it is imperative to address them.

Changing Beliefs

As noted above, beliefs are formed either through direct experience or as a derivative of others' beliefs, and the beliefs formed through direct experience tend to be more central, and as such they are the more influential and powerful beliefs. Of course, many of these central beliefs can be reinforced and affirmed by derivate peripheral beliefs that are developed through social interaction with meaningful others. Not surprisingly, these beliefs are resilient and difficult to change.

In general, the process of belief change is not well understood, and it is not always in intended or desirable ways (Tillema 2000). This is evident in the mathematical beliefs that many seem to develop through their schooling that are often limiting and debilitating (Grootenboer 2010). For an individual to change their beliefs, they need to desert premises that they hold to be true, and often this is difficult and challenging, particularly the more central and primary the beliefs. Many have theorised about the conditions necessary for beliefs to change, but in general it requires attention to experience and practice issues. To this end, belief change usually requires revisiting and reviewing episodes which gave rise to the held beliefs, and then creating new encounters where new and desirable beliefs can be experienced in positive and successful ways. Belief change does not occur simply through the presentation of new, desirable beliefs. Because central beliefs have been developed through experience, new activities giving rise to positive experiences and reflection upon those experiences is critical to belief change (Pajares 1992). The complex and affective nature of beliefs belies a simple, linear, logical approach to belief change, and therefore, issues of memory, practice, emotion and thought need to be attended to in the process of belief change (Tillema 2000). Indeed, if beliefs are to be changed, then not only does the substance of the beliefs need to be explored, but also how they are developed and held.

Beliefs About Mathematics and Mathematics Education

While beliefs are certainly developed and formed in a range of contexts and in different social settings, primarily here we are concerned about mathematical beliefs that are formed and moulded through schooling. In 1989 Ernest identified and noted three conceptions of mathematics;

1. mathematics as an expanding field of human invention which is dynamic and problem-driven (Problem-solving view);
2. a structured, unchanging body of knowledge (Platonist view); and,
3. mathematics as a collection of procedures, facts and skills (Instrumentalist view).

As will be outlined in the following chapters, these three conceptions of mathematics underpinned the instrument and sub-scales in the quantitative study of this book. The traditional view of mathematics reflects primarily the *Platonist view*, but mathematical philosopher Hersh (1985) suggested it was appropriate to review this perspective so that features of mathematics that had been ignored might now be observed. He proposed that "mathematical knowledge is fallible, corrigible, tentative and evolving as is every other kind of human knowledge" (p. 10). The instrumentalist view is akin to modern notions of numeracy (to be numerate is to confidently and effectively use mathematics to meet the everyday demands of life (Department of Education and Training, n.d.)).

Young-Loveridge et al. (2006) interviewed approximately 400 primary school students (aged 6–13 years) about their beliefs on the nature of mathematics by asking; "What do you think maths is all about?" The students saw mathematics in a range of ways that included instrumental, Platonist and problem-solving perspectives. The most common perception they noted was that mathematics was about content, in particular about computation and number. Other views espoused by the students included perspectives on learning mathematics and problem solving, with many noting the importance of mathematics for their futures. The researchers commented;

> Much of the data seems to indicate that children do perceive mathematics in dichotomous ways. Some children considered that mathematics was an external body of "stuff to be learned". Others suggested that they needed to make sense of the mathematics, in order to make connections between related mathematical ideas. Many children were aware of the significance of the mathematics in society, but for others, a more mechanistic view was noted. (p. 589)

Young-Loveridge et al. (2006) suggested that the students beliefs were, to a greater or lesser degree, learned and therefore, teachers need to consider their own beliefs about mathematics and how they might be enacted— consciously and sub-consciously, in the classroom. Similarly, McDonough and Sullivan (2014) suggested that it is important to know and understand students' beliefs about mathematics because they influence the nature of their learning in the classroom, and the way they engage with the mathematical material of their lessons.

Values

Education is value-laden (Bishop 2000; FitzSimons et al. 2001; Seah and Barkatsas 2014). Rokeach (1973) defined a value as, "an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence" (p. 5). Furthermore, like beliefs, values are organised in sets or clusters, and action is influenced by multiple values or value clusters as opposed to individual, isolated values. Clearly, values have a close affinity with beliefs, but the distinction made by Clarkson et al. (1999) is that values "are demonstrated in the actions carried out by a person, whereas beliefs can be verbally assented to, but do not necessarily lead to observable behaviour in public" (p. 3). Alternatively, Philipp (2007) defines values as "the worth of something. A belief one holds deeply, even to the point of cherishing, and acts upon. … Values are less context-specific than beliefs." (p. 259) Values are also closely related to attitudes, with values being held in a deeper and more central position. As with the other dimensions of the affective domain, the vocabulary for values, attitudes and beliefs is often used inter-changeably, again accentuating the complexity of this field.

Over the last 15 years there has been a sustained and focused program of research across a range of countries that centred on values in mathematics education. This pioneering work began with Bishop, Clarkson and their colleagues in Melbourne, Australia in the *Values and Mathematics Project (VAMP)* (Bishop et al. 1999). They suggested that "values in mathematics education are the deep affective qualities which education aims to foster through the school subject of mathematics and are a crucial component of the classroom affective environment" (Bishop et al. 1999, p. 2). The VAMP team found that values tend to be implicit rather than explicit in the mathematics classroom, and that there are three kinds of values evident:

(1) general educational values; (2) mathematical values; and, (3) mathematics educational values (Clarkson and Bishop 1999). The mathematics education values included aspects such as clarity, flexibility, consistency, persistence, creativity and conjecturing (Seah and Barkatsas 2014).

Attitudes

As with the other dimensions of the affective domain, there is some confusion over the concepts and constructs that are labelled as attitudes (Rokeach 1968). Often terms like anxiety, confidence, motivation, enjoyment, feelings and beliefs are used when discussing attitudes. While the definitions of attitude vary in the literature, in general they are seen as learned responses to a situation or object, and they are either positive or negative. After conducting an extensive review of research into affect in mathematics education, McLeod (1992) defined attitudes as, "affective responses that involve positive or negative feelings of moderate intensity and reasonable stability" (p. 581). After his extensive review of literature in 2007, Philipp defined attitudes as "manners of acting, feeling, or thinking that show one's disposition or opinion" (p. 259). So, it seems that attitudes develop from several similar and repeated emotive responses to an event or object.

Repeated emotional reactions to mathematical situations become 'habitual' and an attitude towards mathematics develops that can be characterised as being relatively stable (McLeod 1992). The general consensus in the literature is that attitudes do impact and influence behaviour, although the relationship is not well understood (Rokeach 1968). If attitudes are seen as predispositions to action which invoke preferential responses to the event or object concerned, then indeed they would affect behaviour within contextual parameters.

Attitudes to Mathematics

Research in attitudes and mathematics education appears to precede the relatively more recent interest into beliefs and values. Most of this research into mathematical attitudes has been quantitative in nature and been grounded in the discipline of psychology. The primary aim of much of the early research was to measure attitudes to mathematics and mathematics education, and while this has been useful in identifying the issue of poor attitudes to mathematics, they have not focused on understanding the underlying reasons for the problem.

Unfortunately, it appears that many people have a negative attitude to mathematics, and these attitudes have been largely developed at school in mathematics classrooms (Hubbard 2001; Larkin and Jorgensen 2015; Swars et al. 2007). As far back as 1969, Anttonen found a strong positive correlation between mathematics attitude and mathematical achievement, and 20 years later, Ma (1997) also identified a reciprocal relationship between attitude toward mathematics and achievement in

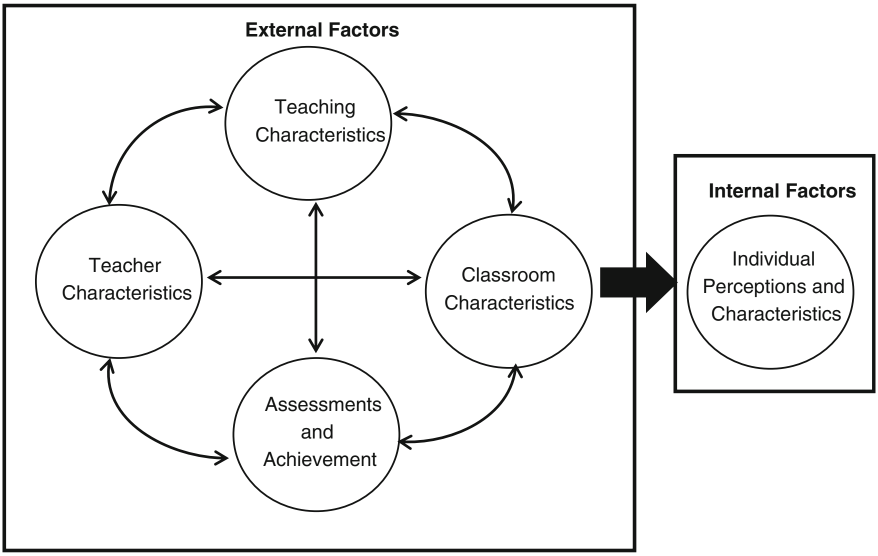

Fig. 2.2 The relationship between factors that affect students' attitude toward mathematics (Goodykoontz 2008)

mathematics and in doing so, highlighted a possible self-perpetuating negative (or positive) cycle. As with beliefs, there is some research support for the idea that teachers' pedagogical practices and their students' development are influenced by their teachers' attitudes to mathematics (Harkness et al. 2007; Leder 1992; Wilkins and Brand 2004).

In her research into how students develop attitudes towards mathematics, Goodykoontz (2008) identified five key factors:

1. teacher characteristics;
2. teaching characteristics;
3. classroom characteristics;
4. assessments and achievement; and,
5. individual perceptions and characteristics.

The first four of these were seen as "external factors" and they are clearly inter-related. Goodykoontz showed the relationship in a diagram that is reproduced in Fig. 2.2.

Emotions

Emotions or feelings are generally conceptualised as affective responses to a particular situation that are temporary and unstable. The distinction between attitudes and feelings is unclear with attitudes being seen as more permanent and consistent versions of repeated feelings to a particular event or object (McLeod 1992). Emotional responses to mathematics can include joy and excitement, but more commonly expressed feelings are panic, boredom and frustration.

Amongst the general public, Furner (2000) suggested that two-thirds of Americans either loathe or hate mathematics. To this end, many, at least in Western societies, are said to suffer from *math*[1] *anxiety* (Radisic et al. 2014). Feelings of anxiety associated with studying mathematics and engaging in mathematical activities seem to be almost proverbial and widely presented in popular media, common discourse, and the research literature, and when this emotional response becomes habitual it functions like an attitude (i.e., a more fixed emotional response to a situation or object). Regardless of whether it is an emotion or an attitude, there has been considerable attention in math anxiety from researchers and educators for many years (e.g., Isiksal et al. 2009; Jackson and Leffingwell 1999; Pekrun et al. 2007). Perhaps the quotation below captures the perspective of someone who is said to experience math anxiety.

> On the eighth day God created mathematics. He took stainless steel, and he rolled it out thin, and he made it into a fence, forty cubits high, and infinite cubits long. And on this fence, in fair capitals, he did print rules, theorems, axioms and pointed reminders. "Invert and multiply." "The square on the hypotenuse is three decibels louder than one hand clapping." "Always do what's in the parentheses first." And when he was finished, he said, "On one side of this fence will reside those who are good at maths. And on the other side will remain those who are bad a maths, and woe unto them, for they shall weep and gnash their teeth."
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> Maths does make me think of a stainless steel wall—hard, cold, smooth, offering no handhold, all it does is glint back at me. Edge up to it, put your nose against it, it doesn't take your shape, it doesn't have any smell, all it does is make your nose cold. I like the shine of it—it does look very smart, in an icy way. But I resent its cold impenetrability, its supercilious glare. (Buerk 1985, p. 59)

In general, it is seen as a fear of using mathematics and engaging in mathematical learning activities, and not surprisingly, it is often accompanied by *math avoidance* and poor achievement in school mathematics (Ball 1990; Radisic et al. 2014). Math anxiety renders the sufferer feeling helpless and panicky, and with a sense of mental disorganisation and paralysis, when faced with a mathematical problem of learning situation. Historically, greater proportions girls and women have been noted as experiencing math anxiety than boys and men, and this was part of the impetus for research into affect in mathematics in the 1970s and 1980s. Indeed, as was captured in the quotation above, many girls (and boys) try to avoid mathematics with strong feelings of inadequacy and incompetence, and this can be related to beliefs about the nature of mathematics. If mathematics is seen as absolute and learning mathematics is about appropriating already established knowledge and products, then it is seen and experienced as 'cold' and 'distant', and therefore,

[1]It seems that in the literature the term 'math anxiety' has been widely accepted rather than 'mathematics anxiety' or the more common Australian expression, 'maths anxiety'. This probably reflects the strong American base for this concept.

unappealing and inaccessible. Again, this highlights the complex nature of the affective domain, where feelings of frustration and powerlessness seem to develop from mathematical experiences (at school) that are based on an absolutist mathematical epistemology.

The Affective Domain

As was noted at the start of this chapter, the affective domain and its components have been notoriously difficult to precisely define, and certainly there are many more aspects we could have included here. Nevertheless, the four key dimensions included in this chapter—beliefs, values, attitudes and emotions, are widely accepted as fundamental aspects of the affective domain, although open to debate and revision. The affective domain represents the deeply held personal views of individuals and as such, they are often firmly held, experientially-based and jealously guarded. As such, when considering affective qualities in education—particularly mathematics learning, care, empathy, respect and understanding are required. In this next section we briefly consider the research and literature about the affective domain in mathematics education.

Affect and Mathematics Education

Of particular interest for mathematics educators is the relationship between mathematical affect, cognition, learning mathematics, mathematical achievement, and participation. This is a complex, convoluted, and not particularly well understood relational web, but a critical one in comprehending and appreciating mathematics education (McDonough and Sullivan 2014; Zan et al. 2006). Here we discuss these various aspects—affect, cognition, learning and achievement, as if they are all separate and discrete dimensions that are 'related', but of course this conceptualisation is only one of convenience to aid discussion and exploration. In reality, these facets of learning mathematics are intimately inter-related and in many respects, difficult to disentangle. It is also the case that while we talk about phenomena like 'the influence of affect on learning mathematics', affect is an integral part of the learning and what is learned in mathematics classrooms (Hannula 2006). Nevertheless, in this section we explore the relationships between affect and mathematics education by first looking at learning, then mathematical achievement and success, followed by a brief discussion of ongoing participation and engagement in mathematics.

Mathematical Affect and Learning Mathematics

While it is widely accepted that learning in general is inherently emotional and affective, there seems to be something about mathematics that commonly sees it as less interesting and less enjoyable than other school subjects (Radisic et al. 2014). This is particularly concerning, and if understanding of mathematical learning is to be advanced, then it is crucial that both cognitive and affective factors be explored in an integrated and orchestrated manner (Leder and Forgasz 2002). However, although there has been a longstanding interest in affect and mathematics education, there is still a lack of clarity about the impact of affective factors on mathematical learning and the development of beliefs and attitudes about mathematics in the classroom, and there are no substantial longitudinal studies to explore these issues developmentally (Hannula et al. 2014). Nevertheless, there have been a number of studies that have examined aspects of this complex relationship between beliefs, values, attitudes, emotions and self-concepts, and learning in mathematics.

The role of beliefs in learning is widespread and influential, particularly because beliefs are seen as a form of "subjective knowledge" (Furinghetti and Pehkonen 2002), so they are affective and somewhat cognitive in nature. In this sense they can 'bridge' or combine these two critical dimensions of mathematical learning. Also, as we have highlighted previously, 'beliefs' and 'mathematical beliefs' are generic and ubiquitous terms, so their influence and role in learning is pervasive. Because beliefs are relatively stable and influence behaviour, the mathematical beliefs of students are influential in their learning in mathematics (McDonough and Sullivan 2014). Indeed, Kloosterman (2002) suggested that students' beliefs effect their interest and motivation in learning mathematics, and this in turn impacts the nature and degree of engagement in the classroom. The mediating role of beliefs on mathematical activity is crucial in students' learning, because it constrains (and enables) their development of mathematical knowledge and skills (Cheeseman and Mornane 2014). For example,[2] a student who holds to a Platonist view of mathematics is likely to see learning mathematics as a process of acquiring known and established mathematical truths, and so may be more inclined towards more 'traditional' ways of studying. On the other hand, a student whose beliefs are more akin to a problem-solving perspective will more readily participate in more open-ended mathematical pedagogies and be more disengaged from content-focussed transmission-type lessons.

Of course, we know from the discussion of beliefs earlier, that beliefs are contextual and held in relatively independent groups or clusters. What that means here is that students learn their mathematical beliefs primarily in the mathematics classroom (even though they experience forms of mathematics every day in a variety of contexts), and so while beliefs impact learning, learning experiences in the classroom also directly influence mathematical beliefs. This means that

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[2]Of course, this is a simplification, because students do not simply hold to a singular belief about mathematics.

mathematical beliefs and learning in mathematics are related reciprocally, symbiotically and dynamically. So, mathematics educators and teachers need to be aware of the mathematical beliefs (and beliefs about learning mathematics) that students bring to the mathematics classroom, and, they also need to be aware that during their lessons they are developing mathematical beliefs, and these beliefs will impact future learning and development in mathematics.

Confidence has been conceptualised as 'self-belief' and has also been shown to be a critical factor in learning mathematics (Wesson and Derrer-Rendall 2011), through a range of primarily quantitative studies. Students' confidence, or lack thereof, will influence their expectations of success in learning the mathematical material at hand, their level of engagement, and their enjoyment (Dimarakis et al. 2014). Furthermore, self-belief or confidence impacts the way that students can access and use their prior understandings, thus limiting what knowledge they bring to new learning situations, and in turn their learning outcomes (Hailikari et al. 2008). In general then, this research shows, and common experience confirms, that students' confidence mediates their capacity to engage in mathematical learning experiences. Furthermore, as with beliefs, their confidence will also be influenced by the nature and perceived success of their involvement in mathematical activities in the classroom.

Similar to confidence, emotions have also been shown to be influential on students' learning and capacity to engage in mathematical situations. Of course, emotions are more changeable than confidence, and are not as stable or 'cognitive' as beliefs, so the role of feelings in learning is more complex and prone to influence by a range of other factors associated to the students' broader lives. Nevertheless, emotions are an integral and important part of learning mathematics, and as noted previously, repeated and regular emotional responses to mathematics can lead to more permanent attitudes and beliefs. At a simple level, it would be difficult to argue against the value of positive feelings in learning, and Cheeseman and Mornane (2014) in their study with primary school children found that positive emotions led to greater persistence in mathematical learning situations. Furthermore, their results showed that Year 3 and Year 4 students:

- Feel pleased with themselves when they learn new mathematics at school (64 %)
- Feel very pleased with themselves when they understand mathematics (63 %)
- Are confident that they can learn most things in mathematics (67 %)
- Enjoy mathematics at school (66 %) (p. 138).

Clearly many of the young students in their study were emotionally engaged in their mathematical learning, and these emotions facilitated deeper participation in the mathematics of the classroom.

On the more negative side, many studies have explored a phenomenon that seems peculiar to mathematics—math anxiety. Without reiterating the discussion of math anxiety outlined earlier, it is suffice to say here that, not surprisingly, it leads to more restricted and limiting participation in mathematics learning situations. Pekrun et al. (2007) found that negative mathematical emotions (math anxiety) led to students using lower-order learning strategies in mathematics like memorisation and repetition, whereas those positively disposed towards mathematics were much more likely to use higher-order and flexible learning approaches (e.g., problem-solving). Furthermore, Cates and Rhymer (2003) noted that mathematically anxious students were more likely to make fundamental errors in their mathematical activities, thus limiting their capacity to engage with more advanced mathematical concepts, and causing them to achieve at a lower level than their non-anxious peers. Again, it is important to once again note that feelings of mathematics anxiety are largely developed in the very classrooms where the subject is taught and promoted, and so like beliefs and confidence, there is a reciprocal relationship between learning and math anxiety. Moreover, through the impact of affective factors on learning and engagement in mathematical experiences, there is an allied reciprocal influence on mathematical success and achievement.

Mathematical Affect and Mathematical Achievement

Although it is not as simple and straightforward as one would expect, in general students who are interested in mathematics will give more time and effort to their learning, use deeper and more effective learning approaches in the mathematics classroom, and have greater success in their learning (Macher et al. 2012). Hannula et al. (2014) stated that "it is well known that mathematics-related affect and achievement are related" (p. 249). This would seem like a common sense connection, but in general there doesn't appear to be a consistent and straight-forward relationship between mathematical affect and mathematical achievement, although there are certainly several studies that reveal connections, even they are often somewhat convoluted (e.g., Yee 2010).

Self-belief, or confidence, has been shown in some studies to be a determining factor and predictor of academic achievement and success in mathematics (e.g., Wesson and Derrer-Rendall 2011). Also, in their meta-analysis of research on the relationship between mathematical affect and mathematical achievement, Ma and Kishnor (1997) found that there was evidence to support a reciprocal relationship between academic self-efficacy or confidence, and achievement, although this diminished as the students got older. However, they reported that the relationship between mathematics-related emotions and mathematical achievement was less clear, but the evidence suggested that there was a reciprocal connection, with the dominant direction most likely from emotions to achievement. In a more recent longitudinal study, Hannula et al. (2014) said:

> The results of this longitudinal study support the view that mathematical self-efficacy and achievement are reciprocally linked and that the dominating direction of this relationship is from achievement to self-efficacy. … it should be noted that the effect of self-efficacy on achievement was larger for older students. (p. 255)

As was noted by both Ma and Kishnor (1997), and Hannula et al. (2014), some relationships were statistically determinable between affective factors and mathematical achievement, but the direction and clarity of these connections were less clear and more indirect. Indeed, it appears that the relationships are at their simplest, reciprocal, but usually mediated by a range of other affective factors related to mathematics and learning mathematics.

Perhaps the body of research that shows the most clear and direct relationship is between math anxiety and mathematical achievement. In another meta-analysis of 26 studies by Ma (1999), she uncovered a statistically significant negative correlation between math anxiety and mathematical achievement, and this relationship was constant regardless of gender, school Year-level, ethnicity, instrument used to measure anxiety, and the date of the study. In summarising and commenting on the PISA results published by the OECD in 2010, Radisic et al. (2014) stated that the

> … results confirm negative correlation between anxiety and achievement, pointing also to cultural differences in respect to math anxiety. Students from Japan and Korea (high achievement countries), in addition to students in Tunisia, Brazil and Thailand (low achievement countries) express high math anxiety levels. In contrast, students from Denmark, Netherlands, Finland, and Sweden (all relatively successful countries in math literacy) express low math anxiety. Despite the differences among students from different countries, one result remains constant—students experiencing math anxiety achieve lower math results.

Given the scale and scope of the PISA data, these findings are quite compelling. And of added concern is the related finding of Frenzel et al. (2007) that, despite girls and boys receiving similar grades in mathematics, the girls reported significantly less enjoyment of mathematics and greater math anxiety. Together, these findings indicate that mathematics anxiety, at least through restricted achievement in mathematical assessments, means that many have limited opportunities post their schooling, and this still appears to be more significant for girls, despite their equivalent achievement to boys.

Mathematical Affect and Future Mathematical Engagement

Perhaps one of the most pernicious issues that arise from poor mathematical affective responses to mathematics developed at school is the restricted opportunities available to these students. Of course, the corollary is that positive attitudes and beliefs about mathematics opens-up a wide range of options in a range of contexts. Unfortunately, in many countries, the number of learners who choose not to participate in mathematics at higher levels of school and beyond is increasing and causing a range of national and international problems (AMSI 2014). This was noted by Hannula et al. (2014):

> Attitudes and motivation are important, because they determine how much people choose to study mathematics after it becomes optional and in many countries the society has a shortage of mathematically educated persons in scientific and technical fields. (p. 249)

Similarly, McGregor (2014) suggested that students' beliefs and attitudes towards mathematics and learning mathematics influence students' propensity to use mathematics in non-educational settings. It seems that although it is difficult to disentangle affective and cognitive dimensions of learning mathematics, students' cognitive competencies influence their confidence in learning, but affective factors are better determinants of further mathematical study and participation in careers that involve mathematics (Frenzel et al. 2007). Thus, mathematical beliefs, attitudes, emotions and dispositions are critical factors in the nature, quality and degree of future mathematical engagement.[3] This is a finding that should be of concern for mathematics teachers and educators, particularly when it is considered that if a student has a significant poor experience during their schooling, then math anxiety is likely to continue to reappear later in their life (Jackson and Leffingwell 1999).

As has been hinted at throughout this section, there is a reciprocal relationship between mathematical affect and mathematical learning, achievement and participation. It is also the case that affective responses toward mathematics are developed in the mathematics classroom, and this is problematic when it appears that so many are developing disabling and negative beliefs, attitudes and emotions in the very site you would want them to develop positive and enabling views.

Mathematics Education as Developing Mathematical Identities

While this book focusses on the affective domain in learning mathematics, we hope it is clear that this is not, and should not, be the sole focus of mathematics education. This would be quite absurd, and of course mathematics education is fundamentally about developing students' mathematical knowledge and mathematical skills, AND, their beliefs, values, attitudes and feelings about mathematics. Indeed, it is important that mathematics education facilitates student's development in all these realms, and the nature of education means that this occurs simultaneously. In other words, in mathematics classrooms students are simultaneously learning and developing knowledge, skills and affective responses to mathematics, and this occurs in an integrated manner. With this in mind, we want to consider learning mathematics as developing a *mathematical identity*. At this stage we only want to briefly introduce this idea, but we will pick it up again in the final chapter. Suffice to say here, in this section we will briefly discuss the development of mathematical identities as a way of understanding the relationship between mathematics education and affect that was discussed in the preceding section.

The power of identity as a concept is that it can bring together a range of aspects that are fundamental to understanding mathematics education. Identity is a unifying idea that brings together multiple and interrelated dimensions that include beliefs,

[3]The work of Attard (2014) on promoting engagement in mathematical learning is helpful here.

values, attitudes, emotions, dispositions, cognition, abilities, skills and life histories. While each of these aspects have been considered independently in many studies in mathematics education, the more comprehensive and holistic nature of identity captures the multi-dimensionality and complexity of mathematics teaching and learning. However, the term *identity* has been used and conceptualised by writers, researchers and theorists from a range of traditions and paradigms. Grootenboer et al. (2006) identified three views that were influential: (1) the psychological/developmental; (2) the socio-cultural; and (3) the post-structural. The psychological/developmental perspective primarily focuses on the individual and identities are mostly self-determined in response to life experiences. In contrast, the socio-cultural perspective sees identity as located internally and externally to the individual, and it is developed through social interactions and practices (Zembylas 2003). Finally, post-structural theorists deny identity as being either individual or social (Foucault 1984), and furthermore, they reject the possibility of a fixed and unified self or even a single identity. These perspectives are summarised in Table 2.1 which presents a range of discourses used by scholars of the respective ideologies when referring to the concept of identity and identity formation.

The researchers and theorists using psychological, sociocultural, and postmodern lenses on identity tend to depend on the position about where identity 'is located'—individual (inner) or social (outer). On this point, Holland et al. (1998) comment:

Table 2.1 Identity discourses across three theoretical perspectives (Grootenboer et al. 2006, p. 613)

	Psychological	Socio-cultural	Poststructuralist
Locus of identity	Individual the "inner world" self, self-concept, self-efficacy intra-psychic cognitive structures emotion	Relational self, the "outer world" connected to otherness embodied	Non-agentic a political posture no unified self all is relative subjectivity rather than identity positionings
Identity formation	Internalised, behavioural repertoires, executive functions of the self (monitoring, choice-making), searching for internal integrity, autonomy and competence individual responsibility for who one is	Constructed and situated communal consciousness and identification sociocultural reproduction and framing	Interior self is populated by others a constant becoming a function of difference constituted by political and institutional processes
Theoretical alignments	Bandura, Erikson, Piaget	Wenger, Vygotsky, Bakhtin, Bourdieu, Bernstein	Foucault, Derrida

> This self-in-practice occupies the interface between intimate discourses, inner speaking, and bodily practices formed in the past and the discourses and practices to which people are exposed, willingly or not, in the present… (p. 32)

From this perspective, identity is always related to practice, and so in mathematics education, the concept of "self-in-practice" is a useful way to understanding the development of mathematical identities.

In this book we are not going to engage deeply in the philosophical and theoretical debates around identity, but we will take a broad view and simply see identity as how people *label* and *understand* themselves (e.g., I am a teacher, I am bad at maths), and how an individual is recognised and viewed by others (e.g., she is good at mathematics, he is tall). Furthermore, we employ the term identity as a unifying concept that includes cognitive, psychomotor, and affective dimensions, and these are complexly interrelated. This conceptualisation will be used in the final chapter to discuss the key findings outlined in the book, and to consider how mathematics education can be further developed to include attention to building positive affect in mathematics.

Overview and Summary

In this chapter we have discussed some of the key conceptual ideas that underpin the educational focus of this book, and this has been done by reviewing some of the appropriate literature. Furthermore, we have endeavoured to emphasise that, while this book focuses on affect, it is important to understand beliefs, values, attitudes and emotions as complexly inter-related to cognition and psychomotor dimensions. That said, we have foregrounded and focused on mathematical affect because, despite attention from researchers over many years, it still remains a substantial and inhibiting factor in mathematics education—a majority of students still finish their schooling disliking mathematics and it "is perceived to be 'hard', 'boring', and 'useless'" (Brown et al. 2008, p. 4). This persistent problem is, in our view, the biggest issue in mathematics education and has been for some time.

The affective domain is not clearly defined and various authors have conceptualised it as being constituted by different components. Furthermore, often the same or similar aspects are labelled with different terms, and also the same term is used to label different affective aspects, thus adding to some of the confusion around research and theorising in education generally, and mathematics education specifically. After considering a range of views, we concluded that the main aspects of the affective domain, particularly in relation to mathematics education, are beliefs, attitudes and emotions (including math anxiety). It also appears that values are relevant to mathematics education, although they have not featured particularly in our research. Beliefs are seen as the more cognitive and stable of the aspects, whereas emotions or feelings are seen as more 'affective', spontaneous, responsive and changeable.

Affect is symbiotically related to learning in mathematics education—students' beliefs, attitudes and emotions influence their learning in mathematics classrooms, and conversely, students develop mathematical beliefs, attitudes and emotions as they are engaging in the activities of the mathematics classroom. Of course, to say that affect and learning are *related* is an understatement because in many respects they are part of the same phenomenon—learning, and one cannot conceptualise any learning that is not affective. That said, by looking at these aspects, somewhat artificially, as separate but related, can help us understand and further develop mathematics education. From this perspective we conducted a number of studies into affect and mathematics education, and these research projects were built on the theoretical perspectives outlined in this chapter. In the next chapter we outline the details of these studies.

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http://www.springer.com/978-981-287-678-2

Mathematics, Affect and Learning
Middle School Students' Beliefs and Attitudes About
Mathematics Education
Grootenboer, P.; Marshman, M.
2016, XVIII, 135 p., Hardcover
ISBN: 978-981-287-678-2