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Operant Subjectivity
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For The Love of Mathematics

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Abstract: In a world that expects its citizens to thrive in a digital society dependent on mathematics, it is still the norm to hear "I hate mathematics." Although there is a plethora of research on why people dislike or hate mathematics, few studies exist on why people love mathematics. This Q methodology study aimed to explore the viewpoints of people who love mathematics and apply the theory of human-centered design to supplement the interpretation of factor arrays. With a Q sample of 45 statements and 47 Q sorters, the study used principal component analysis and varimax. The researcher used a holistic approach to interpret data stories to arrive at five factors for this study. The emerging factors were Factor 1, described as *Creative Mathematics Helps Explore the World*; Factor 2, *Mathematics is My Thing, and I Excel at It*; Factor 3, *As a Tool for Thinking, Mathematics Leads to Opportunities;* Factor 4, *Mathematical Truth is Always Reliable and Dependable*; and Factor 5, *Mathematical Processes Always Give the Correct Answer*. Factor 1 and Factor 5 are interpreted in this article to demonstrate the incorporation of human-centered design and explain the potential of visual personas to support facilitators of learning and influence a more positive engagement with mathematics.

Keywords: education, factor interpretation, human centered design, mathematics, persona, love

Introduction

Disengagement with mathematics is reportedly linked to the perception of mathematics as influenced by an individual's social, cultural, political, and economic environments (Andersson et al., 2015; Attard, 2013; Padula, 2011). A commonly held social-cultural perception is that school-based mathematics is irrelevant to preparing for the reality of life (Marshman & Brown, 2014), thus contributing to an individual's lack of motivation to study mathematics (Latterell, 2004; Murray, 2011; Tcheang, 2014). The perceived irrelevance of mathematics results from a discourse between society's mathematical needs, including practical problem skills for the workplace and school-based mathematics, which are influenced by professional mathematics' formality of practices, resulting in teachers continuing to replicate procedural mathematics (Gravemeijer et al., 2017; Taylor, 2018; Williams & Wake, 2007). As a result, mathematics is often positioned as a discipline concerned primarily with producing correct answers, a framing that can intensify negative associations with the subject (Bartholomew et al., 2011; Mac an Bhaird et al., 2013).

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Much of the existing literature has therefore focused on understanding negative attitudes toward mathematics. These attitudes have been attributed to ineffective teaching approaches or beliefs (Attard, 2013; Pais, 2015; Rösken et al., 2011), insufficient support (Garon-Carrier et al., 2016; Kaur, 2010; Lee, 2009), superficial encouragement (Breen et al., 2015; Brown et al., 2008; Vinner, 2007), or difficulties in comprehending mathematical concepts (Palmer, 2009; Pais, 2014). While this body of research has been valuable, it has largely adopted a deficit-oriented lens, leaving comparatively little attention given to understanding why some individuals develop positive and enduring relationships with mathematics. Although Q methodology has been used to examine subjective perspectives on mathematics and related STEM fields, these studies have largely centered on attitudes, self-efficacy, epistemological beliefs, or mastery (Gao, 2020; Oswald & Harvey, 2003; Shearman, 2021; Wheeler & Montgomery, 2009; Yang & Barth, 2017), rather than on why some people come to love the subject.

Understanding how to engage people in learning and applying mathematics is increasingly important, both for preparing individuals for the future of work (Lipnevich et al., 2011; Sealey & Noyes, 2010) and for supporting economic prosperity at individual and community levels (FitzSimons & Bjorklund Boistrup, 2017; Williams, 2015; Wilson, 2014). Ongoing technological advancement and globalization further heighten the need for mathematical proficiency. As societies become increasingly mathematized (Hwa, 2018; Sriraman & English, 2009; Vithal, 2012), there is a growing need to shift mindsets from "I cannot do mathematics" toward "I am exploring ways to do mathematics." Such a shift may not lead all individuals to love mathematics, but it may support more positive and sustained engagement with the subject (Boaler, 2019; Hersh, 1990).

This study addresses this gap by exploring the question: Why do some people love mathematics? Mathematics and love are conceptualized here as social constructs that evolve within cultural and social systems (Duchhardt et al., 2015; Hersh, 1997; Peck, 2018; Sorokin, 2015). Individuals both shape and are shaped by these systems, resulting in distinctive ways of experiencing, valuing, and engaging with mathematics. By focusing on people who love mathematics, this study seeks to identify the intrinsic and extrinsic components that sustain positive mathematical relationships over time.

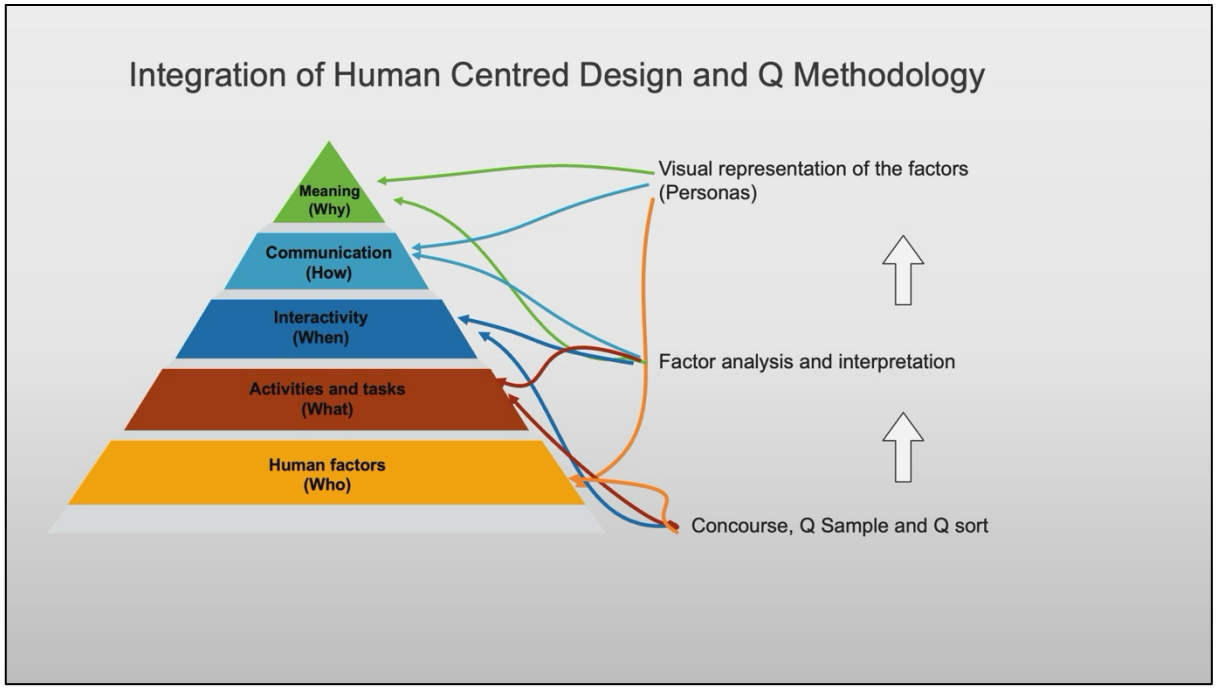
To investigate these perspectives, this research employed Q methodology. Q methodology (Stephenson, 1953, 1993) is designed to identify shared viewpoints by enabling participants to express their subjectivity holistically, rather than through pre-defined measures such as Likert-type scales (Addams & Proops, 2000; Brown, 1993). Well suited to exploratory research, Q methodology supports the systematic examination of complex, value-laden viewpoints (Brown, 1993; McKeown & Thomas, 2013).

To extend the interpretation and communication of Q methodological findings, this study integrates techniques from Human-Centered Design (HCD), specifically the use of visual personas. While personas have previously been used alongside Q methodology in areas such as social media research (Dang et al., 2015), design thinking (Morrisette, 2020), and health contexts (Agapie et al., 2019), their structured use as an interpretive and communicative device within mathematics education remains limited. Human-Centered Design focuses on understanding how people interact with products, services, or ideas by examining questions of *who* is involved, *what* the interaction entails, and *when* meaning is constructed through experience (Altay, 2014; Du Plessis, 2011; Giacomin, 2014). These questions align closely with the phases of Q methodology, from concourse development through factor analysis and interpretation. Both approaches prioritize subjectivity and the voice of the participant, ensuring that findings reflect lived experiences,

values, and meanings (Garcia-Lopez et al., 2020; Hill, 2010). Figure 1 illustrates the conceptual alignment between Q methodology and HCD as applied in this study.

Figure 1

Integration of Human Centred Design and Q Methodology



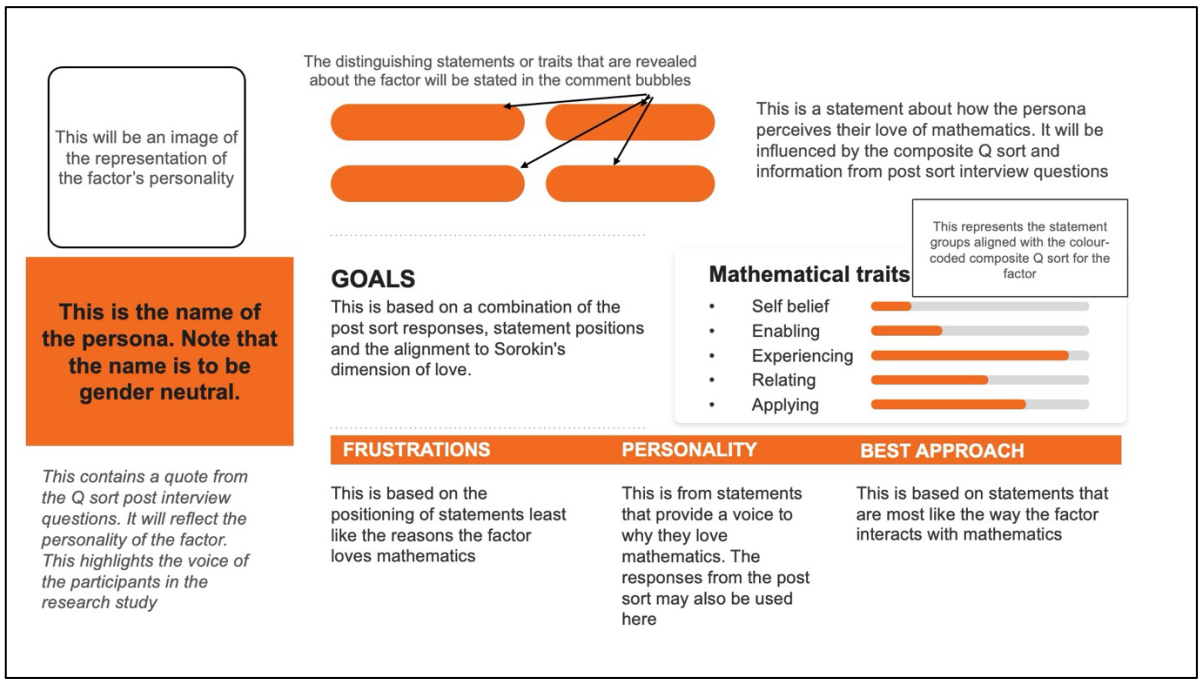
Note. Alignment of Q Methodology (Stenner et al., 2008) and HCD (Giacomin, 2014)

This research focuses on the *why*, or the meaning-making, phase of HCD. This phase aligns with iterative prototyping and testing approaches commonly used HCD corresponds with the interpretive phase of Q methodology (Brown, 2008; Norman, 2013). In this phase, shared viewpoints identified through factor analysis are synthesized into coherent data stories. In HCD, such stories are often communicated visually through personas, giving form and personality to complex data.

A persona is a fictional representation constructed from quantitative and qualitative data that reflects the shared characteristics of a group rather than an individual (Pruitt & Grudin, 2003; Tempelman-Kluit & Pearce, 2014; Thoma & Williams, 2009). Personas support sense-making by translating analytical outputs into accessible visual narratives, particularly for audiences who may lack advanced analytic expertise (Bernard et al., 2022; Holtzblatt et al., 2005; Pruitt & Adlin, 2006). By reducing cognitive load and humanizing abstract data patterns (Friess, 2012; Sweller, 1994, 2011), personas can enhance engagement with research findings. A template for the personas used in this study is shown in Figure 2. The following section outlines the methodological approach used to integrate Q methodology and HCD in exploring why some people love mathematics.

Figure 2

Template Used for All Personas



Method

Concourse

The concourse represents all possible and various opinions and views regarding a topic (Van Exel & De Graf, 2005); its development is a central element of a Q study (Brown, 1993). Thus, concourses may be seen as reflected in internal dialogues shaped by an individual's perceptions and preconceptions influenced by cultural factors (Wolf, 2009; Gerbner, 1969; Stephenson, 1986). The volume of a concourse is considered infinite; the statements vary depending on the research question and the shared knowledge related to it (Brown, 1980; Richardson & Ramlo, 2020).

The statements that make up the concourse are considered empirical and focus on the possible conversation, not merely the information about the topic (Stephenson, 2014). Over 300 statements were generated by reviewing peer-reviewed literature, statements from social media platforms including positive math groups like Mathy Ladies and Changing Math Attitudes, YouTube channels, TEDx talks, podcasts and websites that featured prominent advocates of mathematics, such as Eddie Woo, and bibliographies and autobiographies of recognized mathematicians, such as H.G Hardy. Additionally, 15 participants were interviewed about their positive connections with mathematics to add to the statements collected about why some people love mathematics. Initially the interviewees were selected based on their professional mathematical role, for example one interviewee was a staff member within a governmental mathematical association The interviewees also recommend others to be a part of this initial statement collection phase.

Q Sample

The Q sample was developed from a concourse of 300 statements through an abductive process (Stephenson, 1986; Reichertz, 2013). Rather than proceeding linearly, this involved moving iteratively between organising the concourse into homogeneous groups, as Brown (1980, 2019) suggested, and selecting statements from across those groups, with each pass informing the other. Statements were reviewed for conceptual similarity and grouped into provisional groups reflecting recurring ideas about how individuals experience and relate to mathematics; these were refined through constant comparison until each was internally coherent and conceptually distinct (Charmaz, 2014; Saldaña, 2016). Grouping did more than make meaning from words (Wolf, 2009): it rendered the structure of the concourse visible, so that the range of subjective positions it contained could be assessed and deliberately sampled across rather than assumed.

Once the groups had stabilised through this iteration, a holistic coding pass (Charmaz, 2014; Skjott Linneberg & Korsgaard, 2019) refined selection within them. Descriptive and thematic coding were integrated to review each group and identify the statements that best represented it, with In Vivo coding (Saldaña, 2016) retaining participants' original language. Grouping therefore determined the breadth of the sample across the concourse, while coding determined which statements were retained within each group and in what wording, enabling ideas to be abstracted and connected to the experiences underlying them (Fuller & Goriunova, 2014; Morse & Richards, 2002).

This produced five homogeneous groups, reported throughout as themes. Sampling was balanced across them, with nine statements drawn from each; representativeness therefore rests on the structure of the sample rather than its size, since distributing selection across all five themes, rather than weighting toward the most populous, ensures the Q set spans the breadth of viewpoints in the concourse (Brown et al., 2008; Wright, 2013). Where a single word or phrase recurred across a cluster of statements and captured their shared meaning, it was adopted as the theme label. This ensured that the five theme names (Self-Belief, Enabling, Experiencing, Relating, and Applying) remained close to participants' own framings of their relationship with mathematics. The Q sample was made up of 45 statements (Appendix A). Participants sorted these onto a forced-distribution grid of nine columns, ranging from +4 “Most like how I feel” to −4 “Least like how I feel,” with column depths of [-4 (1), -3 (3), -2 (6), -1 (8), 0 (9), 1 (8), 2 (6), 3 (3), 4 (1)].

P Set

Participant inclusion criteria involved inviting individuals based on their knowledge about or experience with a phenomenon of interest, in this case, mathematics (Brown, 1993; Cross, 2005; Punch, 2013). Purposeful sampling procedures (Creswell & Clark, 2017) enable participants to be recruited according to criteria relevant to the study. As per the CQU University Human Research Ethics Committee (approval number 20791) initial contact for recruitment purposes involved emails, phone calls, and relevant social media sites, such as Facebook. Interested people were provided with an electronic or hard copy of the information letter for participation in the study. The anticipated snowball effect (Schwandt, 2014) occurred as potential participants were recommended for the study by those already participating.

Q Sorting

The Q sorts were conducted online due to Covid-19 restrictions during 2020 and 2021 making it difficult to have the Q sorts in person. Thus, the Q sort was conducted with the assistance of the Q-sort Touch Tool. (https://www.qsortware.net). A forced-choice

distribution was used to complete the Q sorts. Participants sorted the Q sample according to the condition of instruction, "I love mathematics because …." The software enabled collection of demographics of the P set (Appendix B). Post-sort questions through the software allowed the sorter to explain the statement choice at the extreme ends of the sorting grid. In addition, the participants were asked to provide any additional reasons why they love mathematics. A total of 47 online Q sorts were completed.

Findings

The 47 Q sorts were entered into KADE software (Banasick, 2019), which generated a correlation matrix, a factor analysis with extraction and rotation, factor scores, and arranged the factor standard scores into arrays. PCA and Varimax rotation were used, as this combination is commonly recommended for novice Q researchers and supports the extraction of meaningful and essential relationships among Q sorts (Newman & Ramlo, 2010; Watts & Stenner, 2005).

Several parameters guided the initial decision regarding the appropriate number of factors. These included the number of sorts loading significantly on each factor and examination of individual Q sorts to ensure all participant voices were adequately represented (McKeown & Thomas, 2013; Watts & Stenner, 2005). Multiple factor solutions were explored, including three, four, five, six, and seven-factor models. A five-factor solution was ultimately selected, as it provided the clearest differentiation of viewpoints and best captured the uniqueness of participant perspectives. Table 1 presents the distribution of participants across the five factors, demonstrating that each factor represents a distinct viewpoint shared by a subset of participants.

Table 1

Summary of the Five-Factor Solution

Factor	Factor Interpretation	Number of Defining Sorts	Eigenvalue	Composite Reliability
Factor 1	Creative mathematics helps explore the world	20	15.11	0.988
Factor 2	Mathematics is my thing and I excel at it	7	3.96	0.966
Factor 3	Mathematics as a tool for thinking leads to opportunities	10	3.02	0.976
Factor 4	Mathematical truth is reliable and dependable	7	2.58	0.966
Factor 5	Mathematical processes always give the correct answer	3	1.76	0.923

The interpretation phase adopted a holistic approach, focusing on what each factor expressed as an integrated viewpoint. Interpretation proceeded in two stages. Crib sheets were first constructed for each factor, comprising the highest and lowest ranked statements together with those ranked higher or lower in that factor than in any other (Watts & Stenner, 2005). Distinguishing statements ($p < .01$) were identified from the arrays themselves, independent of the thematic structure of the Q sample, and each array was

read as a whole rather than as a set of isolated items (Akhtar-Danesh, 2017; Dziopa & Ahern, 2011).

To support persona development, the theme colour coding used in constructing the Q sample was overlaid on the composite sorts. Because the Q sample was structured as a balanced design, with statements drawn evenly across the five themes (Brown, 1980), the elevation or depression of a theme within an array reflects participants' ranking decisions rather than the composition of the Q set. This overlay made connections across statements visible and supported the narrative account of each factor as its story unfolded. This thematic layer supplemented rather than replaced conventional factor interpretation: statement salience was determined by the arrays, with the colour coding assisting recognition of how salient statements related to one another.

The five themes used in this overlay were those established during construction of the Q sample rather than categories emerging from the factors, and are restated here for reference (Appendix A):

- **Self-belief** (green) statements refer to how mathematics provides an internal sense of identity to the individual.
- **Enabling** (blue) statements are aligned to thinking mathematically and will provide options when approaching a challenge.
- **Experiencing** (purple) statements are aligned with how mathematics is a part of a person's reality.
- **Relating** (pink) statements referring to how a person connects outwardly to mathematics.
- **Applying** (orange)statements referencing how mathematics is a part of the 'toolbox' to survive and thrive daily.

To enhance the communicability of the findings, techniques for constructing a user journey within HCD were applied following the steps outlined in Figure 3. The data stories emerging from the five factors were visualized to support the presentation of findings and to make them more accessible to a broader audience.

Interpretation of the factors drew on information generated through the factor analysis of the Q sorts. In particular, the factor arrays were interpreted to provide insight into how each factor expresses a love of mathematics and to establish the foundational characteristics of each factor's personality. Statements positioned in the "most like" categories (+4 and +3) were used to identify the core ways in which a factor values and engages with mathematics, while statements in the "most not like" positions (−4 and −3) were interpreted as points of tension or frustration.

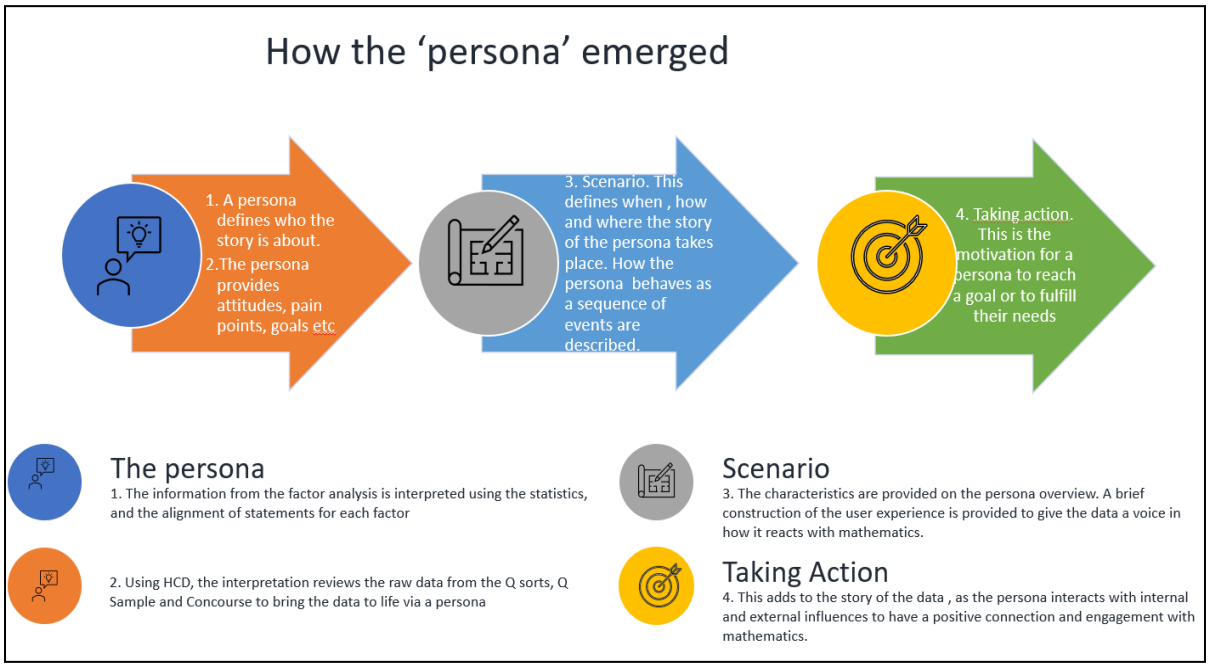
To support interpretation and enhance visual coherence, each composite Q sort was color-coded to reflect the thematic groupings identified within the Q sample (Appendix A). These groupings were then incorporated into a consistent persona template (see Figure 2), which was designed to visually represent the data story of each factor. Each persona includes a direct quote from the written post-sort comments of a participant who defined the factor, selected to emphasize the factor's defining characteristics.

Within the persona template, statements from the −4 and −3 positions were labelled as "frustrations" to support visualization of the user journey, while four colored ovals capture direct quotations or key words drawn from the post-sort data of participants who defined the factor. Mathematical traits displayed within each persona are directly linked to the color-coded thematic groupings in the Q sample (Appendix A), providing a visual representation of how each factor perceives and engages with mathematics. For example,

a higher concentration of enabling statements in favorable ranking positions indicates a perspective that relies on mathematical thinking techniques when approaching challenges.

Figure 3

Process to Construct a Visual Persona



The following section illustrates this interpretive process through a detailed examination of Factor 1 and Factor 5, using Q methodology alongside HCD persona development techniques. All five factors were analyzed, interpreted, and discussed using the same systematic procedure.

Factor 1: Creative Mathematics Helps Explore the World

Persona Creative Charlie

Of the 47 participants, 20 defined Factor 1. The demographics of the who defined Factor 1 are shown in Table 1. The composite Q sort for Factor 1 is shown in Figure 4, and the relative rankings of the statements for Factor 1 are shown in Table 2.

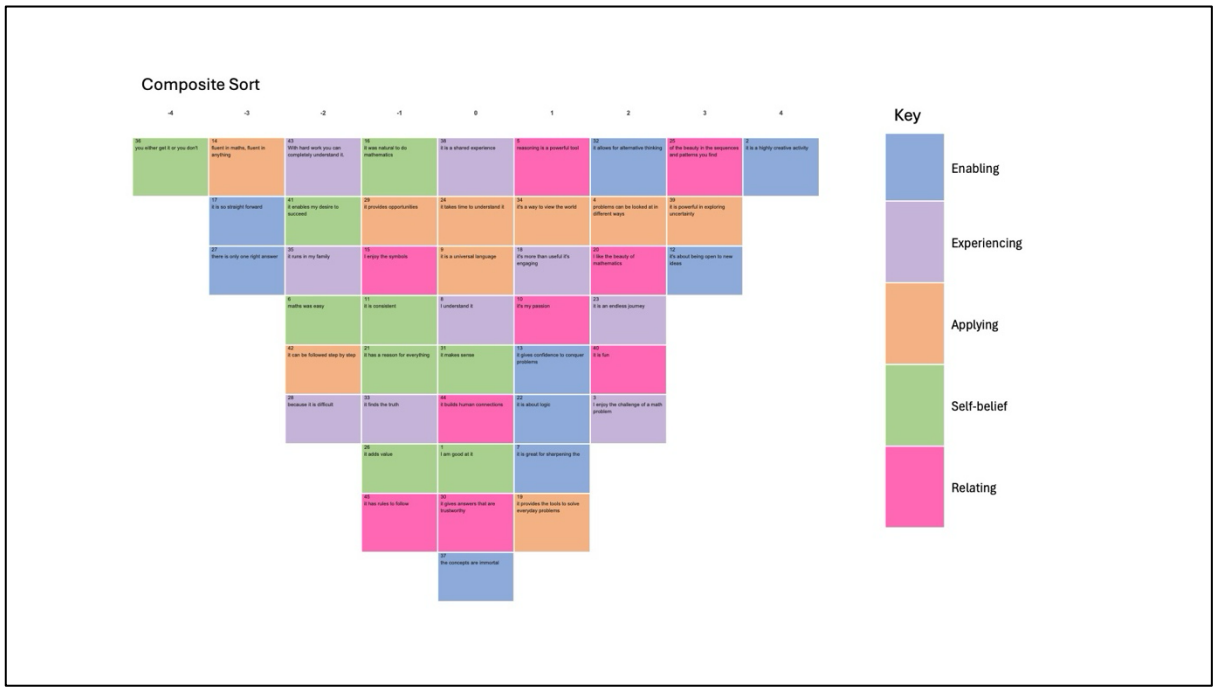
Factor 1 represents a view of mathematics as a creative, exploratory way of engaging with the world rather than a fixed or procedural discipline. For individuals aligning with this factor, mathematics is valued as a means of making sense of uncertainty, generating new perspectives, and expressing creativity. This orientation is most clearly reflected in the composite Q sort, where Statement 2 (*it is a highly creative activity*) is ranked at +4. Creativity within this factor is enabled through flexible ways of thinking, evidenced by Statement 32 (*it allows for alternative thinking*, +2) and Statement 12 (*it's about being open to new ideas*, +3). Participants associated with this factor value mathematics as a means of exploring situations from multiple perspectives and generating novel approaches to problems.

This creative engagement is further demonstrated through the application of mathematical knowledge and skills when navigating uncertainty. Statement 39 (*it is powerful in exploring uncertainty*) is ranked at +3, while Statement 4 (*problems can be looked at in*

different ways) appears at +2. Together, these statements reflect a view of mathematics as an exploratory and adaptive tool rather than a fixed or rigid discipline. This perspective is captured by Participant 20, who wrote: "When I engage with mathematics, I am creative. It demands creativity."

Figure 4

Color-Coded Composite Sort for Factor 1



Factor 1 also resonates strongly with the aesthetic and experiential dimensions of mathematics. Statement 25 (*the beauty in the sequences and patterns you find*) is ranked at +3, highlighting an appreciation for mathematical elegance and structure. Mathematics is perceived as an ongoing and immersive experience, reflected in Statement 23 (*it is an endless journey*, +2), a distinguishing statement for this factor. This deep alignment is expressed by written response of Participant 10: "I am consumed with mathematics I count things without thinking about it. I see patterns in things around me without consciously doing it. I love doing math more than anything else."

In contrast, Factor 1 explicitly rejects procedural and deterministic views of mathematics. Statement 17 (*it is so straightforward*) and Statement 27 (*there is only one right answer*) are both ranked at −3, indicating strong disagreement with the notion of mathematics as linear or rule-bound. Similarly, beliefs that mathematical ability is innate are rejected, with Statement 36 (*you either get it or you don't*) placed at −4 and Statement 14 (*fluent in maths, fluent in anything*) at −3. This rejection is reinforced by Participant 10, who reflected: "I have not understood parts of math for years and when I read about it again or it is explained to me differently, I then understand it. Learning math is an ongoing process."

Table 2

Relative Rankings for Factor 1 Statements

Statement Number	Statement	Array Position	Distinguishing
	Highest Ranked Statements		
2	it is a highly creative activity	4	D
	Positive Statements Ranked Higher in Factor 1 Array than in Other Factor Arrays		
25	of the beauty in the sequences and patterns you find	3	D
39	it is powerful in exploring uncertainty	3	
12	it's about being open to new ideas	3	
4	problems can be looked at in different ways	2	
23	it is an endless journey	2	D*
13	it gives confidence to conquer problems	1	
	Negative Statements Ranked Lower in Factor 1 Array than in Other Factor Arrays		
9	it is a universal language	0	
29	it provides opportunities	-1	
11	it is consistent	-1	
45	it has rules to follow	-1	
41	it enables my desire to succeed	-2	
42	it can be followed step by step	-2	
28	because it is difficult	-2	
14	fluent in maths, fluent in anything	-3	
17	it is so straight forward	-3	D*
27	there is only one right answer	-3	D
	Lowest Ranked Statements		
36	you either get or you don't	-4	

Note. D indicates significance at $p < 0.05$; D* indicates significance at $p < 0.01$

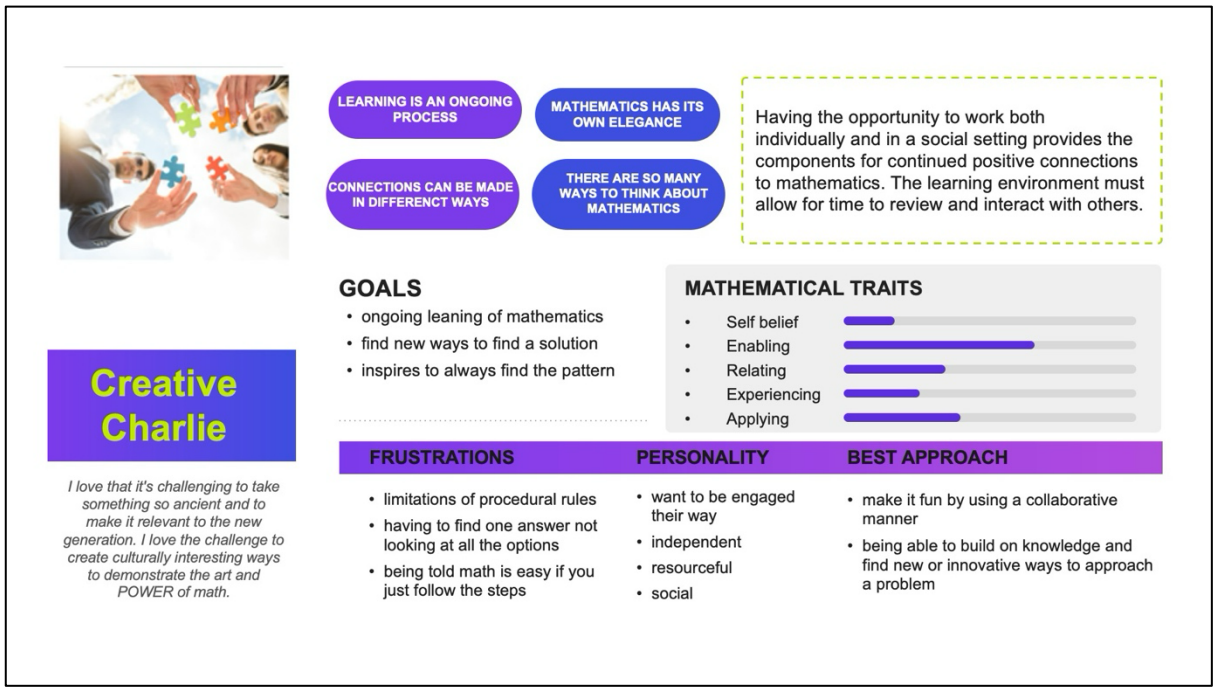
For Factor 1, loving mathematics emerges from the integration of knowledge, skills, and conceptual understanding that can be transferred to explore new or varied solutions. This is reflected in Statement 13 (*it gives confidence to conquer problems*, +1) and Statement 18 (*it's more than useful, it's engaging*, +1). Enjoyment and curiosity are central to this relationship, as shown by Statement 40 (*it is fun*, +2) and Statement 3 (*I enjoy the challenge of a math problem*, +2). As Participant 11 summarized: "Mathematics is who I am. It defines me as a person and it defines how I see and understand this reality I move through."

To support visual interpretation, Factor 1 was represented through a persona using the grouped thematic statements (Appendix A) and relative rankings shown in Table 2. These groupings highlight that mathematics primarily functions as an enabling force for this factor (blue-shaded in Figure 4), supporting creative exploration and meaning-making. The persona does not represent an individual participant, but a synthesized

viewpoint constructed from the factor array and associated qualitative data. The persona Creative Charlie (Figure 5) reflects a view of mathematics as a way of engaging with the world through imaginative problem solving and unconventional thinking. Confidence for this persona is derived not from procedural mastery, but from the freedom to apply mathematics in personally meaningful ways.

Figure 5

Visual Persona for Factor 1: Creative Charlie



Notably, all Self-belief statements (green-coded in Figure 4) are ranked between 0 and −4 for Factor 1. Statements such as Statement 1 (*I am good at it*, 0) and Statement 41 (*it enables my desire to succeed*, −2) indicate limited acknowledgment of personal expertise. Similarly, Statement 6 (*math was easy*, −2) and Statement 36 (*you either get it or you don't*, −4) suggest resistance to fixed notions of ability. This pattern may have important implications for sustained engagement. If Creative Charlie is required to produce single correct solutions using prescribed procedures, there is a risk of disengagement from mathematical learning and application.

What defines Factor 1 is not only a strong alignment with creativity and uncertainty, but also a clear rejection of procedural rigidity and fixed notions of ability. The enabling role of mathematics in creatively exploring uncertainty the following was written by Participant 16: "One of the important things for me as a human being is to explore uncertainties in life and in the world and beyond. I think mathematics and statistics provide great ways for us to explore uncertainties and try to make sense of them."

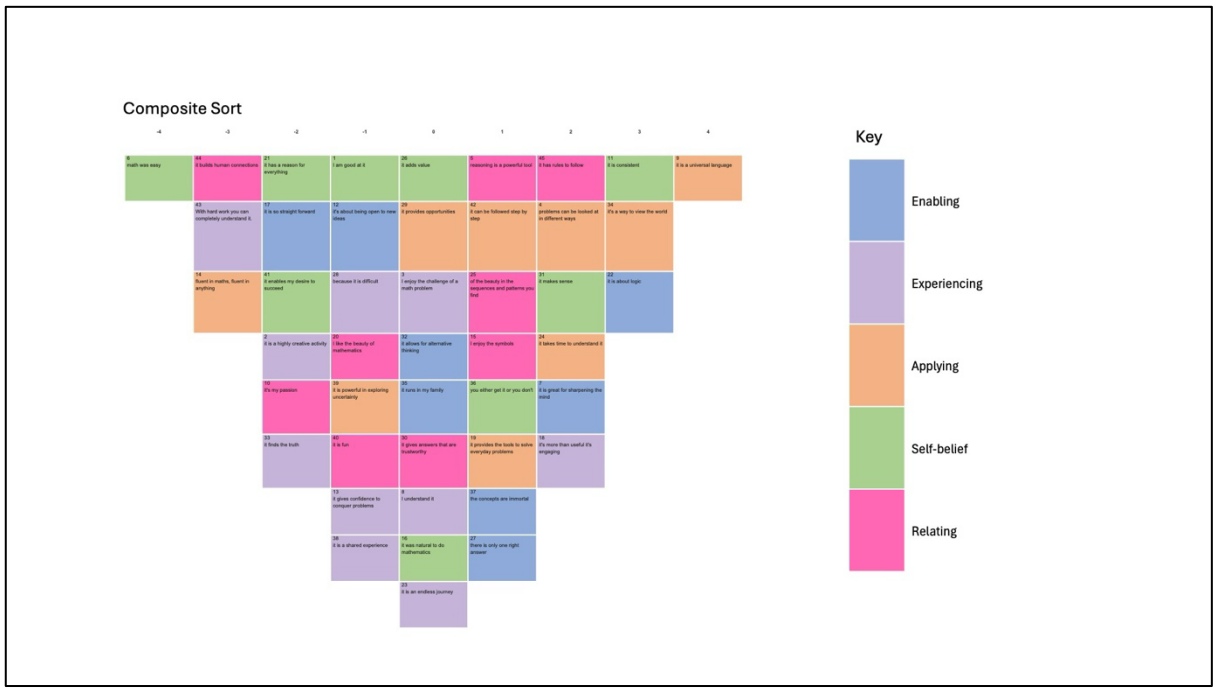
Factor 5: Mathematics Processes Always Give the Right Answer

Persona Perfectionist Pepa

Of the 47 participants, three defined Factor 5. The demographics of the participants that loaded onto Factor 5 (Table 1). The composite Q sort is shown in Figure 6 and the relative rankings of the statements for Factor 5 are shown in Table 3.

Figure 6

Color-Coded Composite Sort for Factor 5



Factor 5 values mathematics as a structured, rule-governed system that reliably produces correct answers when appropriate processes are followed. This orientation is most strongly reflected in Statement 9 (*it is a universal language*), which is ranked at +4. Mathematics is perceived as a discipline grounded in shared linguistic protocols that enable the consistent application of techniques to reach definitive outcomes, as reflected in Statement 27 (*there is only one right answer*, +1).

Comfort and trust in mathematics arise from its perceived consistency and internal coherence. Statement 11 (*it is consistent*, +3) and Statement 31 (*it makes sense*, +2) reinforce the belief that mathematics offers a dependable framework for understanding the world. This logical orientation is further supported by Statement 22 (*it is about logic*, +3) and Statement 34 (*it's a way to view the world*, +3), indicating that mathematics provides an ordered lens through which reality can be interpreted.

Interestingly, Factor 5 also aligns mathematics with notions of natural ability and inherited traits. Statement 35 (*it runs in my family*) and Statement 16 (*it was natural to do mathematics*) are both positioned at 0, suggesting a neutral but present belief that attraction to mathematics may be linked to familial or inherent characteristics. This perspective is reinforced by the positive placement of Statement 36 (*you either get it or you don't*, +1), which is a distinguishing statement for this factor and unique among all factors (see Figure 6). These views suggest that social and cultural influences shape how this group understands mathematical ability and competence (Azzouni, 2005; Polkinghorne, 2011).

Table 3

Relative Rankings for Factor 5 Statements

Statement Number	Statement	Array Position	Distinguishing
	Highest Ranked Statements		
9	it is a universal language	4	D*
	Positive Statements Ranked Higher in Factor 5 Array than in Other Factor Arrays		
11	it is consistent	3	D*
34	it's a way to view the world	3	
22	it is about logic	3	
45	it has rules to follow	2	D
4	problems can be looked at in different ways	2	
31	it makes sense	2	
24	it takes time to understand it	2	
7	it is great for sharpening the mind	2	
18	it's more than useful it's engaging	2	
42	it can be followed step by step	1	
15	I enjoy the symbols	1	
36	you either get or you don't	1	D*
27	there is only one right answer	1	D*
35	it runs in my family	0	D*
16	it was natural to do mathematics	0	
	Negative Statements Ranked Lower in Factor 5 Array than in Other Factor Arrays		
3	I enjoy the challenge of a math problem	0	
32	it allows for alternative thinking	0	
12	it's about being open to new ideas	-1	
20	I like the beauty of mathematics	-1	
39	it is powerful in exploring uncertainty	-1	
13	it gives confidence to conquer problems	-1	D*
38	it is a shared experience	-1	
21	it has a reason for everything	-2	
41	it enables my desire to succeed	-2	
2	it is a highly creative activity	-2	D
10	it's my passion	-2	
33	it finds the truth	-2	
44	it builds human connections	-3	
43	With hard work you can completely understand it.	-3	D
14	fluent in maths, fluent in anything	-3	
	Lowest Ranked Statements		
6	math was easy	-4	

Note. D indicates significance at $p < 0.05$; D* indicates significance at $p < 0.01$

Factor 5 explicitly rejects mathematics as a social or relational endeavor. Statement 44 (*it builds human connections*) is ranked at −3, and Statement 38 (*it is a shared experience*) at −1, indicating limited value placed on collaboration or communal meaning-making. Creativity is also de-emphasized, likely reflecting the importance placed on arriving at a single correct solution through established procedures. This is further supported by the rejection of effort-based learning, with Statement 43 (*with hard work you can completely understand it*) ranked at −3. For this factor, natural ability and adherence to rules are perceived as more important than persistence or exploration.

As a result, mathematics is not viewed as a source of confidence-building or personal growth. Statement 13 (*it gives confidence to conquer problems*) is ranked at −1, suggesting that confidence is derived from correctness and procedural mastery rather than from exploration or conceptual struggle.

Although Factor 5 indicates a preference for working independently mathematics nonetheless retains a social dimension through shared conventions and agreed meanings, particularly through formal language and agreed procedures. The prominence of applying statements (orange-coded) among the "most like" rankings suggests that mathematics is understood as a socially constructed system of rules and symbols, even if engagement with it is primarily individual. Distinguishing statements related to universality and familial traits further highlight the socially influenced foundations of this factor's relationship with mathematics (Cole, 2015; Gergen, 2015).

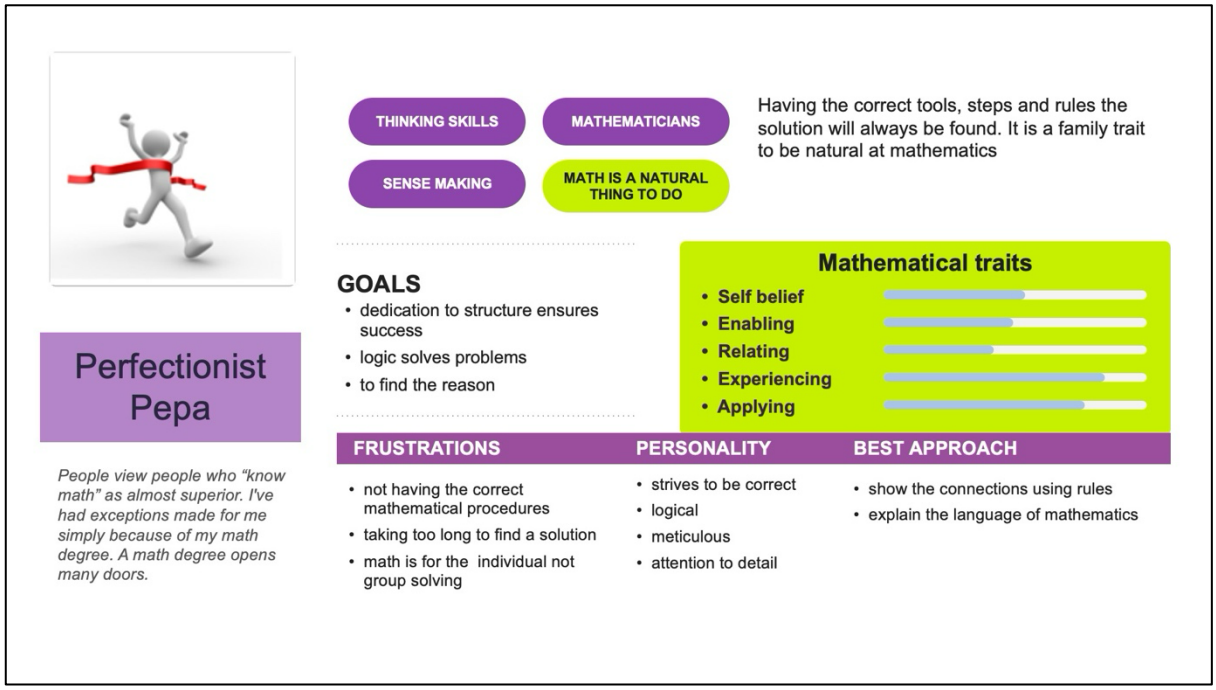
The persona Perfectionist Pepa exhibits strong self-belief in what mathematics can achieve when its processes are followed correctly. This persona acknowledges that problems may be approached in different ways, as reflected in Statement 4 (*problems can be looked at in different ways*, +2), but maintains that these approaches must adhere to logical steps and established rules. Consistency and coherence are central, even if understanding requires time. Once concepts are mastered, mathematics is seen as enabling opportunity and certainty.

Perfectionist Pepa requires explicit instruction and clearly defined pathways that lead to a single correct outcome. This preference is reinforced by Statement 27 (*there is only one right answer*, +1), Statement 11 (*it is consistent*, +3), and Statement 37 (*the concepts are immortal*, +1). The alignment with an internal, rule-oriented logic is a defining feature of this persona.

If Perfectionist Pepa (Figure 7) is required to engage in group-based or exploratory learning approaches too early, there is a risk of disengagement. Statements such as Statement 40 (*it is fun*, −1), Statement 38 (*it is a shared experience*, −1), and Statement 44 (*it builds human connections*, −3) indicate limited alignment with collaborative or playful learning environments. Similarly, an emphasis on creativity (Statement 2, *it is a highly creative activity*, −2) before procedural understanding is established may result in this persona disengaging from mathematics as a meaningful life skill. For Perfectionist Pepa, logical progression and correctness are essential foundations for learning and applying mathematics.

Figure 7

Visual Persona for Factor 5: Perfectionist Pepa



Factors 1 and 5 demonstrate distinctly different ways of engaging with mathematics. To support facilitators in designing and delivering mathematical content, the neutral and shared rankings of statements across both factors were examined. Identifying common themes that support engagement provides an opportunity to inform both teaching practice and the construction of learning environments that accommodate the learning journeys of Creative Charlie (Factor 1) and Perfectionist Pepa (Factor 5).

Table 4 highlights the most significant differences between the two factors, based on Z-score comparisons of statement rankings. These differences illustrate that engagement strategies effective for one factor may not support the other. Creative Charlie engages most strongly when mathematical content draws on uncertainty, exploration, and openness to ideas, as reflected in Statement 39 (*it is powerful in exploring uncertainty*), Statement 2 (*it is a highly creative activity*), and Statement 12 (*it's about being open to new ideas*). Delivery that relies heavily on creativity and exploration supports this factor's engagement with mathematics.

In contrast, such an approach is unlikely to engage Perfectionist Pepa. This factor requires the reassurance of formal mathematical language and prescribed processes that lead to a correct solution. Engagement for this persona is supported through Statement 9 (*it is a universal language*), Statement 27 (*there is only one right answer*), and Statement 36 (*you either get it or you don't*). As a result, creative or open-ended delivery alone may disengage Perfectionist Pepa, despite supporting Creative Charlie.

Table 4

Main Difference Between Factor 1 and 5

Statement Number	Statement	Factor 1	Factor 5	Difference	Q sample Theme
2	it is a highly creative activity	1.77	-0.925	2.695	Enabling
39	it is powerful in exploring uncertainty	1.391	-0.558	1.949	Applying
12	it's about being open to new ideas	1.312	-0.491	1.803	Enabling
27	there is only one right answer	-1.902	0.312	-2.214	Enabling
9	it is a universal language	0.058	2.314	-2.256	Applying
36	you either get or you don't	-2.522	0.447	-2.969	Self-belief

To create a learning environment that supports both factors, it is therefore essential to focus on shared orientations toward mathematics. Table 5 presents the statements that are commonly valued by both factors.

Table 5

Similarities for Factor 1 and Factor 5

Statement Number	Statement	Factor 1	Factor 5	Difference	Q sample Theme
21	it has a reason for everything	-0.488	-0.782	0.294	Self-Belief
5	reasoning is a powerful tool	0.892	0.819	0.073	Relating
4	problems can be looked at in different ways	1.192	1.166	0.026	Applying
41	it enables my desire to succeed	-0.904	-0.887	-0.017	Self-belief
18	it's more than useful it's engaging	0.756	0.887	-0.131	Experiencing
19	it provides the tools to solve everyday problems	0.247	0.447	-0.2	Applying

The Self-Belief statements, particularly Statement 21 (*it has a reason for everything*) and Statement 41 (*it enables my desire to succeed*), suggest that both factors view mathematics as contributing to their sense of purpose and identity. This shared orientation indicates that learning experiences which explicitly explain the relevance and purpose of mathematical concepts may support engagement for both Creative Charlie and Perfectionist Pepa. Emphasizing *why* a concept matters, rather than focusing solely on *how* it is applied, may therefore be an effective pedagogical strategy.

While both factors align with Statement 5 (*reasoning is a powerful tool*), the meaning attributed to reasoning differs. For Perfectionist Pepa, reasoning is primarily grounded in logical structure and procedural correctness, functioning as an extrinsic mechanism for validating decisions. In contrast, Creative Charlie employs reasoning more

intrinsically, using mathematical understanding to explore alternative interpretations and unconventional solutions. Despite this difference, both factors value mathematics as a tool for interpreting and making sense of information.

Community context also influences how both factors engage with mathematics. Statements such as Statement 19 (*it provides the tools to solve everyday problems*) and Statement 4 (*problems can be looked at in different ways*) highlight the role of mathematics in everyday decision-making for both personas. External influences, including economic and political conditions, are further reflected in Statement 18 (*it's more than useful, it's engaging*), highlighting the relevance of mathematics beyond formal learning contexts.

Engagement with mathematics for both factors is enhanced when learners can clearly see how mathematical concepts support understanding in real-world situations. This can be achieved by explicitly demonstrating where and how mathematical ideas are applied in everyday decision-making. For example, using a straight-line model to analyze Arctic sea ice data encourages critical evaluation of climate change claims (Beatty et al., 2017). Such an approach appeals to both factors by allowing mathematical concepts to be applied procedurally through identifying a single solution and creatively by estimating trends or lines of best fit. Similarly, explaining that the formula $y = mx + b$ can be used both to calculate a precise outcome and to explore probable relationships enables facilitators to address the needs of both Creative Charlie and Perfectionist Pepa. In doing so, mathematical learning experiences can be designed to support engagement across divergent orientations toward mathematics without privileging one factor at the expense of the other.

Discussion

This study demonstrates the value of using Q methodology to explore positive perceptions of mathematics and provides insight into how lifelong positive connections with mathematics may be encouraged. By focusing on individuals who love mathematics, the study shifts attention from deficit-based narratives toward understanding enabling conditions that support sustained engagement. In addition, the interpretation phase of QM was extended through the application of a technique more commonly used in business contexts. This involves the construction of visual personas to enhance sense-making and support the practical application of the findings by educators and practitioners.

Integrating Q methodology with Human-Centered Design (HCD) enabled each factor to be represented visually through a persona that reflects the underlying data patterns (Bernard et al., 2022; Holtzblatt et al., 2005). These personas provide a practical and accessible way to understand how different factors experience and engage with mathematics. As representations of collective viewpoints rather than individuals, the personas offer facilitators and educators a user-centered lens through which to interpret the factors' relationships with mathematics.

For example, both Creative Charlie and Perfectionist Pepa require a clear articulation of the benefits and purpose of mathematics to support and maintain their mathematical identity. Explicitly connecting mathematical concepts to meaningful outcomes may strengthen intrinsic motivation and contribute to a more positive mathematical self-image. Over time, such support may influence how individuals align with these factors position statements such as Statement 1 (*I am good at it*) and Statement 26 (*it adds value*) in future Q sorts, potentially shifting them toward more favorable rankings.

Opportunities to discuss mathematical proficiency in positive and affirming ways within an individual's social and cultural context may further enhance perceptions of

mathematics (Colley, 2011). Supporting learners to analyze and interpret data that is personally relevant may enable those aligning with Creative Charlie and Perfectionist Pepa to deepen their connection to mathematics. In this way, the factors and their accompanying data stories, visualized through personas, may assist educational practitioners in workplaces and educational institutions to design environments that support a broader range of learners in developing positive experiences with mathematics.

While this study offers insights into facilitating positive experiences with mathematics, several qualifications should be acknowledged. Q methodology is designed to identify and describe the distinct viewpoints present within a given group, rather than to establish how prevalent those viewpoints are within a wider population (Akhtar-Danesh, 2017). The five factors reported here therefore represent viewpoints held among the participants who completed the Q sort and are bounded by the composition of that participant group. A P set assembled from different cultural, geographical, or educational contexts may surface further viewpoints, or configure them differently; the factors reported here should be read as a defensible account of the perspectives present in this study, not as an exhaustive map of how love for mathematics can be experienced.

Relatedly, the findings are specific to the time and context in which the study was conducted. Because Q methodology is sensitive to the particular participants, statements, and conditions involved, a subsequent study would not be expected to reproduce these factors exactly. This reflects the situated, interpretive aims of the method rather than a shortcoming of the analysis, but it does mean the personas should be understood as context-dependent rather than fixed types.

Finally, factor interpretation in this study rested on the abductive judgement of a single researcher. Although distinguishing statements were identified statistically and the thematic colour coding was applied only as a supplementary layer over interpretations anchored in the factor arrays, the reading of each factor as a coherent viewpoint, and its development into a persona, remained an interpretive act. The colour overlay in particular, while aiding recognition of patterns across statements, may also have foregrounded the five themes at the expense of connections that cut across them. A second analyst, or a participant-validation stage, would offer a check on these interpretations that the present design did not include.

Conclusion

This Q methodological study investigated the perceptions of individuals who love mathematics, revealing distinct patterns in how mathematics is understood, valued, and applied. The use of Q methodology enabled the identification of shared viewpoints, which were then interpreted through the structure of factor arrays and participant narratives. The findings highlight that engagement with mathematics is influenced by social interaction, experience, and meaning-making, as reflected in the statement rankings across the sorting grids (Ernest, 2019; Black et al., 2010; Kartal & Demir, 2017).

The reasons why individuals may love mathematics were illustrated through the data stories of Factor 1 and Factor 5 and their associated personas, Creative Charlie and Perfectionist Pepa (Figures 5 and 7). Extending the interpretation of Q methodological findings through HCD techniques enabled these factors to be represented visually as personas, supporting clearer communication of complex data patterns.

The integration of personas provides insight into the environmental conditions that may support positive mathematical engagement. Facilitators and educators may use

these personas to inform teaching approaches and learning design when supporting diverse learners in understanding and applying mathematical concepts. Further research is recommended to investigate the effectiveness of using personas within educational settings and to explore how this approach may support inclusive and responsive mathematics education.

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Appendices

Appendix A

Color coded like groups (or themes) statements

Enabling	Experiencing	Applying	Self- Belief	Relating
2 it is a highly creative activity	3 I enjoy the challenge of a math problem	4 problems can be looked at in different ways	1 I am good at it	5 reasoning is a powerful tool
7 it is great for sharpening the mind	8 I understand it	9 it is a universal language	6 math was easy	10 it's my passion
12 it's about being open to new ideas	18 it's more than useful it's engaging	14 fluent in maths, fluent in anything	11 it is consistent	15 I enjoy the symbols
13 it gives confidence to conquer problems	23it is an endless journey	19 it provides the tools to solve everyday problems	16 it was natural to mathematics	20 I like the beauty of mathematics
17 it is so straight forward	28 because it is difficult	24 it takes time to understand it	21 it has a reason for everything	25 of the beauty in the sequences and patterns you find
22 it is about logic	33 it finds the truth	29 it provides opportunities	26 it adds value	30 it gives answers that are trustworthy
27there is only one right answer	35 it runs in my family	34 it's a way to view the world	31 it makes sense	40 it is fun
32 it allows for alternative thinking	38 it is a shared experience	39 it is powerful in exploring uncertainty	36 you either get or you don't	44 it builds human connections
37 the concepts are immortal	43 With hard work you can completely understand it.	42 it can be followed step by step	41 it enables my desire to succeed	45 it has rules to follow

Appendix B

Demographics of Factor 1

Participant No	Age bracket	Gender	Country	Mathematician
1	25 to 34	F	USA	Y
5	25 to 34	F	Australia	Not sure
7	25 to 34	M	USA	Y
8	25 to 34	F	UK	Not sure
10	55 to 64	F	USA	Not sure
11	65+	F	USA	Y
12	55 to 64	F	Brazil	Y
15	45 to 54	F	USA	N
16	25 to 34	F	USA	Not sure
20	45 to 54	F	Australia	Y
22	45 to 54	F	USA	Not sure
25	25 to 34	F	USA	N
27	34 to 44	F	USA	Y
28	25 to 34	F	USA	N
29	25 to 34	F	USA	Y
30	45 to 54	F	USA	Y
33	45 to 54	F	USA	Y
36	35 to 44	F	USA	N
42	35 to 44	F	Australia	N
43	45 to 54	M	Demark	Y

Demographics of Factor 5

Participant No	Age bracket	Gender	Country	Mathematician
19	65+	F	Australia	N
45	18 to 24	F	Australia	Y
46	65+	F	Australia	N