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Identifying Emotional Expressions During Family Science Engagement at Home—A Case Study From a Parent's Perspective

Neta Shaby[1] | Nancy Staus[2] | Christian Bokhove[1]

[1]Southampton Education School, University of Southampton, Southampton, UK | [2]STEM Research Center, Oregon State University, Corvallis, Oregon, USA

Correspondence: Neta Shaby (n.shaby@soton.ac.uk)

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ABSTRACT

Families play a pivotal role in fostering children's science literacy, interests, and identities through everyday interactions and informal learning contexts, with parents as main facilitators. An essential, yet often underexplored, aspect of this process is the role of emotions in shaping science learning experiences. Emotions serve as powerful mediators of engagement, influencing key learning outcomes such as interest, motivation, achievement, and persistence. Despite the recognized importance of family engagement in science learning and the emotional dimensions associated with it, there is a significant gap in research specifically examining how families engage with science at home and the role emotions play in these settings. In this case study, we employed a mixed methods approach consisting of electro-dermal activity (physiological) and recorded observations (behavioral) to identify the emotional expressions of a mother as she engaged in five science activities with her children (ages 13, 11, 7, and 4) at home. All five activities were analyzed utilizing the following procedures: 1. Peak analysis, 2. Structural breaks, and 3. Microanalysis. We complemented our interpretation of the data with reflective notes and a reflective interview (self-reports) with the participant. The study reveals that mediated activities elicit more positive emotional expressions; the interrelationship between emotions and cognitive, social, and cultural domains needs to be accounted for while analyzing emotions, and highlights the methodological challenges of measuring emotions. By focusing on how a parent guides home science activities, it fills critical gaps in understanding family-based science engagement and sheds light on the affective dimensions of informal science learning. Employing a mixed methods approach provides a comprehensive understanding of emotional expressions during home science activities, which enhances the validity of the findings and captures the dynamic nature of emotions, offering a robust approach for analyzing the interplay between physiological, behavioral, and interpretive emotional expressions in real-world contexts.

1 | Introduction

Parents play a pivotal role in providing children with opportunities to engage in science, serving as a key context for the development of science-related skills and knowledge. Research has shown that family engagement in science facilitates children's disciplinary talk, supports their scientific thinking, and scaffolds their understanding of scientific concepts (Ash 2003; Crowley et al. 2001). Through everyday interactions and shared experiences, parents introduce children to science not only as an academic subject but also as a part of everyday life. These experiences position parents as essential agents in shaping children's emerging science literacy, interests, and identity, thereby playing a critical role in children's overall development of science knowledge and competencies (Calabrese Barton et al. 2013). Family participation in science extends beyond formal educational contexts and includes various informal learning settings, such as activities at home, community events, and cultural practices. These informal contexts provide rich opportunities for "disciplinary talk" that occur when families discuss scientific ideas, engage in problem-solving, or make observations about everyday phenomena (Ash 2003; Crowley et al. 2001). In these moments, parents and caregivers can help bridge the gap between everyday experiences and scientific concepts by explaining phenomena, asking open-ended questions, and encouraging children to think critically. This support functions as scaffolding, wherein adults guide children's learning processes by providing just enough assistance to help them achieve higher levels of understanding or skill (Mermelshtine 2017).

Emotions play a crucial role in the science learning process as mediators of engagement that significantly impact a variety of learning outcomes, including interest, motivation, achievement, and persistence (Pekrun and Stephens 2012). Despite the recognized importance of family engagement in science learning and the emotional dimensions associated with it, there is a significant gap in research specifically examining how families engage with science at home and the role emotions play in these informal learning settings. Much of the existing literature on science learning and emotions has focused on formal educational environments, such as schools, or in designed informal settings, like science museums (National Research Council 2010; Pattison and Dierking 2013). This focus overlooks the everyday science learning that occurs within the family context, where the dynamics of engagement and the influence of emotions may differ considerably from designed settings (Vedder-Weiss 2017). As families provide a distinctive context for learning that integrates cultural, social, and emotional dimensions, understanding the emotions expressed by parents during science engagement in these settings is crucial for advancing educational practices and interventions that support family-based science learning beyond traditional educational institutions.

Research on emotions and learning gained more attention in the last decades, often utilizing self-report instruments (Russell 2003), observable indicators of emotions (Rowe et al. 2023) and physiological measures (Staus and Falk 2017). However, studying emotions in naturalistic settings such as family science activities in the home presents unique challenges (Shaby and Bokhove 2024). Emotions are inherently complex and dynamic, often fluctuating rapidly in response to changing contexts and interactions (Russell 2003). This makes it difficult to capture the full range of emotional experiences using a single methodological approach (Shaby and Bokhove 2024). Additionally, emotions are often intertwined with other cognitive and social processes, complicating efforts to isolate their specific role in learning (Tyng et al. 2017). These challenges are compounded in family-based learning contexts where interactions are less structured and more variable (Vedder-Weiss 2017). As such, understanding the emotions expressed during family science engagement requires careful consideration of the methodological limitations and the adoption of a multifaceted approach to capture the complexity of emotional experiences.

The aim of this research is to identify the emotional expressions of a parent during science activities with her children at home, using a combination of electro-dermal activity (EDA), observational data, structural breaks analysis, and reflective interviews. The integration of the various methods advances methodological approaches for capturing emotions outside of laboratory settings, offering insights into the advantages and limitations of each method and how they complement each other. By focusing on the parent perspective, this case study seeks to deepen our understanding of the affective dimensions of family-based science engagement and shed light on how parents facilitate and shape science learning at home.

2 | Literature Review

2.1 | Family Engagement in Science Learning

Substantial research suggests that families play a critical role in supporting children's science learning and persistence. Theories of child development, such as Bronfenbrenner's bioecological model (Bronfenbrenner and Morris 2006), posit that family environments shape children's cognitive and emotional development by providing foundational support for exploration and curiosity. In this model, the family is part of the "microsystem" which includes the child's most immediate relationships and environments such as parents and siblings in the home and classmates at school (Bronfenbrenner 1977).

The relationships children have within the microsystem significantly influence their beliefs and actions, directly impacting all aspects of their social development (Bronfenbrenner and Evans 2000). For example, research has consistently demonstrated that families influence children's long-term engagement with science, both in terms of developing interest and supporting persistence in STEM-related activities (National Academies of Sciences, Engineering, and Medicine 2016; National Research Council 2000). The family provides an essential environment where children can receive encouragement, resources, and opportunities to engage in everyday scientific thinking and exploration, which can set the stage for lifelong learning.

Much of the literature on family learning outside of school has focused on interactions in designed learning environments such as museums and science centers, rather than in the home (Crowley et al. 2001; Haden et al. 2014; Rowe et al. 2023; Scalfi et al. 2023). These settings offer intentionally designed experiences that facilitate learning through exhibits, demonstrations, and guided activities, often explicitly intended to foster family engagement. Studies have shown that these experiences can strengthen parent–child interactions and support the co-construction of knowledge, as families engage in inquiry-based learning, observation, and discussions centered on scientific phenomena (Rowe et al. 2023). However, while these designed environments provide valuable opportunities for learning, they represent only a fraction of the spaces where family learning takes place.

While understanding science learning in the context of designed environments is important, it is essential to also understand what family science learning looks like in the natural environment of the home. Studies have shown that "serendipitous" everyday routines in the home environment, such as cooking, gardening, or observing nature, naturally lend themselves to science learning (Callanan and Jipson 2001; Rigney and Callanan 2011). Parents and caregivers frequently participate in conversations with their children that revolve around scientific concepts, even if these conversations are not formally recognized as "science talk." Through such activities (intended or not), parents send important messages about the relevance and value of science in daily life, which can lead to the development of positive science interest and attitudes in their children (Alexander et al. 2015). In addition, activities like discussing weather patterns, experimenting with objects in play, or following curiosity-driven questions about the natural world are opportunities where parents and children can jointly engage in scientific thinking (Barron et al. 2009; Pattison and Dierking 2019). These home-based science engagement activities reflect the informal and often unnoticed ways families contribute to children's science interest and learning. Most research has primarily focused on family interactions as a whole or specifically on children's experiences, while studies that examine parents often concentrate on their mediation strategies during science learning (Crowley et al. 2001; National Academies of Sciences, Engineering, and Medicine 2016). This emphasis tends to overlook the parents' own emotional experiences and their role as active participants in shaping the learning environment.

2.2 | Concept of Emotion

Emotions are complex and multidimensional, encompassing a blend of physiological changes, expressive body movements, and evaluations of situational contexts and cues (Keltner et al. 2019; Thoits 1989). Decades of research in psychology, neuroscience, and education have revealed the importance of emotions for learning, engagement, achievement, and psychological health (Larson and Brown 2007; Linnenbrink-Garcia and Pekrun 2011; Santos et al. 2023). Emotions have historically been understood through various theoretical lenses, including evolutionary and cognitive perspectives, which emphasized their biological nature, including physiological responses (e.g., skin conductance) and expressive reactions such as facial movements (Darwin 1872; James 1884). From these perspectives, individuals' emotional experiences have been conceptualized in two primary ways. Early emotion researchers viewed emotions as *discrete entities* such as sadness, anger, or fear that exist as unitary faculties of the mind (Ekman 1984; Izard 1977). However, because of the variation in emotional experiences among individuals, many researchers have adopted a *dimensional perspective* in which each discrete emotion is comprised of two basic dimensions along a continuum: valence (unpleasant to pleasant), and arousal/activation (bored to very excited; Russell 2003). The combination of valence and activation is referred to as "core affect" and is often considered to provide a more reliable measure of individuals' emotional experiences than discrete emotions alone, though perspectives on this vary within the field (Barrett and Russell 2014).

While the above perspectives interpret emotions in light of their biological nature within individuals, they do not consider the social aspects that link emotions to their context and determine the meaning of emotional experiences (Bembich and Gaspardo 2022). More recently, the social constructivist perspective has emphasized the influence of cultural and relational aspects in shaping emotions by focusing on the social functions of emotions and how they serve to maintain culturally determined value systems (Armon-Jones 1986; Averill 1980; Kuppens et al. 2017; Mesquita et al. 2017). From this perspective, emotions can act as social mediators, influencing both thinking and actions (Mesquita 2001). Importantly, the social constructivist perspective does not deny the evolutionary and biological aspects of emotions, but it suggests that the meaning of emotional experiences must be interpreted in light of relevant social, cultural, and relational factors (Goodman 2024; Lutz and White 1986). Therefore, in this study, we consider both the biological and social aspects of a parent's emotional experiences while engaging in science activities.

2.3 | The Role of Emotions in Science Learning

A growing body of research indicates a complex interrelationship between emotion and other domains of cognition, including attention and memory, that can affect learning outcomes in consequential ways (Bechara et al. 2000; Immordino-Yang and Damasio 2007). For example, emotionally arousing/activating events are more likely to command attention and be remembered in the future, thus potentially leading to more successful learning outcomes associated with those events (Cahill and McGaugh 1995; Ochsner 2000; Phelps et al. 2006). Similarly, positive emotions, such as curiosity, interest, and excitement, are linked to enhanced attention and focus (Pekrun et al. 2002). While negative emotions like anxiety, frustration, or boredom can detract from attention and result in disengagement from learning activities, recent research in informal learning settings indicates that, in certain circumstances, negative emotions can lead to a process called productive struggle, which can facilitate learning (Owens et al. 2012; Rappolt-Schlichtmann et al. 2017).

Although emotions in science education have received comparatively less attention in the past (Zeidner 2007), recently there has been increasing research on emotions in science teaching and learning, examining how emotion influences disciplinary activity, student learning, and science teachers' learning (Davidson et al. 2020; Jaber 2021; Radoff et al. 2019; Zembylas 2016). For example, researchers have shown that science anxiety, a fearful emotional state about science in general or a particular domain of science, results in poor performance and anti-scientific attitudes (Mallow et al. 2010) while feelings of enjoyment were strongly associated with interest and persistence in science (Maltese and Tai 2011; Osborne et al. 2003). In addition, negative emotions such as anxiety can increase cognitive load, which may restrict the capacity of attention and memory, thus leading to less positive learning outcomes (Choi et al. 2014; Plass and Kalyuga 2019). Combined, such work has revealed that emotion is integral to how science interest, learning, and participation are sparked and sustained for some and thwarted for others (Lanouette 2022; Rowe and Fitness 2018).

Recent work in informal science learning (ISL) contexts has shown the power of emotions to directly affect engagement and learning. In designed environments such as zoos, aquariums, and science centers, researchers have documented numerous positive emotions such as awe, fascination, and pleasure, as well as negative emotions such as concern, frustration, and anxiety that may affect visitors' learning outcomes (Ballantyne et al. 2011; Krogh-Jespersen et al. 2020; Myers et al. 2004; Price et al. 2021). Research to date has focused on positive emotions, suggesting that they facilitate learning while negative emotions hinder learning in ISL settings (Clayton et al. 2009; Myers et al. 2009; Sinatra et al. 2014). However, investigating emotions in ISL settings poses significant challenges, leading most research to focus on related factors such as participation, engagement, and attitudes. This is because the direct connection between emotions and learning is often complex and difficult to capture in less structured environments, without clear learning outcomes that can be measured.

2.4 | Emotions in Family Science Engagement

While many studies have examined the emotions of individual learners, others have begun to investigate the emotional expressions among families interacting with science museum exhibits. For example, Scalfi et al. (2023) examined the emotional responses of families toward animals during visits to a zoo specializing in birds in Brazil. By analyzing video-recorded observations, the results showed that although families experienced a range of emotions, positive emotions such as excitement and admiration were more frequent than negative emotions such as doubt or sadness. In a similar study at a science museum, Rowe et al. (2023) utilized a social constructivist perspective to examine the role of emotions in collaborative learning activities as a type of mediated action that is jointly produced by interacting agents, in this case family members. From this perspective, emotions are influenced by the activity itself, as well as the emotional expressions of other family members, which can support or hinder further conversation and interaction. The most frequently occurring categories of emotional expression among the families were those associated with being actively engaged in positive emotional interaction. In addition, the reactive emotions of curiosity and surprise, when co-occurring sequentially, supported collaborative activity, joint attention, and meaning making. These findings underscore the potential importance of parents creating a positive emotional environment to better facilitate family engagement during science activities.

While similar work has rarely taken place during family activities in the home, research related to children's development of science interests suggests that when parents demonstrate positive attitudes toward science while involving children in science-themed activities that promote observation and experimentation, children are more likely to internalize those values and develop an intrinsic interest in scientific topics and activities (Alexander et al. 2015; Barron et al. 2009; Staus et al. 2020). Therefore, we may expect that parents' positive emotional responses to science learning activities in the home may foster children's positive relationships with learning that contribute to the development of curiosity, inquiry, and perseverance in science learning.

2.5 | Measuring Emotions

Measuring emotions can be challenging, especially in a home context, leaving a substantial gap in literature. We employed several methodologies to study the role of emotions in science engagement, in order to capture both the individual and the social aspects of a variety of emotional experiences. We describe some key methodologies below, along with examples from the literature and the benefits and challenges of each.

2.5.1 | Self-Report Measures

Self-report measures, such as surveys and interviews, are widely used to assess learners' emotional states (e.g., enjoyment, anxiety, frustration) during science learning. Surveys often use Likert scales or other rating systems to quantify students' emotions. For example, the Achievement Emotions Questionnaire (Pekrun et al. 2023) has been used widely to assess students' emotions in the classroom across disciplines. In ISL contexts, surveys have been used to investigate visitors' emotional responses in museums, zoos, and science centers to better understand how emotions influence a variety of learning outcomes (Falk and Gillespie 2009; May et al. 2022; Myers et al. 2004). Interviews are often used in conjunction with self-reports to allow participants to reflect on their emotional experiences and explain why the activities triggered certain emotions (De Angeli et al. 2020; May et al. 2022). While self-reports of emotions are generally considered to be reliable measures of emotional experiences (Barrett 2006), they can be intrusive if administered during an activity and may not capture the complexity or causes of emotional experiences.

2.5.2 | Observational Studies

In observational studies, researchers watch learners, either in real time or on video recordings, as they engage in science learning activities and examine their behaviors, expressions, and interactions to infer emotional states and to examine the social and relational aspects of emotional experiences. Observations can be done in classrooms, labs, or informal learning environments like science museums. For example, Rowe et al. (2023) used GoPro cameras attached to visitors to examine the emotional experiences and interactions of families at a science center in Brazil to better understand the most commonly occurring emotions among families and how they shaped interactions with science exhibits. Observational methodologies have the advantage of being noninvasive, while allowing observation in the context of actual learning events including interactions with others and environmental influences (Boekaerts 2011). However, since emotions are inferred from behaviors, their identification can be influenced by the observer's interpretations. In addition, emotional expressions may not fully reflect a learner's internal emotional experience.

2.5.3 | Physiological Measures

From a biological perspective, emotional experiences trigger arousal of the sympathetic nervous system, leading to physiological changes in the body, such as skin conductance, heart rate, chest expansion, pupil dilation, etc. Such physiological measures have been used to examine learners' emotional arousal and stress levels during science learning tasks in both formal and informal learning environments (D'Mello and Graesser 2013). Researchers have used sensors to measure Galvanic Skin Response (GSR) or EDA as an indicator of arousal/activation in a number of ISL contexts (Rappolt-Schlichtmann et al. 2017; Staus and Falk 2017). While physiological measures have the advantage of providing objective information about changes in arousal or heart rate, they suffer from several shortcomings, including the discomfort of wearing sensors, a lack of specificity in determining valence, and an inability to identify discrete emotions without additional interpretive data (Tyng et al. 2017). Despite recent controversy about the role of arousal in emotion (Smith et al. 2025), decades of research in psychology and neuroscience have indicated that it is a useful concept in understanding human behavior (Barrett 1998; Russell 2003).

2.5.4 | Mixed Methods Studies

Because of the trade-offs associated with using one of the above methodologies alone, some emotion researchers have used a mixed methods approach to allow for a more holistic understanding of how emotions affect science engagement. For example, Staus and Falk (2017) measured galvanic skin conductance in combination with a self-report instrument to examine how emotion affected different aspects of cognition, such as attention and memory, in the learning of scientific content in an ISL context. Similarly, Rappolt-Schlichtmann et al. (2017) measured visitors' EDA and eye movements in conjunction with a survey to better understand learning outcomes in a science museum. Thus, while mixed methods approaches may be more labor and resource intensive, they can result in a more nuanced understanding of participants' emotional experiences while also allowing researchers to examine the social and relational aspects of these experiences.

2.6 | Research Objective

In the current case study, we examine the emotional experiences of a parent while engaging in science activities with her children (ages 13, 11, 7, and 4) at home. This research aims to identify the mother's emotional expressions during home science activities employing a mixed methods approach, using EDA, observations, reflective notes, and reflective interview. This case study posits that positive parental attitudes toward science can cultivate children's interest in scientific topics. By focusing on how parents influence and mediate home science activities, this research seeks to deepen our understanding of family engagement in science, ultimately fostering children's curiosity and perseverance in scientific endeavors. Additionally, employing a combination of methods advances research by allowing for a comprehensive and triangulated understanding of emotional expressions in home science activities. This integrated approach enhances the validity of the findings, captures the dynamic nature of emotions, and provides a robust approach for analyzing the interplay between physiological, behavioral, and subjective emotional expressions in real-world contexts.

2.7 | Methods

In this case study we employed a mixed methods approach consisting of EDA (physiological) and observations (behavioral) to identify the emotional expressions of an adult participant as she engaged in five science activities with her children. All five activities were video recorded and analyzed concurrently with EDA data utilizing the following procedures: 1. Peak analysis, 2. Structural breaks, and 3. Microanalysis (see below). We complemented our interpretation of the data with reflective notes and a reflective interview with the participant.

2.8 | Participants and Settings

In this research, one participant (Irit) video recorded her participation in designed activities that were intended for science learning. Such informal activities at home differ both in choice and structure, ranging from free-choice learner's initiated serendipitous activities to rejecting other's initiative, and from structured activities intended for specific science engagement to unstructured activities that do not (Vedder-Weiss 2017). Furthermore, engaging with such activities as a family often involves mediation (e.g., scaffolding) in which family members engage in joint activity, while questions are asked and explanations are provided (Ash et al. 2012). We classified each activity to indicate the design, structure, and mediation.

The activities took place at home and Irit wore EDA sensors located on a wearable vest to record her physiological responses. Irit chose five web-based structured and unstructured activities to engage in with her children; therefore, none of the activities was classified as serendipitous science engagement. All activities were mediated by the website itself (e.g., written instructions), by Irit through asking questions and providing answers for her children, or by a combination of both (Ash et al. 2012). Each activity is fully described in the findings section: 1. Watching scientific videos (with daughter Ofri, age 11, 13 min 19 s long), designed activity, mediated by website, unstructured; 2. Science quiz (with daughter Ofri, age 11, and son Yoav, age 7, 22 min 45 s long), designed activity, mediated by website and Irit, structured; 3. Invisible ink experiment (with Ofri and Yoav, 9 min 48 s long), designed activity, mediated by website and Irit, structured; 4. Lava lamp experiment (with Ofri, Yoav, and son Eyal age 4, 17 min 30s long), designed activity, mediated by Irit, structured, and 5. Physics homework (with daughter Yael, age 13, 11 min 52 s long), designed activity, mediated by teacher's instructions and Irit, structured. After selecting each activity, Irit wore a vest with EDA sensors and set up the software and backup camera. Prior to initiating the study, the researcher (first author) provided Irit with detailed instructions on operating the wearable EDA sensors and activating the software that was installed on a specific laptop (see Section 2.9). This preparation allowed Irit to conduct the activities independently, creating a more natural environment for data collection without the researcher's presence.

2.8.1 | The Family

Irit was a PhD student conducting research in science education and a former elementary and junior high school science teacher. Her husband worked as an engineer in the aeronautics industry, a role that required frequent travel. Together, they had four children (ages during time of data collection): Yael (13), Ofri (11), Yoav (7), and Eyal (4). The family regularly engaged in science-related activities at home, and the children participated in after-school science programs. Based on the parents' occupations, values, beliefs, social networks, and the children's interests, they could be described as a "science family."

Data collection for this research took place over 3 weeks in February–March 2021, during which several COVID-19 restrictions were still in place, including a night lockdown. At this time, the education system in Israel was gradually returning to in-person instruction, though inconsistently, with some children still learning remotely. As a full-time PhD student, Irit worked from home while caring for her children. Engaging them in science activities was a common practice in their household, independent of the pandemic. The children's father was not present for any of these activities. Although Irit was aware of the research topic, she was not involved in the data analysis, nor was she given access to the results.

The authors would like to acknowledge that the participants requested the use of their real names and images, in accordance with ethical guidelines to obtain consent and assent.

2.9 | Data Collection

We used the Equivital Wearable vest (see https://www.adinstruments.com/products/equivital-starter-pack-single), which includes skin temperature, heart rate, and chest expansion sensors, along with two electrodes attached to the palm of the nondominant hand to measure EDA. This vest is one of various wearable tools enabling the collection of physiological data outside the laboratory. In this research, we focused on the EDA measurements.

We utilized LabChart software (Equivital intellectual property) to measure and record physiological data, including a video capture mode that synchronizes video recordings with sensor data (using a laptop web camera). EDA is measured in micro-Siemens (μS), with the software sampling at approximately one measurement per second. Figure 1 demonstrates data output as seen in the software (GSR = EDA which appears first was the data used in this research).

We also used a backup GoPro camera that was positioned next to the laptop. The GoPro provided high-quality recordings, used when the laptop webcam recordings were unclear, both visually and audibly. The EDA data were collected over a 2-week period. After each activity, Irit wrote reflective notes describing the events and her overall feelings.

After the EDA data collection ended, the specific laptop with the software was retrieved from Irit, and peak analysis was performed on the data (see Section 2.10). The peak analysis formed the basis for the reflective interview with Irit 2 weeks after EDA data collection ended. The first author reviewed all recorded videos and performed peak analysis to identify episodes with elevated measurements. During the reflective interview, Irit was asked to watch each episode and describe the emotions she recalled. The interview was scheduled 2 weeks later to allow time for initial data analysis and identification of specific episodes, while ensuring the activities and emotions were still fresh in Irit's memory. Ideally, the reflective interview would occur immediately after the activity, but this is unrealistic with intensive data collection such as EDA. The reflective interview was conducted via Zoom due to COVID-19 restrictions and was video recorded.

2.10 | Data Analysis

In a previously published paper (see Shaby and Bokhove 2024) we detailed three methods to analyze EDA data: peak analysis, structural breaks, and microanalysis, which we employ in this case study. This paper outlined the advantages and

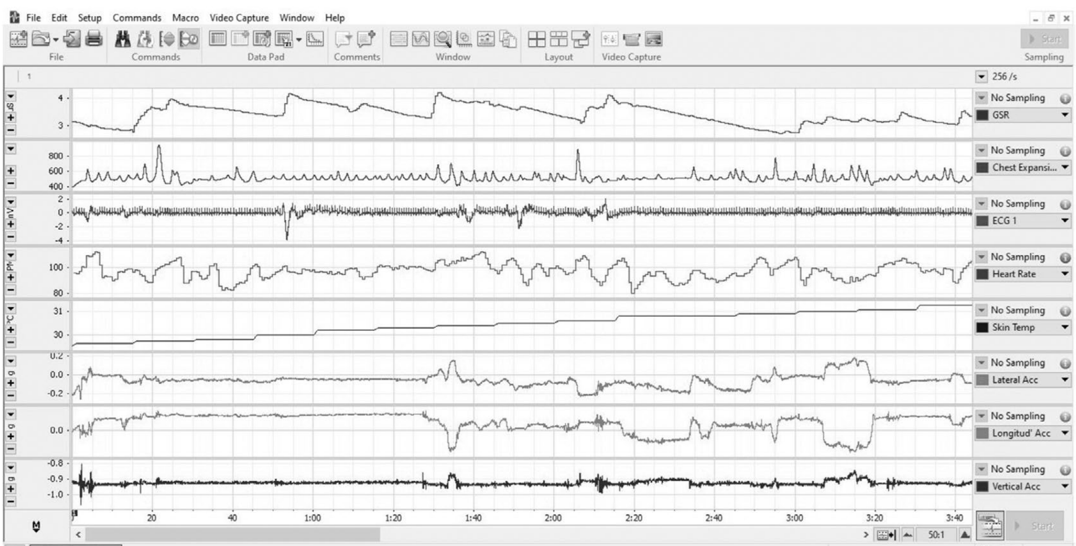

FIGURE 1 | LabChart software output.

disadvantages of each method, leading us to combine all three in this analysis, supplemented by reflective notes and an interview. Utilizing these multiple methods allowed us to conduct an in-depth examination of the emotions that Irit experienced, how they manifested in terms of valence and arousal, and our interpretation of potential causes of her emotional expressions during home activities (Yin 2009). This case study also provided us the opportunity to shed empirical light on the concept of emotions and the theoretical frameworks grounding it in the context of learning within the family (Yin 2009). Here, we describe the application of each method in this research; for elaboration on each method, see Shaby and Bokhove (2024). In the first step of analysis, we qualitatively summarized each recorded activity, describing events, participants' roles, actions, and speech. We included general impressions of their emotional state during the activities, noting changes in expressed emotions. In this step we described all participants in the activity, however, only Irit's emotions are the focus of this case study. In the second step, we performed both automated and manual peak analysis (see below). In the third step, we identified emotions corresponding to peaks by reviewing the video footage, accounting for the 3–5 s delay between stimulus and galvanic response (e.g., EDA output). While peak analysis indicated arousal, physiological data alone do not specify the emotion. Therefore, we interpreted observed behavior employing microanalysis through various modes of communication, including speech, gestures, posture, and facial expressions. We conducted this microanalysis twice: once on the entire dataset (focusing on Irit) and again on specific structural breaks (in the fifth step). The fourth step of the analysis included structural breaks, in which we used an algorithm on the time series data to capture shifts in the time series (see below). We compared our qualitative descriptions with the structural breaks analysis to determine correlations with various activities. The structural breaks helped to highlight "emotions rich" segments in each activity. Therefore, in the fifth step, we revisited these segments for more detailed microanalysis. Lastly, we summarized our interpretations of emotional expressions and compared them with reflective notes and the reflective interview data. These data were used to verify or contradict our interpretations; no further analysis, such as thematic analysis, was performed on this dataset.

2.10.1 | Peak Analysis

We utilized the Peak Analysis Module for LabChart, which automatically detects and analyzes peaks as measured by skin conductance (e.g., EDA). The software is proprietary and not publicly available (see https://www.adinstruments.com/products/peak-analysis). The default settings were used, with a threshold of 0.05 μS and a minimum peak height of 2 standard deviations. LabChart includes an artifact detection algorithm to remove false peaks. Additionally, a researcher manually verified all peaks and, if necessary, removed false peaks. The peaks identified by the software represent arousal moments, which we refer to as emotions. The number of peaks, after both automatic and manual artifact deletion and peak smoothing (see Shaby and Bokhove 2024), is presented in Table 1 as the number of emotions. This analysis was used to identify video episodes for the reflective interview.

2.10.2 | Structural Breaks

We extracted time series data from the software, measuring EDA every second for each activity, resulting in thousands of data points. Structural breaks in time series refer to sudden changes at specific points, indicating a shift. This analysis divides the time series into linear segments, using algorithms and regression models to identify multiple structural breaks. We used the R package 'strucchange' (Zeileis et al. 2002, 2003) within the Rstudio environment (RStudio Team 2021) in R version 4.1.1 (R Core Team 2021), which uses the Bai and Perron (2003) algorithm for estimating multiple breakpoints. The function breakpoints calculated breakpoints in the time series, with the default minimal segment size ($h = 0.15$). Structural breaks are marked with dashed horizontal lines on the EDA diagrams (see Figures 3–8 in Section 2.11).

2.10.3 | Microanalysis

LabChart software displays physiological data alongside the captured recordings on the same screen. Users can select a specific channel, such as EDA data, and zoom in on each peak. The software also includes a coding feature directly on the output (see Shaby and Bokhove 2024, Figure 2). In the first microanalysis step, we noted behaviors indicating emotion (only for Irit), such as smiles, laughter, or statements like "this is not interesting." This analysis was conducted on the entire dataset, regardless of peaks. We then compared this analysis to the peaks, coding the specific peaks and noting any observed emotional behavior without peak detection. To identify the specific emotions, we created an operational definition to each emotion, using literature on emotions (see Appendix A—American Psychological Association (n.d.); Ekman and Ekman 2016; Rowe et al. 2023; Sinatra et al. 2014) to select specific terms that are considered emotions (e.g., "fun" describes an emotional state but does not qualify as an emotion per various definitions). Additionally, some emotions cannot be distinguished by observation alone. Expression of excitement, enthusiasm, joy, and pleasure are difficult to differentiate, therefore, we used a small set of emotions that could be identified through observation. Positive emotions indicating happiness were coded as joy (as we could not distinguish between them).

We then utilized the definitions to code each of the emotions in the peaks. This process was conducted independently by two researchers, and any disagreements were discussed and resolved, in accordance with definitions in Appendix A. Emotional behaviors were coded to indicate one emotion. In the second microanalysis of specific structural breaks, we detailed the data second by second, describing verbal utterances, gestures, postures, and facial expressions. We also indicated our interpretations of the origin of the emotions and if they originated or were directed to the children or the activity.

Although this research is a case study following one participant, the extensive data collected (thousands of data points) and the meticulous microanalysis offer valuable insights into a parent's emotional experiences during family science activities at home.

TABLE 1 | Emotions expressed during all five activities.

Activity	All emotions		Valence of all emotions		Valence of emotions only related to the activity	
Watching scientific videos 13 min 19 s Designed activity, mediated by website, unstructured	Annoyance	7				
	Joy	6				
	Surprise	3	Positive	7	Positive	6
	Unknown	4	Negative	11	Negative	4
	Fear	2	Neutral	3	Neutral	3
	Confusion	1	Unknown	4	Unknown	4
	Boredom	1				
	Empathy	1				
	Total	25				
Science quiz 22 min 45 s Designed activity, mediated by website and Irit, structured	Annoyance	11	Positive	10	Positive	10
	Joy	10	Negative	11	Negative	3
	Surprise	3	Neutral	3	Neutral	3
	Unknown	24	Unknown	24	Unknown	24
	Total	48				
Invisible ink experiment 9 min 48 s Designed activity, mediated by website and Irit, structured	Annoyance	10	Positive	10	Positive	10
	Joy	10	Negative	10	Negative	2
	Surprise	2	Neutral	2	Neutral	2
	Unknown	2	Unknown	2	Unknown	2
	Total	24				
Lava lamp experiment 17 min 30 s Designed activity, mediated by Irit, structured	Annoyance	10				
	Joy	7	Positive	7	Positive	7
	Frustration	7	Negative	17	Negative	17
	Total	24				
Physics homework 11 min 52 s Designed activity, mediated by teacher's instructions and Irit, structured	Annoyance	20				
	Anger	8	Negative	31	Negative	27
	Unknown	8	Unknown	8	Unknown	8
	Frustration	3				
	Total	39				

2.11 | Findings

To analyze the data, we performed automated peak analysis, structural breaks, and microanalysis of selected video sections based on the structural breaks. We also referred to Irit's reflective notes and the reflective interview. The following sections describe the analyses for each of the five activities. Figure 2 presents the EDA measurements of all activities. This figure illustrates that most activities had a similar starting point (EDA measure in μS), except for the invisible ink experiment (which was the lowest).

Table 1 summarizes the emotions identified through the microanalysis of the peaks—all identified emotions in the entire recordings, valence (positive, negative, neutral, and unknown) for all emotions in the recordings, and the valence of emotions that were only related to the activity itself.

2.12 | Watching Scientific Videos

In this 13-min and 19-s recorded activity, Ofri (daughter, age 11) invited Irit to watch scientific videos with her. Irit sat in front of a laptop while Ofri stood beside her, navigating to the website and selecting videos she had previously enjoyed. We classified this activity as deliberate science activity as it was designed for science engagement and mediated by the website's content. Irit choose to engage with the activity that was initiated by her daughter. The participation itself was unstructured, while Irit could navigate through various videos, not required to follow specific instructions (Vedder-Weiss 2017). Some videos failed to capture Irit's interest, prompting her to ask Ofri to switch to different ones. Eyal (son, age 4) joined them after a few minutes but mainly caused disruptions. Irit expressed annoyance at Eyal, while Ofri attempted to keep him away from the laptop. All seven expressions of annoyance were directed at Eyal's interruptions and not the activity itself (see Table 1). Irit's empathy expression was directed at Ofri, and all other emotions expressed by Irit were related to the activity (the videos on the website). Therefore, out of 25 expressed emotions, 17 resulted from the activity (while 8 were from social interactions with the children which were unrelated to the activity).

Figure 3 illustrates the structural breaks analysis, revealing four shifts in the data, resulting in five distinct segments. In this example, we will describe each segment and the transitions between them. In subsequent examples, we will focus primarily on segments with "emotions rich" data.

During the first segment of the activity, there was confusion over the chosen video: Ofri initially selected the wrong one and replaced it after Irit had watched part of it. Concurrently, Eyal's interruptions were a source of distraction. The range of emotions experienced included annoyance (toward Eyal and not the activity), joy, surprise, empathy, and confusion. By the end of this segment, Ofri selected a video on artificial intelligence for Irit, who began watching it while Ofri attempted to manage Eyal's disruptions. In the second segment, Irit primarily watched the artificial intelligence video, exhibiting two instances of unknown arousal (peaks) and some annoyance at Eyal. At the conclusion of this segment, Irit indicated her lack of interest in the video, prompting Ofri to select a new one. During the third segment, Irit watched a roller-coaster video chosen by Ofri. She displayed joy, evidenced by a significant increase in EDA measures. Reacting to the roller-coaster in action, Irit exclaimed, "Oh My Good!" (or "אמאלה" in Hebrew), covering her mouth with her hand (see Figure 4). This moment of arousal resulted in two approximate peaks, with the EDA measure reaching a high of 10.8734 μS—the highest in the entire dataset (see Figure 2).

Then, the video content shifted to facts about roller-coasters, which were reflected in decreased EDA measurements and a break in the structure. During the fourth segment, Irit continued watching the same video, with a sudden EDA peak when

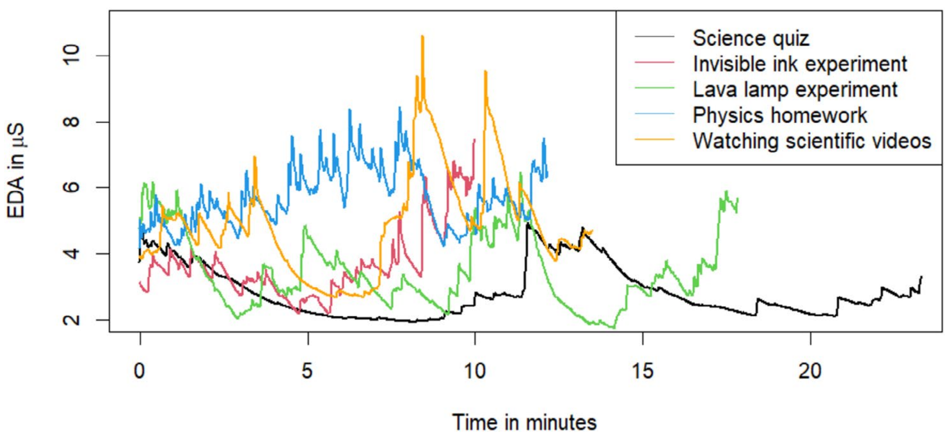

FIGURE 2 | EDA data for all five activities.

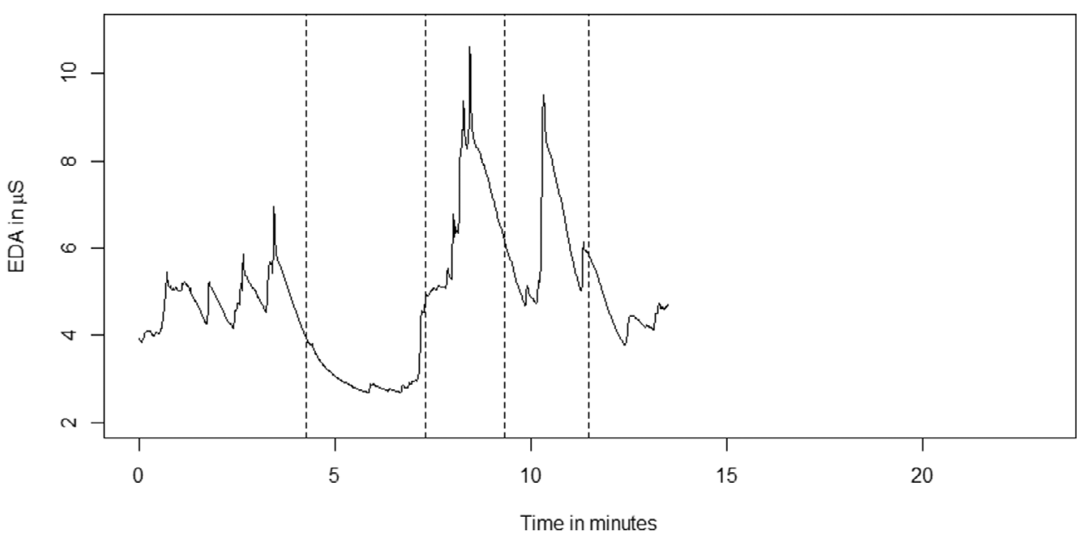

FIGURE 3 | Structural breaks for the watching scientific videos activity.

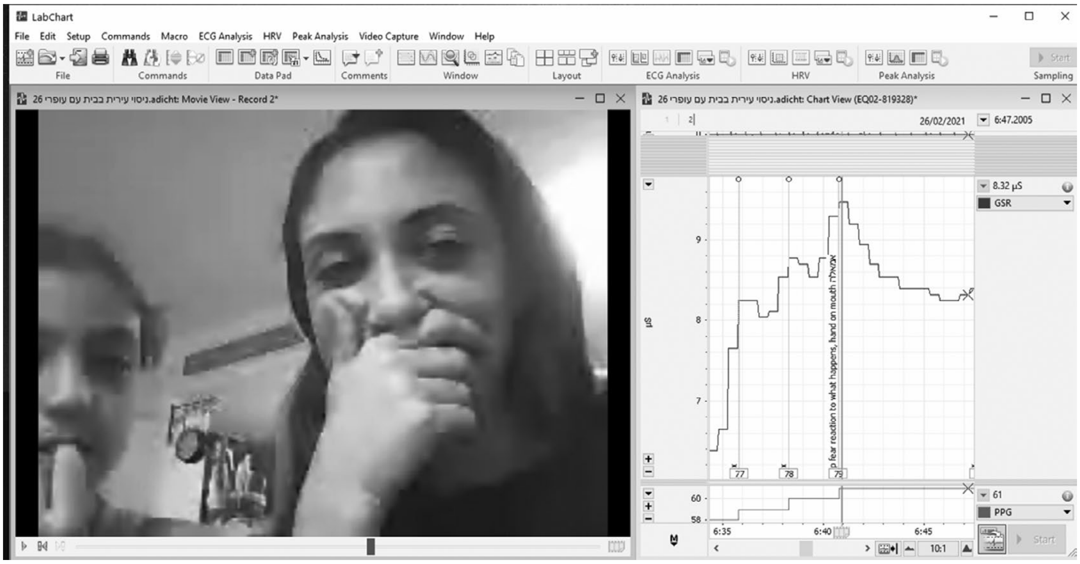

FIGURE 4 | Expression of fear as captured by LabChart video with coding on the output.

she shouted at Eyal to be quiet. The fifth segment of the video included instances of surprise in reaction to the presented facts.

The structural breaks analysis highlights the transitions between various activities within this recording, serving as a useful organizational tool, especially for larger datasets. This method can also direct researchers to "emotions rich" episodes within the data for microanalysis. By describing the specific activities within each segment, we can identify which ones elicit more emotions, such as the roller-coaster video in this instance.

Table 1 indicates 25 emotions expressed throughout the activity. As mentioned, annoyance was primarily directed at Eyal's actions. There were two instances where Irit verbally told Eyal that he was annoying her, but no corresponding peaks were recorded. Therefore, in this activity, from the 17 expressed emotions that were related to the activity (and not unrelated interactions with the children), we classified six as positive, four as negative, and three as neutral (Table 1). Four peaks remained unknown, as there were no verbal or gestural indications of the emotional state. However, the video revealed that during these peaks, Irit was closely watching the screen, illustrating the limitations of both analysis methods. While peak analysis can record arousal, it cannot identify specific emotions. Microanalysis of video recordings typically mitigates this limitation, but in this case, there were no observable behaviors to reveal the emotions. In her reflective notes, Irit described her overall feelings but did not address specific instances. The only method that could help identify these specific arousal moments would be a reflective interview, where specific recordings are played back to the participant, asking them to describe their emotions if they can recall them. This approach, although potentially time-consuming, requires the researcher to weigh the benefits against the costs. Additionally, a detailed analysis must be conducted beforehand to identify specific video episodes for the participant to review. In our reflective interview, we presented Irit with the roller-coaster episode. She described her emotions as excitement (or joy), stress, fear, and overall fun (though fun is not a specific emotion).

In her reflective notes, Irit mentioned that she appreciated Ofri's effort in selecting videos for her, which might also explain why she was annoyed when Eyal disrupted the mother–daughter interaction. She found the AI video uninteresting but enjoyed the roller-coaster video. Irit indicated that she is generally interested in facts, which kept her engaged with the videos and contributed to her annoyance when Eyal disturbed her. This sentiment was also reiterated during the reflective interview.

2.13 | Science Quiz

In this 22-min and 45-s recorded activity, Irit and her children, daughter Ofri (age 11) and son Yoav (age 7), engaged with a science quiz on the Davidson Institute Online scientific website, which they frequently use. We classified this activity as deliberate science activity as it was designed for science engagement and mediated by the website's content, with additional mediation required from Irit to clarify some of the questions and answers. The children chose to engage with the activity. The participation itself was structured, following the specific instructions of the quiz (Vedder-Weiss 2017).

The quizzes consist of 10 multiple-choice questions, each followed by an explanation of the related scientific concept or phenomenon. The family sat in front of a laptop, with Irit controlling the website. She read the questions, possible answers, and, upon solving, the explanations. This activity, similar to the previous one, was designed and guided by the website's content and required no additional mediation. However, for some questions, Irit provided further information or answered the children's queries, necessitating mediation moves. Figure 5 shows the structural break analysis, revealing five segments. At the beginning of the activity (segment 1), the family was selecting a quiz. Segments 2–5 involved engagement with the quiz, with Irit reading the questions, answers, and explanations. In terms of "emotions rich" data, we focus on segment 4, which showed a sharp increase in the EDA measurement, although not as high as during the scientific video activity.

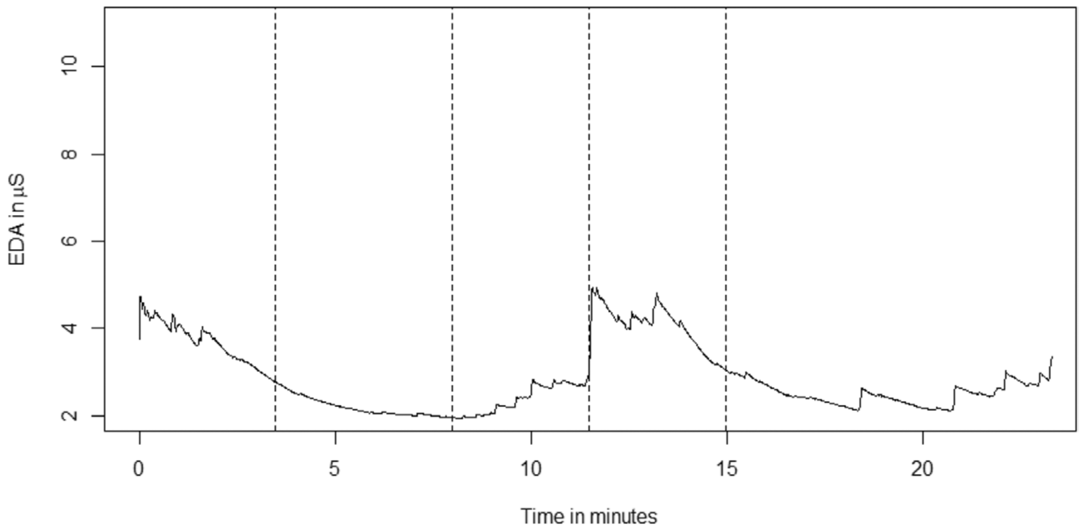

FIGURE 5 | Structural breaks for the science quiz activity.

Table 1 indicates 48 emotions expressed during this activity. Out of 11 annoyance expressions, 8 were unrelated to the activity and directed at the children (mainly Yoav pulling the laptop cord by accident), while 3 were related to the activity; from 10 expressions of joy, 3 resulted from children's actions when they correctly answered questions and 7 from the activity itself; all three surprise expressions resulted from Ofri's answers (Irit seemed surprised that she knew the answers). Thus, from the 24 expressed emotions we could identify, 16 were related to the activity. Of these, 3 were classified as negative, 10 positive, and 3 neutral. The additional 24 unknown emotional expressions were related to the activity. Interestingly, those 24 peaks were classified as unknown since no observable emotional expressions or verbal indications were present. Upon examining the video's content, it was evident that moments of arousal often occurred when Irit was trying to understand or explain a scientific concept that appeared in the quiz (elaborating on the explanation). In segment 4, all peaks were classified as unknown, with the highest levels of EDA measurement. During this segment, the question concerned the characteristics of mammals. Irit read that mammals have hair and produce milk, prompting Ofri to note that whales and dolphins, despite being mammals, do not have hair. Irit struggled to provide a satisfactory explanation and tried various explanations that did not satisfy Ofri. A possible explanation is that Irit was experiencing confusion or frustration, which was not captured in her speech or body language. The arousal resulting from these emotions might have increased her cognitive load, which limited her capacity for information processing, leading to her inability to find a satisfactory explanation (Moran 2016). Eventually, Irit gave up on the explanation and moved on to the next question, which resulted in a decrease in EDA measurements.

In her reflective notes, Irit mentioned that she did not know the answer to Ofri's question and lacked the energy to look it up, so she decided to move on. She did not refer to any specific emotional reaction caused by this instance. Since this event stood out in the peak analysis, this video episode was used in the reflective interview. Irit stated that she only wanted Ofri to understand the answer and did not recall being emotional during this part, which might support our interpretation of cognitive load. Her lack of recollection of any emotional state might indicate that perceptions of emotions can also be socially constructed. Although she clearly experienced a bodily reaction to the situation, she did not perceive her inability to answer her daughter's questions as emotional, rather as a common situation in daily interactions between parents and children (in this family).

Another notable observation was that Irit smiled twice in this video when the children answered questions correctly, yet there was no corresponding change in EDA. This suggests that the smiles might have been driven by social conventions, prompting parents to offer positive feedback through facial expressions, rather than reflecting a genuine emotional response. In contrast, in other instances, the emotions expressed were accompanied by changes in EDA. This observation could also imply the reverse situation: during the scientific video activity, Irit verbally stated her annoyance with Eyal, but there was no EDA indication to support this, which might be an expression of her values while trying to convey to her son that his behavior was unacceptable.

2.14 | Invisible Ink Experiment

In this 9-min and 48-s recorded activity, Irit and her children, daughter Ofri (age 11) and son Yoav (age 7), engaged with a science experiment from the Davidson Online website, which they frequently use. We classified this activity as a deliberate science activity as it was designed for science engagement and mediated by the website's content, with additional mediation required from Irit to clarify the instructions of the experiment. The children chose to engage with the activity. The participation itself was structured, following the specific instructions of the experiment (Vedder-Weiss 2017). Ofri selected the experiment, and Irit, along with the children, watched the video in the kitchen that explained the steps of the experiment.

After listing the ingredients specified in the video, Irit paused to gather all the necessary items. The experiment involved writing a secret invisible message on paper with milk as ink, which would become visible when heated. Figure 6 shows the structural break analysis, revealing five segments. Table 1 indicates that 24 emotions were expressed during this activity. During segments 1, 2, 3, and part of 4, Irit and the children watched parts of the video, paused to follow instructions, and resumed playback intermittently. Emotions during this period included annoyance, primarily due to the children misusing the ingredients (such as spilling milk and arguing about tasks), joy upon completing each step, four of which were directed toward the children's actions and five to the activity, with one instance in which the activity prompted action from Yoav that caused an expressed emotion from Irit, and surprise when Yoav did or said unexpected things, indicated by raised eyebrows and verbal exclamations like "ooooh." The two unknown peaks occurred at the beginning (segment 1) when Irit was gathering the ingredients for the activity. In segment 4, after completing the secret message and placing the papers in a toaster as instructed, Irit asked the children science-related questions while waiting. This led to two higher peaks in EDA measurements, indicating joy. Therefore, in this activity, 16 expressed emotions were related to the activity itself, 10 were classified as positive, 2 as negative, 2 neutral, and 2 unknown.

There was a decrease in EDA measurements while waiting for the paper to come out of the toaster, followed by an increase when the ink was revealed, and all family members expressed joy about the outcome. In this case, the structural breaks analysis was less precise in predicting changes in activities, as segment 4 should have been divided into two separate segments based on the occurrences in the recordings. In her reflective notes, Irit mentioned that she was unfamiliar with the experiment beforehand, which caused some stress—potentially accounting for the two unknown peaks at the beginning of the recording. She generally felt that the activity was not very exciting and created numerous opportunities for friction between the children. Irit described the activity as somewhat boring, which may explain why the EDA measurements started relatively low compared to other activities. However, despite this, her expressed behavior did not indicate boredom (as noted in Table 1). This discrepancy could be attributed to social conventions, suggesting that even if Irit was bored, she might have chosen to mask this emotion to avoid affecting the children's engagement with the scientific activity. Alternatively, the reflective notes may reflect her meta-cognitive interpretation of the activity rather than her immediate emotional experience in the moment.

In the reflective interview, Irit was shown an episode including the first segment and confirmed that she indeed felt stressed due to her unfamiliarity with the experiment and annoyed by the children's apparent lack of interest, despite the fact that they chose the experiment. She likened the situation to being a teacher in a classroom, preparing everything alone and feeling compelled to push the children to participate. This sense of frustration emerged while waiting for the papers to heat, during which she felt she was trying to forcefully engage the children by asking them questions. As noted, most of these emotions were not visibly recorded, highlighting not only the way emotions are socially constructed, but also how past experiences shape our own emotional expressions as individuals.

2.15 | Lava Lamp Experiment

In this 17-min and 30-s recorded activity, Irit prepared a science experiment with which she was familiar from her time as a science teacher. She arranged the materials on the dining room table and invited son Eyal (age 4), son Yoav (age 7), and daughter Ofri (age 11) to join her. We classified this activity as a deliberate science activity as it was designed for science engagement and mediated by Irit, who also chose this experiment. The participation itself was structured, following the specific steps of the experiment (Vedder-Weiss 2017).

The experiment involved pouring water into a clear glass jar to fill a quarter of its volume, then adding oil to reach three-quarters of the jar. Due to their immiscibility, oil and water formed two distinct layers. Next, water-based food coloring was added drop by drop, which sank through the oil without breaking and dissolved in the water below. After approximately

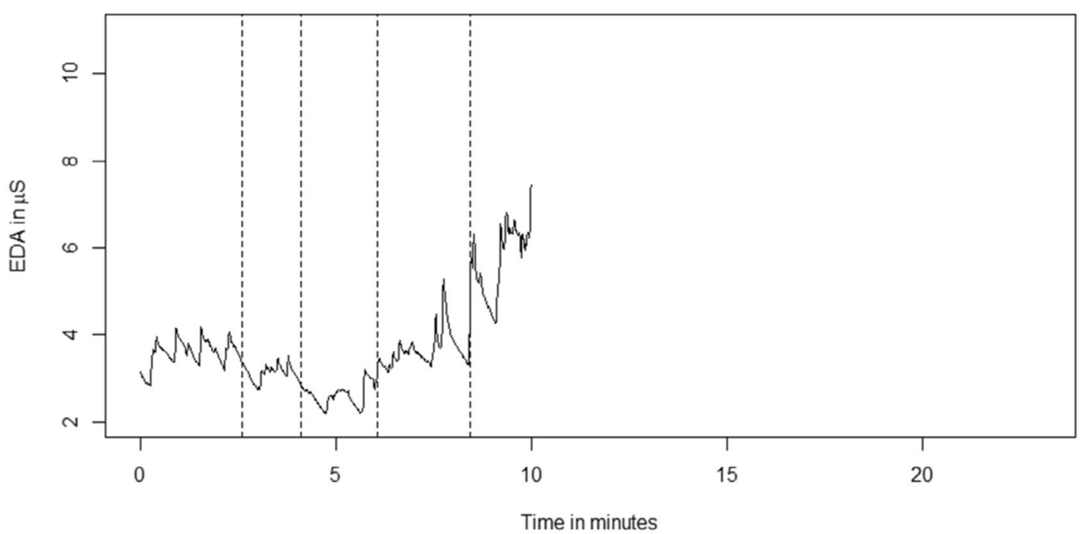

FIGURE 6 | Structural breaks for the invisible ink experiment activity.

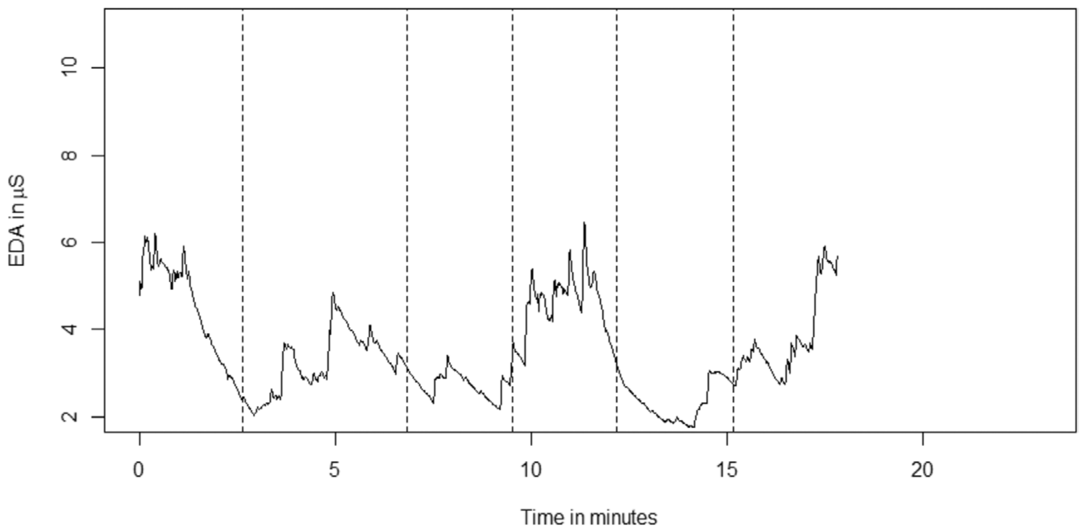

FIGURE 7 | Structural breaks for the lava lamp activity.

20 drops, Alka-Seltzer was introduced. The effervescence of the Alka-Seltzer created bubbles of CO_2 gas that rose through the colored water. This activity was delivered by Irit herself and did not rely on external instructions, making her the sole mediator.

Figure 7 illustrates the structural break analysis, revealing six segments, while Table 1 indicates 24 emotions expressed during the activity. The expressions of annoyance were mainly due to the activity not working (7), and some were toward the children's lack of attention (3). All expressions of joy and frustration resulted from the activity itself.

In segment 1, Irit prepared the experiment, and in segment 6, she put it away. The emotions in these segments included annoyance, initially due to difficulties in locating all materials and the children's lack of attentiveness, and later due to the experiment's failure. During segments 2 and 3, Irit conducted the experiment with the children, explaining each step. The engagement type was consistent across these segments, raising questions about the structural breaks analysis in this case. Emotions ranged from joy while enthusiastically explaining the steps to annoyance when the experiment did not proceed as planned. As this activity was entirely planned by Irit, we attribute all expressed emotions to the activity, with 17 emotions classified as negative and seven as positive. Our analysis focused on segments 4 and 5. In segment 4, it was evident that something had gone wrong with the experiment and Irit was attempting various solutions to correct it. Both her verbal and facial expressions signaled annoyance. This annoyance eventually shifted to clear frustration, as indicated by her observed behavior, structural breaks, and EDA measurements. Additionally, the EDA measurements decreased during the period of frustration. The reflective notes and interview corroborated the interpretation of annoyance and frustration. During the interview, when shown the video, Irit remarked, “I don't feel like watching this,” suggesting that even the recollection of the activity elicited a negative emotional response. She confirmed that she did not feel joyful during the activity, as initially suggested. Instead, she had been pretending to engage and excite the children, while actually feeling frustrated. This highlights the importance of considering the social context of emotions and the limitations of methods used to detect emotions in family learning settings.

2.16 | Physics Homework

In this 11-min and 52-s recorded activity, Irit assisted her daughter Yael (age 13) with her physics homework. Irit stated that she usually preferred not to help her children with their homework (and they often do not require such assistance); however, she does help when it is necessary, as it was in this case. We classified this activity as a deliberate science activity as it was designed for science engagement and mediated. Although the activity was guided by the physics teacher's instructions, Irit had to mediate due to Yael's lack of understanding. The participation itself was structured, following specific instructions (Vedder-Weiss 2017). Additionally, this activity originated from school, a formal setting; however, the form of participation was informal, with mother and daughter determining the form of engagement at home.

Figure 8 displays the structural break analysis, identifying six segments, while Table 1 indicates 39 emotions expressed during the activity. In the first segment, Yael was seated at the dining room table with the required materials (coil, battery, roller, pencil, and her phone with instructions). Then, Irit and Yael prepared the experiment and reviewed the instructions. In the second segment, they conducted the experiment. From the start, Irit appeared annoyed, evidenced by her nervous gum-chewing. Her verbal utterances revealed frustration with Yael's apparent confusion about the task. Unknown arousal moments occurred when Irit was listening to Yael's explanations of the instructions. In the third segment, Irit asked Yael to explain the experiment again and reviewed the instructions herself. Her body language and speech reflected annoyance, as she remarked, “It does not work like that, come on!” The fourth segment involved Irit trying to comprehend the experiment's objective, with consistent patterns of emotional measurements indicating annoyance and frustration. A distinct break occurred in the fifth segment when

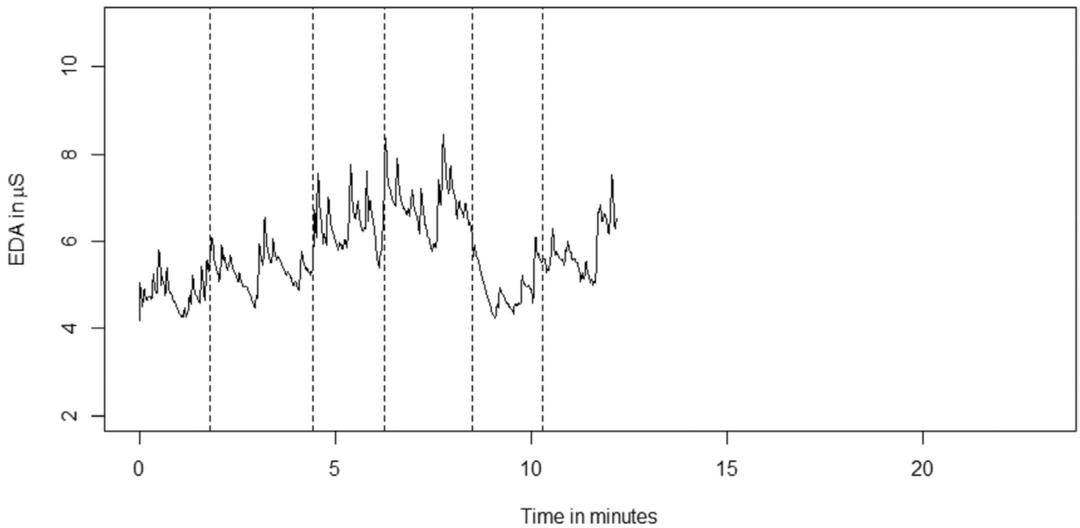

FIGURE 8 | Structural breaks for the physics homework activity.

Irit attempted to call her husband, who she believed could provide physics expertise. While waiting for his response (which he did not provide), Irit was further distracted by Ofri, who came downstairs and asked unrelated questions. By the final segment, Irit's annoyance and frustration had escalated to anger. She expressed her frustration by telling Yael, "Do whatever you want," and conveyed her disappointment over the lack of understanding of the task. Thus, all expressed emotions in this activity were classified as negative, 27 of these negative emotions were directly related to the activity. Eight of the peaks were classified as unknown, however, given the overall emotional state Irit was in, we believe these emotions were negative as well. It appeared that Irit might have been attempting to conceal some of the negative emotions, when it was possible, to reduce the negativity surrounding this entire activity, or considering her daughter's feelings as well.

In her reflective notes, Irit expressed disappointment that Yael appeared uninterested in the experiment, seemingly engaging with it only because the teacher required it. Irit stated that she expected more from her daughter, who was in an advanced science class. Notably, the notes did not mention any annoyance or anger, just disappointment. During the reflective interview, when shown the video, Irit rolled her eyes and sighed deeply. In the initial episodes of the video, which showed the beginning of the experiment, Irit reiterated her disappointment, consistent with her reflective notes. She also expressed uncertainty, stating, "I hate not knowing," referring to her lack of understanding of the experiment's purpose. Irit claimed not to recall specific emotions at this stage, which contradicts our interpretation of her verbal utterances and body language. She further noted that she felt like she was in a constant state of problem-solving, which she disliked. In the final episode of the video, Irit admitted to feeling very angry, particularly after calling her husband for assistance and receiving no response. She reflected that, in hindsight, she should have delegated this homework activity to her husband, who had a better understanding of physics. This acknowledgment underscores the complexity of accurately interpreting emotions in real time versus retrospective analysis—while the recordings indicated annoyance, anger, and frustration, the retrospective self-report indicated disappointment. This could result from misinterpretations, or the inability to identify specific emotions such as disappointment. It could also suggest that self-report might not be accurate specifically in situations where individuals might feel uncomfortable revealing their actual emotions (being angry at your child for example).

3 | Discussion

This case study examined the emotional experiences of a parent as she engaged in science-related activities with her children in her home in order to better understand which emotions she experienced during these activities, and how we saw those expressed through physiological measures and behaviors. The significance of this research lies in several key areas, by offering new insights into the role of emotions during family science learning and how different activities may influence emotional experiences, and underscoring the benefits and challenges of various methodological approaches to measure emotional experiences in these settings. Our findings also shed light on the relationships between emotions, cognitions, and sociocultural elements during science activities at home that may inform our understanding of how to better foster family engagement and learning in science.

3.1 | Emotional Experiences During Science Activities

Substantial research indicates that parental attitudes toward science and parental encouragement and support of youth STEM interest play an important role in the development of interest in science and math studies and subsequent aspirations to careers in STEM (Archer et al. 2012; Harackiewicz et al. 2012). Specifically, when parents express positive emotions while engaging in science activities with their children, it is more likely that those children will develop their own interest in science topics and activities (Alexander et al. 2015; Rowe et al. 2023).

Our findings indicated that Irit experienced a variety of positive, neutral, and negative emotions while engaging in five science-related activities with her children, with joy and annoyance being the most commonly expressed emotions (Table 1). The total number of positive or neutral emotions expressed by Irit for all five activities (42) was about half the number of negative ones (80). In addition, there were 38 instances of emotions that we were unable to identify as described in the findings. This finding was somewhat surprising given that much ISL research in designed spaces such as zoos and science centers has documented significantly more positive emotions such as awe, fascination, and pleasure than negative ones (Ballantyne et al. 2011; Myers et al. 2004). Irit's strong negative reaction during family science activities would seem to indicate that these experiences were unlikely to support science engagement and learning in her children. However, not all of these emotions were "activity emotions" that were in response to the science activities; rather many of the negative emotions such as annoyance were actually "social emotions" in response to interactions that she had with her children (see discussion below). In addition, emotional responses were not the same across the five activities. When we examined each activity separately, we found that three of them, Watching a video, Science quiz, and Invisible ink, were associated with a greater number of positive (26) than negative (9) or neutral (8) emotions. These activities differed from the others in that they were externally mediated by a website, rather than requiring mediation by Irit. While it is not entirely clear why external mediation was associated with more positive emotions, evidence suggests that the mediation included in these activities, such as specific instructions for conducting the experiment, might have reduced stress related to the role of the parent as mediator, thus providing more space for enjoyable interaction. Whatever the reason, Irit's positive emotions associated with participation in science activities with her children provided an environment in which collaborative activity, joint attention, and meaning making could be supported, potentially enhancing children's immediate involvement and fostering long-term outcomes such as self-efficacy, values, and aspirations in science (Itzek-Greulich and Vollmer 2017; Martin et al. 2016).

3.2 | The Interrelationship Between Emotions and Cognitive, Sociocultural Domains

3.2.1 | Emotions and Cognition

The mixed methods design of our case study allowed us to examine not just the individual emotions that Irit experienced during science activities with her children, but also how her emotions interacted with her cognitive experiences and were shaped by sociocultural factors such as social norms and expectations.

Substantial research indicates that emotions are deeply intertwined with cognitive outcomes in several ways. For example, positive emotions like excitement or joy can enhance motivation and focus, making it easier to learn and retain information. On the other hand, negative emotions such as anxiety or frustration can impair cognitive functions, narrowing attention and making it harder to process new information or make sound decisions (Bechara et al. 2000; Immordino-Yang and Damasio 2007).

One important relationship between emotion and cognition is related to the concept of cognitive load in which strong emotions can overwhelm learners' information processing abilities, thus negatively affecting learning outcomes (Lang 2000; Plass and Kalyuga 2019). We found evidence for this phenomenon during the Science quiz activity in which Irit's observable behavior indicated that she was engaged in thinking. However, because the EDA measurements indicated arousal, we classified this emotional experience as "unknown" during analysis. This finding, combined with Irit's reflection about feeling in control and "knowing what to do," suggested that Irit was experiencing strong negative emotions due to her uncertainty in her scientific explanations (e.g., why dolphins and whales are mammals if they have no hair?). Since negative emotions and uncertainty can limit the capacity of working memory by competing with processes that are essential for completing the task (Moran 2016), Irit may have struggled with the explanation, which to an observer seemed like she was thinking. This finding suggests that factors such as cognitive load should be considered while researching emotions during learning activities, especially when participants may be experiencing strong emotions.

3.2.2 | Sociocultural Influences on Emotion

Sociocultural factors significantly shape how emotions are experienced and expressed. Culture plays a large role in defining what emotions are appropriate in different contexts, and the social norms around emotional expression can vary widely (Kuppens et al. 2017; Mesquita 2001). The findings from the Science quiz activity illustrate how social norms, specifically expectations tied to one's professional identity, can influence emotional expressions. Irit, as a former science teacher, felt that it was expected that she would be able to provide the answer to her child's question, thus creating more "pressure" on her in the situation and causing more stress that potentially affected her ability to access her long-term memory to find the explanation (Plass and Kalyuga 2019). Presumably, in a different family, there may be no expectations for the parent to provide an explanation to such a question asked by a child, and the resulting emotional experience might be quite different.

In other instances, such as the Invisible ink experiment, Irit exhibited positive emotions (e.g., smiling and saying "nice" to her children) in the recordings, but without a corresponding peak in the EDA data, leading us to conclude that the positive emotions may have been simulated in response to social expectations in which parents feel they should appear excited and provide positive feedback to children while engaging in home activities (National Research Council 2010). The above example of a parent feigning positive emotions or concealing negative emotions (in the Physics homework) while engaging in science learning activities with their children provides strong evidence of the sociocultural norms that can shape emotional responses based on what emotions are believed to be appropriate in different contexts. Although these examples are specific to this family, they emphasize the importance of attending to the social and cultural elements that may be present in science learning environments to better understand the subsequent learning outcomes (Mesquita et al. 2017). Additionally, it is important to acknowledge the wider sociocultural context of this case study, taking place during COVID-19 restrictions, a challenging and stressful time for all of us, particularly families with young children.

3.3 | Methodological Affordances and Constraints

Our findings highlight the challenges in researching emotions, especially in an informal environment like the home. While physiological measures, such as EDA, offer a more objective means of detecting emotional arousal, they do not directly reveal the nature or cause of the emotion, necessitating further interpretation and triangulation with other data sources. Observable indicators of emotions, such as facial expressions or body language, can provide insights into participants' emotional reactions but may not always clearly indicate the underlying emotional state, especially in informal learning settings where social norms and cultural factors can influence how emotions are expressed. In addition, both methods are time-consuming and labor intensive. Self-report instruments such as interviews can be conducted more quickly but may be less accurate as they rely on individuals' ability to recall and articulate their own emotions. Structural breaks are fairly quick as an analytical method, however, they cannot be interpreted without observational data. Using structural breaks can be beneficial with a larger sample size (focusing analysis on "emotions rich" segments), or multiple participants to compare within the same activity (Eisenhauer 2019). Another challenge emerges from the ability to identify emotions accurately, considering multiple perspectives (not just psychologically), as some emotions such as fear, that is classified as negative, might be perceived differently depending on the context (e.g., while watching a roller-coaster video).

Our case study highlights the importance of using a mixed methods approach when conducting emotion research, as one instrument may be insufficient to capture the complexity of emotional experiences. Despite the growing popularity (with the advance of technology) of using physiological measurements, identifying specific emotions requires additional data and analytic methods. This research also highlights the significant contribution of reflective interviews that were critical for interpreting the data and shedding light on the participant's internal processes. Using this method should be considered with the caveat of conducting the reflective interview in close proximity to the learning activities to reduce recall bias.

3.4 | Implications, Limitations and Future Research

This research contributes to theoretical, practical, and methodological understandings in several ways. Theoretically, it advances the understanding of emotions in ISL, particularly within the family context—a setting that is often overlooked. By identifying the emotions a parent experiences during science activities with her children and highlighting the interplay between emotions and cognitive and sociocultural factors, the study builds on existing theories that conceptualize emotions as both biologically based and culturally shaped adaptive responses. It emphasizes the need to consider emotions not as isolated phenomena but as interconnected with cognitive processes like cognitive load and influenced by social norms and expectations, as demonstrated in situations where the parent's stress affected her cognitive performance during scientific explanations and the way parents regulate emotional expressions when interacting with their children according to their values and social expectations.

Methodologically, the research illustrates the complexities involved in measuring emotions in informal settings and highlights the value of mixed methods approaches to capture the nuanced nature of emotional engagement, including both the individual and social/relational elements, by integrating physiological data, observable behaviors, and reflective interviews. The study's findings point to the need for triangulation across methods to account for the multidimensional nature of emotions and their expression in diverse contexts.

This case study focused on one participant's emotional expressions during science-related activities at home, and as such, the main aim is not the ability to generalize, as the emotional expressions during learning activities that we observed may not be representative of other families with different social or cultural contexts. Due to logistic constraints (the availability of only one vest with sensors), this research only collected EDA data from the mother and not the children. In the future, we suggest that researchers collect data from all participants in the interaction, capturing children's emotions as well to examine how emotions co-occur among family members, and how parents' emotions support or hinder collaborative activity, engagement, and meaning making.

Additionally, a more in-depth exploration of the nature of the activities should be examined to gain a better understanding of the relationship between the features of the activity, emotions, and learning outcomes. For example, the differences between the activities could emerge from the age appropriateness of each activity, whether the activity was passive or interactive, if it was child-driven or parent-driven, open-ended or closed-ended, fully digital, hands-on, or hybrid, and so on.

Furthermore, the study focused on short-term emotional expressions during specific activities and therefore does not fully capture the long-term impact of emotional engagement on science learning outcomes. As such, further research with a larger and more diverse sample, along with longitudinal studies, would be needed to strengthen the findings and address these limitations.

Notwithstanding these limitations, our study advances understanding of how emotions are manifested during family-based science learning, highlighting the dynamic interplay between emotional, cognitive, social, and cultural factors in informal settings. By employing an innovative mixed methods approach, it offers a comprehensive approach for studying emotional engagement, addressing methodological challenges and providing insights applicable to real-world educational practices.

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Ethics Statement

This research was approved by Ben Gurion University of the Negev, School of Education's ethical board.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Appendix A

Definitions of Emotions

Discrete emotion	Valence	Definition	Behavioral indicators
Joy	Positive	Broad emotion encompassing excitement, enthusiasm, and pleasure. It arises when something is perceived as positive or worth celebrating.	Marked by increased energy, expressed through smiling, laughter, clapping, or verbal excitement (e.g., “YEY!”).
Empathy	Positive	Understanding others from their perspective, shown through caring actions and efforts to help.	Facial expressions like raised eyebrows, smiles, nods, and eye contact, often mirroring others' emotions. Verbal cues include phrases like “How can I help?” and speaking with a softer tone.
Surprise	Neutral	A brief, neutral emotion triggered by unexpected events, often leading to other emotions after further appraisal.	Characterized by raised or arched eyebrows, wide eyes, an open mouth, gasping, and verbal reactions like “Ohhh!” (with a gasp).
Confusion	Neutral or negative	Uncertainty caused by incomprehensible information, leading to questioning. It can be neutral or negative, depending on context.	People often pause, frown, and express confusion verbally with phrases like “Huh?” or “What?”.
Frustration	Negative	The feeling of being blocked from achieving a desired outcome.	Expressed solely through verbal communication, conveying disappointment with a situation.
Boredom	Negative	A lack of interest or engagement.	Detected only through verbal communication, as physical disengagement doesn't always indicate boredom.
Annoyance	Negative	A mild irritation when something disrupts or opposes our desires.	Shown through a frown, hand gestures, or changes in intonation (e.g., “sto::p it!”).
Anger	Negative	A strong reaction to harm or offense, more intense than annoyance.	Shown through furrowed brows, raised cheekbones, flared nostrils, and pressed lips.
Fear	Negative	The response to a perceived imminent threat, prompting a desire to escape or withdraw.	Expressed with wide eyes, stretched lips, and raised, furrowed eyebrows. Verbal cues include “I'm scared.”