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Exploring Elementary Students' Emotional States within Engineering Design Tasks in an Afterschool Program (Fundamental)

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Abstract

This study investigated how elementary students emotionally responded to engineering design tasks in an after-school STEM program, focusing on positive and negative experiences. The study involved nine grades 3–5 participants in various engineering tasks to combine creativity and technical problem-solving. Activities ranged from creating circuits with *Makey-Makey Piano* to assembling drones and hacking toys. Data were collected through structured interviews and emotion-tracking sheets, capturing students' feelings about successes, challenges, and moments of difficulty. The results indicated that students frequently expressed positive emotions such as excitement, happiness, and pride during tasks that allowed for tangible, creative outcomes. These emotions were often associated with activities that provided immediate feedback and visible success. Conversely, frustration and confusion were more common during technically demanding tasks, particularly when students faced iterative problem-solving challenges. However, many students reported a sense of accomplishment and pride after overcoming these obstacles with scaffolding and peer collaboration. This study demonstrated how task design and instructional strategies are vital in shaping students' emotional engagement in STEM education.

Keywords

STEM Education, Emotional Engagement, Engineering Design Tasks, Elementary Education, Social Emotional Learning

Introduction

STEM (Science, Technology, Engineering, Mathematics) education is designed to foster curiosity and engagement, but it also introduces emotional challenges such as frustration and confusion, particularly in engineering problem-solving [1-2]. While negative emotions may initially seem detrimental for young learners, they can provide opportunities for growth, resilience, and the development of problem-solving skills [3]. This study aligns with Social Emotional Learning (SEL) frameworks, which emphasize the development of emotional regulation, resilience, and collaborative problem-solving in educational settings [4]. Understanding students' emotional responses to engineering tasks can contribute to SEL-driven instructional strategies supporting academic and emotional growth [5].

Although there is growing recognition of the importance of emotions in STEM education, most research has focused on older students, leaving a gap in understanding how emotional states influence younger learners [6-7]. Younger students, who may lack the emotional regulation skills of older peers, could benefit from instructional strategies designed to support resilience and engagement. However, these strategies require a foundational understanding of the emotional dynamics during learning tasks, particularly in informal settings like after-school programs. Informal learning environments provide unique opportunities for students to engage in hands-on, exploratory tasks without the pressure of grades or rigid academic structures. These settings allow greater freedom to experiment and navigate challenges at their own pace, making them ideal contexts to observe how students experience and manage emotions during complex STEM activities [8-9].

This exploratory study examined how elementary students experienced positive and negative emotions during engineering design tasks in an after-school program. Understanding these emotional experiences is crucial, as navigating frustration and confusion is often integral to learning in STEM, especially in engineering contexts where iterative failure and persistence are part of the process [10]. While it does not aim to establish causal relationships, the findings offer preliminary insights to inform future research and practice in STEM education, particularly regarding emotional regulation and persistence in early learners.

Literature Review

The Role of Emotions in STEM Learning

Emotions significantly shape students' learning experiences and outcomes in STEM education. Positive emotions, such as curiosity, excitement, and enjoyment, are widely recognized for their role in fostering motivation and engagement. Fredrickson’s broaden-and-build theory posited that positive emotions expand cognitive resources, enabling creativity and exploration [11]. In STEM education, such emotions facilitate sustained interest and perseverance, particularly during the early stages of learning when students are encouraged to experiment with novel ideas [3][12]. These emotions also contribute to collaborative behaviors essential in group-based problem-solving tasks [9]. SEL plays a crucial role in fostering emotional regulation, perseverance, and collaboration in STEM education [13]. SEL frameworks highlight the importance of self-awareness, emotional management, and relationship skills, all essential in navigating the challenges of engineering design tasks [14]. Research suggests integrating SEL principles into STEM education can enhance student engagement, encourage productive responses to frustration, and improve teamwork in collaborative problem-solving scenarios [15].

Conversely, negative emotions such as frustration, confusion, and anxiety were historically perceived as detrimental to learning. However, emerging research challenged this perspective by highlighting their potential to foster deeper engagement and problem-solving when appropriately addressed [2-3]. For instance, frustration catalyzed persistence, encouraging students to seek alternative solutions when their initial approaches failed [12]. Similarly, confusion enhanced learning by prompting students to reconcile conflicting information and construct more robust mental models [2]. These findings underscore the dual role of emotions in STEM learning, where both positive and negative experiences contribute to cognitive and affective growth.

Emotional Dynamics in Engineering Education

Engineering education uniquely amplified the emotional dynamics of STEM learning due to its reliance on design thinking, iterative problem-solving, and open-ended challenges [13][16]. The design process often involves repeated failure and revision, eliciting intense emotions such as frustration and confusion [11]. These emotions are particularly pronounced when students engage with complex problems that lack clear solutions, requiring them to exercise creativity and resilience [12-13]. Despite these challenges, negative emotions served as powerful learning opportunities. Research suggested that experiencing and overcoming frustration fostered persistence and adaptability—skills essential for success in engineering professions [15]. Moreover, environments that encourage students to articulate and reflect on their emotions enhance collaboration and self-regulation, which are critical for effective teamwork and problem-solving [9][17]. For example, educators who explicitly addressed emotional experiences during engineering tasks helped students develop a realistic understanding of professional engineering work, where failure and iteration were integral [11].

Emotions in Elementary STEM Education

While much research on emotions in STEM has focused on secondary and post-secondary students, understanding these dynamics in elementary education has remained underexplored. Younger learners, still developing cognitive and emotional regulation skills, experience emotions differently from their older peers [8]. For instance, frustration in elementary students can lead to disengagement if not effectively supported, whereas structured interventions may transform these experiences into opportunities for growth [8]. Elementary students engaging in engineering tasks in informal learning environments, such as after-school programs, faced unique emotional challenges. These activities often involved iterative design and problem-solving, which evoked strong emotional responses, including excitement and frustration [9][18]. However, research showed that such experiences helped younger learners develop emotional resilience and problem-solving skills [15]. For example, structured reflection on emotional experiences improved elementary students' engagement and persistence during engineering tasks [12]. Similarly, fostering a supportive environment that normalized failure as part of the learning process helped younger students build confidence and adaptability [3][13].

Gaps in Current Research

Despite growing recognition of the importance of emotions in STEM education, significant gaps remained in understanding how elementary students experienced and regulated emotions during engineering tasks [4][15]. Most existing studies focused on older students, leaving a need for research that explores emotional dynamics among younger learners, particularly in informal settings like after-school programs [5]. Additionally, while the benefits of positive emotions were well-documented, the productive potential of negative emotions, such as frustration and confusion, are less explored, particularly in elementary education [2-3]. This study addressed these gaps by exploring elementary students' emotional experiences during engineering design tasks.

Methods

Participants

The study included nine participants, with pseudonyms used to maintain confidentiality. The group consisted of four girls and five boys enrolled in an after-school STEM program focused on engineering design tasks. Participants were in grades 3–5, ranging in age from 7 to 10 years. The group was demographically diverse, with students representing Hispanic, White, African American, Asian, and multiracial backgrounds. The participants self-identified gender and racial/ethnic information. Table 1 overviews their demographic information, interests, and career aspirations.

Pseudonym	Grade	Age	Gender	Ethnic Background	Preferred Learning Style	STEM Interest	Career Aspiration
Emily	3	8	Female	Hispanic	Group work	Engineering	Engineer
Noah	5	10	Male	White	Independent work	Technology	Scientist
Sophia	4	9	Female	African American	Group work	Science	Doctor
Liam	3	7	Male	Asian	Group work	Engineering	Engineer
Olivia	5	10	Female	Multiracial	Independent work	Technology	Engineer
Ethan	4	9	Male	African American	Group work	Engineering	Engineer
Mia	3	8	Female	Hispanic	Independent work	Science	Doctor
Lucas	5	10	Male	White	Group work	Engineering	Engineer
Ava	4	9	Female	Asian	Independent work	Technology	Scientist

Table 1. Overview of the participants' demographic information

Material and Setting

The program was a collaborative effort between our research team and a local library, which hosted the sessions in its well-equipped maker space. This partnership offered students access to tools, materials, and resources that supported hands-on engineering exploration. The library's community-focused environment also provided an inviting space where students could collaborate, share ideas, and engage in creative problem-solving. During each session, students were introduced to foundational engineering concepts through tasks that combined creativity, technical skills, and critical thinking. The activities included:

- **Makey-Makey Piano**: Students used Makey-Makey kits to create a piano using everyday objects like bananas or aluminum foil. This task introduced them to basic circuits and demonstrated how technology can turn simple items into functional instruments.
- **Making Robots**: Students built simple robots using motors, sensors, and recycled materials. As they brought their creations to life, they explored the basics of robotics, including movement and control.
- **Drones**: Participants assembled and tested small drones, learning about aerodynamics, propulsion, and remote-control technology. This task fostered problem-solving as students adjusted their designs for optimal flight performance.
- **Lighting Up Valentines**: Students created Valentine's cards that lit up using LEDs, batteries, and conductive tape, integrating creativity with basic electronics.

- **Buzzing Trucks**: Students designed and built trucks that buzzed or vibrated using small motors, exploring motion and energy concepts.
- **Microbots**: Tiny, simple robots were constructed with basic materials, teaching students about robotics on a microscale.
- **Reaction Games**: Students designed electronic reaction games that tested their response times, reinforcing the integration of engineering and play.
- **Rock-Paper-Scissors Bots**: Students built robots capable of playing the classic game, exploring randomness and programming principles.
- **Soccer-Bots**: Using kits and sensors, students created robots capable of playing a miniature game of soccer, combining robotics with teamwork and strategy.
- **Toy Hack**: Students disassembled and reassembled toys to modify or improve functionality, developing reverse engineering and innovation skills.
- **Taking Apart Electronics**: Participants explored the inner workings of common electronic appliances, such as old radios or phones, to understand their components and how they function.

These tasks were intentionally diverse, blending artistic, mechanical, and technical elements to cater to various interests and skills. Each activity encouraged teamwork, creativity, and iterative problem-solving, allowing students to engage in an engineering design process.

Data Collection

To capture students' emotional experiences in greater detail, the study expanded the data collection methods to include a combination of structured interviews and emotion-tracking activities. After each session, students were given a visual emotion-tracking sheet at the end of each session. This sheet included a list of emotions—both positive (e.g., excitement, curiosity, pride) and negative (e.g., frustration, confusion, disappointment)—accompanied by simple illustrations and checkboxes. Students were asked to circle or check the emotions they experienced during the session. This approach offered a nonverbal option for students who might find it easier to express their feelings visually, providing richer and more nuanced data.

In addition, students participated in brief, structured interviews conducted by either a parent or a university student volunteer. These questions probed into the emotions identified on the visual emotion-tracking sheet. For instance, “I noticed you circled sad. Tell me more about that.” Further, the interview questions focused on eliciting emotional responses to specific aspects of the engineering tasks, such as their reactions to moments of difficulty and their feelings about successes or failures. For example, students were asked, “How did you feel when your project didn’t work as expected?” to prompt reflections on emotions like frustration or confusion and “What made you feel excited or proud during today’s activity?” to encourage them to share positive emotions tied to successes or enjoyable moments.

Combining interview responses with the emotion-tracking sheets, we aimed to capture a comprehensive picture of students’ emotional journeys, highlighting patterns in how emotions evolved across different tasks and activities. This dual-method approach ensured that we obtained detailed accounts of individual experiences and broader trends in the group’s emotional engagement with the engineering program.

Data Analysis

The emotional responses collected from the interviews were analyzed qualitatively to understand how students experienced and expressed their emotions during the program. Each interview was transcribed, and the responses were carefully reviewed to identify specific emotional expressions. These emotions were categorized into two primary groups: **positive emotions** (e.g., excitement, happiness, pride) and **negative emotions** (e.g., frustration, confusion, disappointment). The context of each response guided the categorization, ensuring clarity in distinguishing between positive and negative emotions. During the coding process, student responses were tagged with emotional codes based on their descriptions of experiences. For example:

- **Positive Emotions**:
    - One student in the *Makey-Makey Piano* activity said, “I felt so happy when the banana actually made a sound—it was like magic!” This indicates excitement and a sense of accomplishment.
    - Another student expressed pride during the *Lighting Up Valentines'* task, stating, “When my card lit up, I was really proud because I had to figure out where to put the wires to make it work.”
- **Negative Emotions**:
    - Frustration was a recurring theme in the *Drone Assembly* task, with one student stating, “It was really frustrating when the drone wouldn’t fly straight, no matter what I tried.”
    - The *Toy Hack* activity was confusing. One student noted, “I didn’t know how the motor worked, and it was really confusing at first, but it got better when someone explained it to me.”

The analysis further focused on identifying patterns in emotional responses, specifically about the various activities. As a research team, we categorized the activities as “creative and achievable” or “technically challenging.” We considered the task complexity, required skills, and the level of support needed to complete each task. Activities classified as creative and achievable, such as Makey-Makey Piano, Lighting Up Valentines, and Reaction Games, involved creative problem-solving with clear, tangible outcomes and minimal troubleshooting. These tasks were designed to be completed with basic guidance, making them suitable for younger learners with varying technical skills. In contrast, activities classified as technically challenging, such as Drone Assembly, Toy Hack, and Soccer-Bots, required sustained effort, troubleshooting, and iterative problem-solving. These tasks often involved complex technical concepts and materials that demanded more advanced skills and significant support from instructors or peers. Lastly, the timing of emotional expressions was also considered. For example, students frequently described initial frustration during problem-solving phases, followed by pride or excitement when their solutions succeeded. This shift highlighted the importance of overcoming challenges in fostering positive emotional outcomes.

Results

The analysis revealed a predominantly positive emotional experience among the students, with most reported emotions categorized as positive. These emotions—such as excitement, happiness, and interest—were frequently associated with hands-on, creative tasks and moments of project success. However, a smaller but meaningful portion of reported emotions was negative, with students describing frustration and confusion, particularly during challenging or unpredictable tasks.

Positive Emotional Experiences

Positive emotions made up 88% of the emotional responses, emphasizing the engaging and fulfilling nature of the program. Students often expressed excitement and joy during hands-on activities that allowed them to see tangible results from their efforts. For instance:

- **Excitement**: Emily shared his enthusiasm for the program, stating, “I was so excited to come here!” Similarly, Liam expressed joy during the drone activity, saying, “It was exciting to fly them... even when some crashed into buildings.” These responses illustrate how the dynamic, interactive nature of the activities captivated students’ interest and created a sense of anticipation.
- **Happiness**: Students frequently reported happiness when completing successful projects. Ethan reflected on the *Makey-Makey Piano* activity: "I was happy because it was a fun day, and I could make a floor piano to do all this stuff.” This sense of accomplishment was a recurring theme, highlighting the value of achievable yet creative tasks.
- **Interest**: Curiosity and engagement were evident as students tackled tasks that introduced them to new skills. For example, during the *Reaction Game* activity, Mia shared, “I felt interested when I started doing the first coding part and thought, ‘Oh, this is fun.’”

These examples underscore the role of engineering design tasks in fostering excitement and curiosity in STEM education. Integrating engineering concepts into hands-on tasks provides students with opportunities to explore and innovate, contributing to high levels of engagement.

Negative Emotional Experiences

While less frequent, negative emotions such as frustration and confusion comprised 12% of reported responses. These emotions were often linked to technical difficulties, iterative problem-solving, or unexpected failures. For example:

- **Frustration**: Repetitive challenges were a common source of frustration. During the *Tracks/Cars* activity, Mia described, “It was not working, and it was not, and again,” expressing his exasperation at repeated failures.
- **Confusion**: Complex or unfamiliar tasks occasionally left students unsure of what to do. Olivia shared her feelings during the drone project: "I didn’t know what was going on and whether the drones were actually out of control.” This confusion often stemmed from the unpredictable nature of some activities.

Although negative emotions were less frequent, they provided valuable insights into students' challenges and how these moments influenced their learning. For many students, these emotions prompted them to seek help, try new strategies, or collaborate with peers, demonstrating the role of frustration and confusion in fostering resilience and problem-solving skills. For example, during the Drone Assembly task, Olivia expressed frustration, saying, "I couldn't get it to fly right, so I asked [Ethan] what he did, and we figured out what was wrong together." Similarly, Lucas mentioned during the Toy Hack activity, "It was really confusing at first, but when I saw someone else's idea, I tried something new, and it worked better." These examples illustrate how students actively sought peer support and adjusted their approaches to overcoming challenges, turning moments of confusion into opportunities for growth.

Emotional Trends Across Activities

The analysis revealed distinct emotional responses across the activities, reflecting the required levels of difficulty, creativity, and problem-solving involved in each task. These emotional trends demonstrated how the nature of the task shaped students' experiences and emotional engagement during the after-school program.

- **Creative and Achievable Tasks:** Certain activities, such as Makey-Makey Piano, Lighting Up Valentines, and Reaction Games, consistently evoked positive emotions like pride, excitement, and joy. These tasks balanced creativity with relatively straightforward technical execution, making them accessible to most participants. For example, Sophia expressed joy during the Makey-Makey Piano activity, saying, "I didn't think I could make music with just wires, but it worked, and it sounds so cool!" Lucas shared a similar sentiment about Lighting Up Valentines: "The Valentine's light is my favorite. It's fun and makes me feel like an inventor!" Similarly, Mia remarked during the Reaction Games activity, "I felt excited because I could actually play the game I made!" These activities allowed students to see tangible results, quickly reinforcing their confidence and engagement.
- **Technically Challenging Tasks:** More technically complex tasks, such as Drone Assembly, Toy Hack, and Soccer-Bots, elicited a broader range of emotional responses, particularly frustration and confusion. These tasks required sustained effort, iterative problem-solving, and troubleshooting, often leading to emotional challenges. Ethan described his experience during Drone Assembly: "I kept getting it wrong, and it made me feel stuck, but when it finally worked, it was awesome!" Olivia reflected on the Toy Hack activity, saying, "Taking it apart was easy, but putting it back together was really tricky. I felt frustrated, but when it moved again, I was so proud!" These tasks provided opportunities for students to experience and overcome challenges, which fostered resilience and a sense of accomplishment upon completion.

The diversity of emotional responses across these activities underscored the importance of task design in STEM programs. Creative tasks with achievable goals provided immediate rewards that boosted students' confidence and enthusiasm. Conversely, more complex tasks required perseverance through difficulties, allowing students to experience the satisfaction of overcoming obstacles. These emotional dynamics contributed to a well-rounded learning experience, balancing immediate gratification with long-term skill-building.

Limitation of study

A key limitation of this study was the self-selected nature of the participant sample. Students who enrolled in the after-school STEM program likely had a pre-existing interest in STEM fields, which may have influenced their high levels of engagement and positive emotional responses. Additionally, most participants demonstrated familiarity with engineering concepts and expressed ambitious STEM-related career aspirations, positioning them to respond favorably to the activities. As a result, the findings may not be fully generalized to students with lower initial interest or those who face barriers to STEM engagement.

Another limitation was the small sample size, which restricted the generalizability of the results. While this study provided valuable insights into students' emotional experiences in STEM activities, a larger sample would allow for more robust statistical comparisons and a deeper understanding of how different backgrounds, learning styles, and prior experiences influence engagement. Additionally, the study was conducted in a single after-school program, limiting the ability to examine how these findings apply to other informal learning environments.

Discussion

The findings from this study contribute to the growing body of literature examining the role of emotions in STEM education, particularly among elementary students in informal learning settings. While this study did not directly measure engagement, learning, or resilience, the emotional responses observed during engineering design tasks offered insights into the interplay between task design, instructional support, and students' emotional experiences.

Positive emotions like excitement and pride frequently emerged during tasks that balanced creativity with clear, achievable outcomes. Activities like *Makey-Makey Piano* and *Lighting Up Valentines* demonstrated how accessible, hands-on tasks could foster curiosity and enthusiasm among younger learners. These findings align with Fredrickson's broaden-and-build theory, which suggests positive emotions expand cognitive resources, encouraging exploration and creative problem-solving [7]. Additionally, the motivational benefits observed are consistent with [8] emphasis on the role of positive emotions in fostering sustained interest in STEM. While this study did not establish causality, the observed expressions of pride and excitement suggest that well-designed, tangible tasks may help shape positive attitudes toward STEM fields, as previously noted by [9].

In contrast, more technically demanding activities, such as *Drone Assembly* and *Toy Hack*, elicited mixed emotions, including frustration and confusion. These negative emotions were particularly prominent when students encountered technical challenges or iterative problem-solving demands. However, consistent with [2] and [3], the findings suggest that these emotions may catalyze deeper engagement and resilience when successfully navigated. For instance, students who initially expressed frustration often reported feelings of accomplishment and pride upon overcoming obstacles with peer or instructor support. This dynamic aligns with research by [9] and [12], highlighting the potential for guided emotional adversity to foster tolerance for ambiguity and a growth-oriented mindset—skills essential in engineering and other STEM fields.

The variation in emotional responses across activities underscored the importance of task design in shaping students' experiences. Creative and achievable tasks were consistently associated with positive emotions, while more complex challenges evoked a broader emotional spectrum. This observation reinforces Strobel et al.'s findings on the dual role of engineering design as both a source of challenge and an opportunity for growth [19]. While these findings are consistent with prior research, this study also identified gaps in the balance of challenge and support, particularly when tasks became overwhelming. Providing adequate scaffolding and feedback could help mitigate negative emotional responses and sustain engagement during complex activities [20].

Despite its contributions, this study had limitations that must be addressed. The small sample size and focus on a single after-school program restricted the generalizability of the findings. Furthermore, the study's cross-sectional nature did not allow for an analysis of how students' emotional responses evolved over time or influenced their long-term engagement with STEM. These limitations highlight the need for longitudinal research to explore how emotional dynamics in informal STEM education settings contribute to students' cognitive and affective growth.

Implications

The results of this study have implications for designing STEM education programs, particularly those aimed at younger students. First, the prevalence of positive emotions highlights the importance of incorporating hands-on, project-based activities that allow students to see the immediate impact of their efforts. These tasks enhance engagement and build students' confidence to tackle STEM challenges. For example, activities that combine creativity with tangible outcomes, such as building functional prototypes, can inspire curiosity and reinforce a sense of accomplishment. Incorporating SEL principles into STEM curricula can provide students with strategies to manage frustration, enhance peer collaboration, and develop resilience—critical skills for long-term success in engineering and problem-solving tasks [21].

Second, negative emotions underscore the need for supportive structures to help students navigate frustration and confusion. Providing scaffolding, peer collaboration opportunities, and timely feedback can transform these emotions into productive learning experiences. As [22] noted, confusion can serve as a "learning signal" that prompts deeper inquiry when students receive adequate support to resolve it. Educators might incorporate strategies such as breaking complex tasks into smaller, manageable steps, offering examples or hints during problem-solving, and fostering a classroom culture where struggles are normalized as part of the learning process. These approaches mitigate the adverse effects of frustration and equip students with the emotional resilience to persist in STEM fields.

Lastly, the diversity of emotional responses across tasks suggests the value of offering a range of activities that cater to different interests and skill levels. Programs benefit from balancing creative exploration and technical rigor, ensuring students are challenged and supported. For instance, incorporating tasks that vary in complexity can accommodate a wide spectrum of learners, from those just beginning to explore STEM concepts to those ready for advanced problem-solving. This flexibility fosters inclusivity and helps sustain engagement by addressing young learners' diverse needs and preferences.

By integrating these principles, STEM education programs can create environments that promote emotional growth, build resilience, and cultivate a lasting interest in STEM disciplines [23]. Like research on exhibit design in museum settings, where interactive and hands-on displays engage visitors through emotional and cognitive experiences, STEM programs can benefit from incorporating diverse, task-centered activities that balance creativity and challenge [24]. These findings highlight the significance of task design in shaping positive and productive emotional experiences, emphasizing the need for educators to consider both the cognitive and emotional aspects of learning to foster long-term engagement and interest in STEM fields.

Conclusion

This study contributes to the growing body of literature emphasizing the integration of emotional dimensions into STEM education [25-26]. By recognizing the dual importance of fostering positive emotions and supporting students through negative ones, educators can adopt holistic approaches to STEM learning that engage and sustain students' interests, particularly during critical formative years. As such, the study highlights the importance of designing educational environments that balance creative exploration with technical rigor. Carefully structured programs that offer a variety of activities catering to diverse interests and skill levels can ensure that students remain engaged while being adequately challenged. Such environments enhance students' technical competencies and equip them with the emotional tools to persist in STEM fields, where iterative processes and failure are inherent. This balance can potentially foster the cognitive and emotional resilience essential for success in STEM disciplines.

Future research should expand on these findings by exploring emotional dynamics across diverse educational contexts and with larger, more varied populations. Longitudinal studies could provide further insights into how students' emotional experiences in STEM learning evolve over time and influence their long-term engagement and success in STEM fields. By continuing to explore the interplay between emotions, task design, and instructional support, educators can create more effective and inclusive STEM programs that prepare students for the challenges and opportunities of STEM careers.

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References

[1] M. Ammar, N. J. Al-Thani, and Z. Ahmad, "Role of pedagogical approaches in fostering innovation among K-12 students in STEM education," *Social Sciences & Humanities Open*, vol. 9, no. 1, p. 100839, 2024. [Online]. Available: https://doi.org/10.1016/j.ssaho.2024.100839

[2] D. M. D'Mello and A. C. Graesser, "Confusion and its role in learning: A theoretical and empirical analysis," *Learning and Instruction*, vol. 22, no. 5, pp. 320–334, 2012. [Online]. Available: https://doi.org/10.1016/j.learninstruc.2012.01.002

[3] R. Pekrun, T. Goetz, W. Titz, and R. P. Perry, "Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research," *Educational Psychologist*, vol. 37, no. 2, pp. 91–105, 2007. [Online]. Available: https://doi.org/10.1207/S15326985EP3702_4

[4] V. T. T. Nguyen, H. L. Chen, and V. T. K. Nguyen, "Integrating social-emotional learning into gamified flipped classrooms: Impacts on emotion regulation, achievement, and communication tendency," *Journal of Computer Assisted Learning*, vol. 41, no. 1, p. e13109, 2025. [Online]. Available: https://doi.org/10.1111/jcal.13109

[5] A. L. Schoch, *A quantitative examination of the social-emotional competence, beliefs about social-emotional learning school culture, and job satisfaction among teachers in restorative practice schools*, Ph.D. dissertation, Baylor University, 2023.

[6] A. L. Reschly and S. L. Christenson, *Handbook of Research on Student Engagement*. New York, NY: Springer, 2022. [Online]. Available: https://doi.org/10.1007/978-1-4614-2018-7

[7] E. R. Kahu and K. Nelson, "Student engagement in the educational interface: Understanding the mechanisms of student success," *Higher Education Research & Development*, vol. 37, no. 1, pp. 58–71, 2018. [Online]. Available: https://doi.org/10.1080/07294360.2017.1344197

[8] J. Bellocchi, A. P. Ritchie, and S. Tobin, "Emotions in science and engineering education," *International Journal of STEM Education*, vol. 4, no. 5, pp. 1–13, 2017. [Online]. Available: https://doi.org/10.1186/s40594-017-0069-1

[9] H. Fredricks, J. Blumenfeld, and P. Paris, "School engagement: Potential of the concept, state of the evidence," *Review of Educational Research*, vol. 74, no. 1, pp. 59–109, 2019. [Online]. Available: https://doi.org/10.3102/00346543074001059

[10] J. Lönngren and M. Svanström, "Assessing emotional aspects of learning in engineering education: A new perspective," *European Journal of Engineering Education*, vol. 47, no. 3, pp. 383–400, 2022. [Online]. Available: https://doi.org/10.1080/03043797.2021.1889463

[11] K. Murphy, *Engineering Education and Emotional Resilience in Elementary Students*. Chicago, IL: Education Research Press, 2024.

[12] B. Fredrickson, *Positive Emotions and Their Impact on Creativity and Learning*. New York, NY: Basic Books, 2013.

[13] Y. Lin, M. A. A. Kadir, and D. Kaur, "Preschool educators' perceptions on value education," *Education Sciences*, vol. 15, no. 2, p. 140, 2025. [Online]. Available: https://doi.org/10.3390/educsci15020140

[14] Y. Zong and L. Yang, "How AI-enhanced social-emotional learning framework transforms EFL students' engagement and emotional well-being," *European Journal of Education*, vol. 60, no. 1, p. e12925, 2025. [Online]. Available: https://doi.org/10.1111/ejed.12925

[15] H. N. Schwartz, A. Skoog-Hoffman, J. Polman, O. Kelly, J. Bañales, and R. Jagers, *Integrated learning, integrated lives: Highlighting opportunities for transformative SEL within academic instruction*, Social and Emotional Learning Innovations Series, Collaborative for Academic, Social, and Emotional Learning, 2023.

[16] R. Wlodkowski and M. Ginsberg, *Enhancing Adult Motivation to Learn: A Comprehensive Guide for Teaching All Adults*, 4th ed. San Francisco, CA: Jossey-Bass, 2022.

[17] S. Linnenbrink-Garcia, K. Rogat, and A. Pekrun, "Emotional foundations of engagement and achievement in STEM education," *Educational Psychology Review*, vol. 28, no. 1, pp. 125–170, 2016. [Online]. Available: https://doi.org/10.1007/s10648-015-9316-3

[18] R. Adams, D. Turns, and C. Atman, "Educating effective engineering designers: The role of reflective practice," *Design Studies*, vol. 32, no. 3, pp. 295–313, 2011. [Online]. Available: https://doi.org/10.1016/j.destud.2010.09.003

[19] P. Matusovich, M. Ohland, and R. Case, "Understanding the complex dynamics of engineering design emotions," *Journal of Engineering Education*, vol. 112, no. 2, pp. 178–200, 2023. [Online]. Available: https://doi.org/10.1002/jee.20478

[20] S. Daly, R. Adams, and G. Bodner, "What does it mean to design? A qualitative investigation of design practitioners' perspectives," *Journal of Engineering Education*, vol. 101, no. 2, pp. 187–219, 2012. [Online]. Available: https://doi.org/10.1002/j.2168-9830.2012.tb00048.x

[21] G. Sultanova and N. Shora, "Comparing the impact of non-cognitive skills in STEM and non-STEM contexts in Kazakh secondary education," *Education Sciences*, vol. 14, no. 10, p. 1109, 2024. [Online]. Available: https://doi.org/10.3390/educsci14101109

[22] R. Sheppard, S. Macatangay, and A. Colby, *Educating Engineers: Designing for the Future of the Field*. San Francisco, CA: Jossey-Bass, 2022.

[23] L. N. Yeganeh, N. S. Fenty, Y. Chen, A. Simpson, and M. Hatami, *The Future of Education: A Multi-Layered Metaverse Classroom Model for Immersive and Inclusive Learning.* New York, NY: Future Internet, 2025, vol. 17, p. 63. [Online]. Available: https://doi.org/10.3390/fi17020063.

[24] J. Strobel, S. Wang, N. Weber, and M. Dyehouse, "The role of empathy in engineering design thinking," *Design Studies*, vol. 32, no. 2, pp. 207–230, 2021. [Online]. Available: https://doi.org/10.1016/j.destud.2010.09.005

[25] C. C. Chang and S. T. Yang, "Learners' positive and negative emotion, various cognitive processing, and cognitive effectiveness and efficiency in situated task-centered digital game-based learning with different scaffolds," Interactive Learning Environments, vol. 32, no. 9, pp. 5058–5077, 2024. [Online]. Available: https://doi.org/10.1080/10494820.2023.2123451

[26] R. Azevedo et al., "Learning as an emotionally regulated process: Insights from cognitive and educational psychology," Educational Psychology Review, vol. 34, no. 1, pp. 123–147, 2022. [Online]. Available: https://doi.org/10.1007/s10648-022-09627-3