TPM Vol. 32, No. S4, 2025
ISSN: 1972-6325
https://www.tpmap.org/

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# INFLUENCE OF COGNITIVE AND EMOTIONAL FACTORS ON DESIGN THINKING IN ENGINEERING EDUCATION

SOUMYADEEP CHAKRABARTI[1], DR. SANDEEP SONI[2], PARVEEN KAUR[3]

[1]ASSISTANT PROFESSOR, KALINGA UNIVERSITY, RAIPUR, INDIA.
[2]ASSISTANT PROFESSOR, KALINGA UNIVERSITY, RAIPUR, INDIA.
email: ku.sandeepsoni@kalingauniversity.ac.in ORCID:0009-0000-3692-6874
[3]ASSISTANT PROFESSOR, NEW DELHI INSTITUTE OF MANAGEMENT, NEW DELHI, INDIA.,
e-mail: parveen.kaur@ndimdelhi.org, https://orcid.org/0000-0002-5750-7115

**Abstract**

The adoption of design thinking in engineering education as a problem-solving, innovative, and user-focused skill-building method has greatly increased. Nevertheless, the emotional and cognitive aspects of student participation in design thinking activities remains largely unexplored. This research examines the impact on outcomes of design thinking in an engineering context as shaped by cognitive attention, working memory, problem-solving methods, and emotional motivation, frustration, and empathy. Information was gathered using a mixed methods approach which included behavioral observation, self-report surveys, and physiological measures of heart rate variability and facial emotion recognition during design tasks. Findings show that emotional engagement enhances participant ideation and prototype creative expression and that cognitive overload during complex tasks can inhibit iterative problem-solving. Emotions such as curiosity and frustration were demonstrated as constructive engagement enhancers when properly managed. The research emphasizes the need to define learning environments that foster emotional self-management in tandem with cognitive flexibility. A proposed focus on adaptive design thinking engineering curriculum frameworks informs instructional aims as shifts in STEM education focus on technology integration and the next generation of emotionally responsive learning systems. These conclusions underpin the need for STEM education to focus on technology integration and the next generation of emotionally responsive learning systems.

**Keywords:**Engineering pedagogy, educational technology, affective domain, interdisciplinary curriculum design, design-based implementation research.

## 1. INTRODUCTION

The application of design thinking in engineering education marks an evolution from traditional instructional models and rigid, one-sided, problem-oriented, solution-focused paradigms to more flexible frameworks that center on the user and iterate on empathy, ideation, prototyping, and testing [1][8][10]. This shift in teaching practices along with the emerging needs of Industry 4.0 and, hence, moving in the direction of design thinking models, motivates instructors to integrate teaching design thinking in the classroom, in the form of capstone and project-based interdisciplinary innovation labs focused on collaboration and creativity, as well as, hands-on learning [14]. Beyond a simple practice, design thinking is a mindset and a challenge that invites students to deal with ambiguity, learn from their mistakes, tackle uncertainty, and integrate their technical competencies with non-technical, soft skills, including, but not limited to, effective communication, empathy, and ethics. At the same time, design thinking's impact cannot be attributed to purely step-by-step frameworks; it is also the result of the impact of structure and process, along with emotional and cognitive elements that determine the degree to which students engage, as well as, the outcomes of their learning. Elements such as cognitive working memory, attentional control, and mental cognitive flexibility are crucial when it comes to configuration design which is laden with ambiguity [15]. At the same time, emotional states of curiosity, frustration, as well as, excitement can be helpful or a barrier to advance. Often, the nurturing of positive emotional states leads to creative risk taking, while the nurturing of negative emotional states, when approached constructively, can inspire reflection and growth. New findings from cognitive science and affective neuroscience emphasize the relationship between emotion and cognition in the learning process[6].

In design thinking, these dynamic guides students' information processing, challenge engagement, and motivation maintenance [5]. It follows that assimilating cognitive-emotional aspects in the engineering curriculum is crucial for fostering up-to-par engineering design courses that are adaptive, inclusive, and center on humans [12]. It's not just about teaching problem-solving; educators must equip students with skills of empathy and deep comprehension relevant to the engineering outcomes and the people served.

## 2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

The literature on design thinking in engineering education underscores its importance in developing creativity, collaborative skills, and problem-solving abilities through iterative, user-centered processes [2][7]. More recent research has pointed out the roles of cognitive functions like attention, working memory, cognitive flexibility, as well as some motivational and empathic emotional processes in learning outcomes[4]. The organizing framework for this study blends cognitive and affective theories with experiential learning, suggesting transformative design thinking comes from the shifting interplay of objective and subjective mental processes and emotional involvement [3]. This framework underpins the formulation of adaptive design instruction aimed at improving students' performance and adaptive resilience as well as their innovative thinking in engineering design education [11][9].

### 2.1 Cognitive Foundations of Design Thinking

- The more advanced thought processes, including diverging thinking, mental adaptability, and iterative reasoning, are considered the key parts of design thinking. This enables learners to create, assess, and improve innovative responses to multifaceted, broad issues which undergo several transformations.

### 2.2 Emotional Engagement in Problem-Based Learning

- An individual's positive emotion framework, which includes the individual's curiosity, empathy, and resilience, greatly enhances one's motivation and persisted in problem-based learning, enabling a design task to be approached with much deeper and keen engagement, thus, improving the learning outcomes[13].

### 2.3 Integrative Models of Learning and Innovation

- Modern learning paradigms focus on the cognitive and emotional aspects simultaneously since innovative outcomes result from the interplay of analysis and feelings in interactionsand collaboration in practice.

## 3. RESEARCH METHODOLOGY

This research explores the impact of both cognitive and emotional processes on design thinking in the context of engineering education and adopts a mixed-methods research framework. The approach integrates quantitative analysis of physiological and behavioral metrics with qualitative data from self-reported reflections and observational assessments. The participants of the study were undergraduate students from an engineering department undergoing a design thinking course with an iterative problem-solving framework that included brainstorming, prototyping, and user testing cycles. The sampling included 30 students with a wide range of academic and creative professional backgrounds that were selected through purposive sampling.

Data collection was done in three cycles which included a pre-task phase, a during-task phase, and a post-task phase. During the pre-task phase, students completed a baseline assessment of cognitive styles and emotional intelligence. Students' design tasks also included the collection of real-time data using non-invasive wearable devices that measured heart rate variability and facial emotion AI-enabled analytics video-based assessment of feelings. These devices measured the cognitive and emotional engagement indicators across the ideation, prototyping, and peer assessment stages.

Self-report surveys, the NASA-TLX workload index, and the participants' mental and emotional fluctuations, along with their coping and problem-solving methods were captured in follow-up semi-structured interviews. Physiological, behavioral, and narrative data were integrated to provide a more comprehensive picture of the relationship between emotion and thinking in design-based learning. Ethical policies such as informed consent, confidentiality, and the participants' comfort levels with biometric devices were fully observed. The approach aimed to capture both quantitative and qualitative data to explain the interplay of the cognitive and emotional factors in shaping creativity and learning in the context of engineering education.

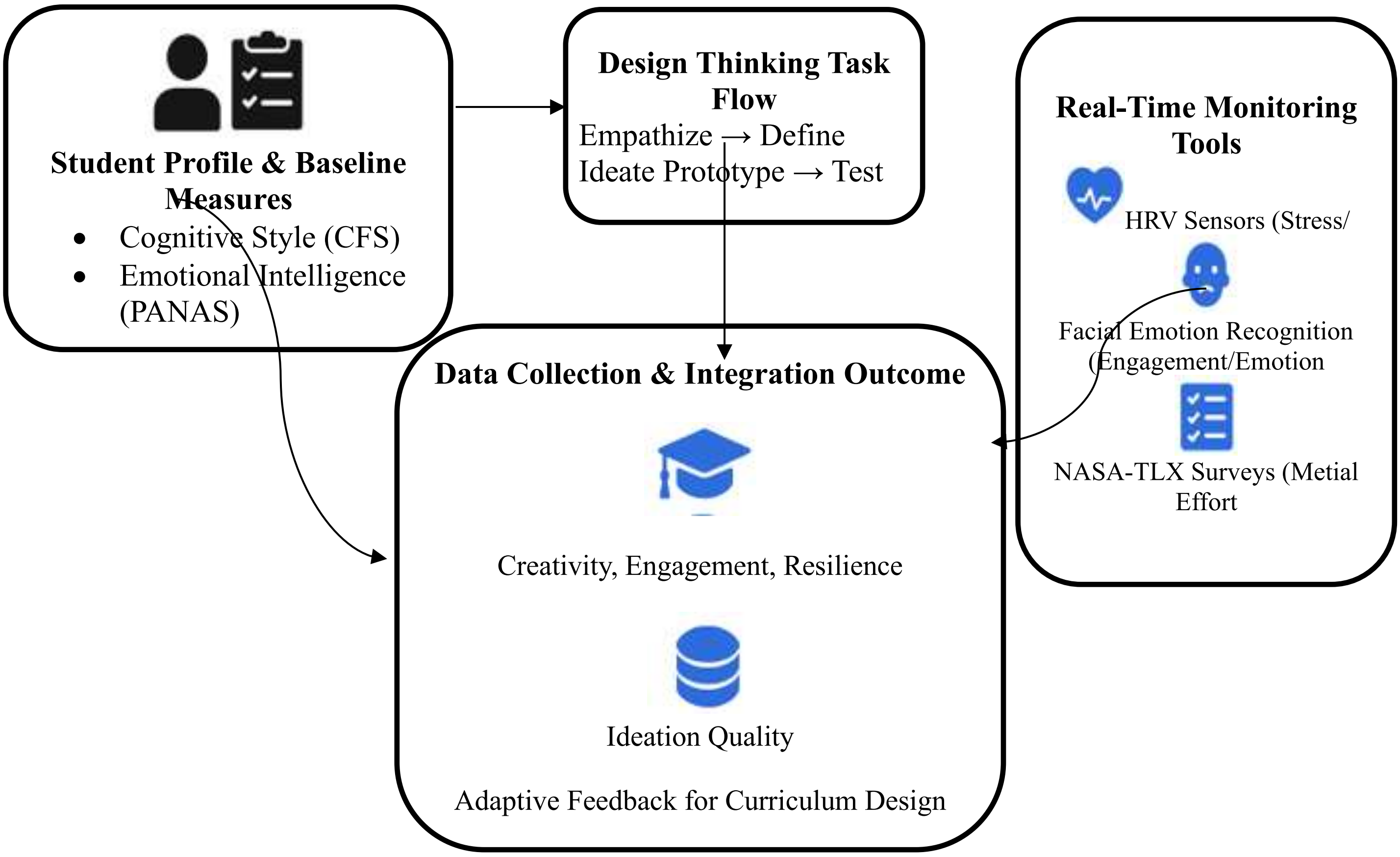


**Figure 1 Cognitive-Emotional Learning Framework**

Figure 1, the design thinking process in the context of engineering education is framed by cognitive and emotional factors. It starts with evaluating the student's cognitive style and emotional intelligence using CFS and PANAS. Students go through the design thinking process of empathize, define, ideate, prototype, and test in a structured manner. During design thinking, students' stress and emotional engagement are monitored in real time using HRV and facial emotion recognition systems. All data are integrated—behavioral data, physiological data, and self-report data—to assess creativity, engagement, and the quality of ideation. This algorithm improves curriculum design and gives the learner adaptive feedback, fostering emotional intelligence and cognitive awareness in the learning environment for engineering students.

### 3.1 Participant Profile and Educational Setting

The research identified a sample of 30 undergraduate engineering students from a well-known institution which offered a course on design thinking as part of its engineering curriculum. As blend of disciplines, gender, and prior knowledge of creative problem solving was required, participants were selected through purposive sampling. All participants fell within the age range of 19 to 24, had completed a basic engineering design or systems thinking course, and had participated in creative problem solving. Students were briefed about the purposes and procedures of the study, and participation was voluntary. Informed consent was collected prior to the study.

The education took place in an innovation and design lab, which featured modular workstations, whiteboards, and digital tools for collaboration, as well as lab materials and equipment for prototyping. In a design challenge, all learners took part in a construct-based design challenge where they had to understand a user need, brainstorm and provide several solutions, construct basic prototypes, and present to the peer review panel. Learning labs were arranged to provide appropriate problem contexts in real worlds. The researchers structured the course for a total of five lessons across a two-week span in order to capture as well as observe the participants' emotions and thoughts during the design thinking process. This lab offered an excellent setting for studying how learners behave in real-life problem situations within interdisciplinary contexts.

### 3.2 Assessment Tools for Cognitive and Emotional States

The design thinking process requires intensive cognitive and emotional work from the participants. Relating their feelings and thoughts from the thinking process requires self-reporting tools and even observatory techniques. Internationally recognized self-reporting tools like the NASA TASK Load Index and the cognitive flexibility scale serve to assess cognitive load. Mental demand, effort, and performance all contribute to the subjective workload assessment done alongside cognitive flexibility assessment and self-reporting.

Pre and post assessments for emotional engagement are done using the Positive and Negative Affect Schedule. The self-reporting system is also supplemented using AI based facial recognition software which enables video emotion expression recognition and thus catching the micro expressions that are indicative of grief, joy, annoyance and many more.

The heart and emotion work hand in hand. This stress indicator can also be viewed and studied during the design process which allows for deep assessments and patterns to emerge. The design thinking process is stress intensive or at least during the prototyping phase or the peer reviewing step. By evaluating emotion alongside cognitive flexibility and integrating observation, one can achieve balanced multi-dimensional perspective and assessment throughout the entire design process.

### 3.3 Design Thinking Task Flow and Data Collection

- In this study, a design thinking task flow was developed based on a five-phase structure: empathize, define, ideate, prototype, and test. Each phase was crafted to evoke certain thinking patterns and emotions from the participants, allowing for in-depth observation and data gathering. Students were organized into small interdisciplinary teams and given a real-world problem scenario—for instance, enhancing the accessibility of campus facilities—that demanded user-centered research and innovative design.
- In the identify and empathize phases, participants captured brief interviews to define user-centered issues. Both in analyzing and assuming roles, participants were applying perspective-taking reasoning. In the ideation phase, brainstorming was conducted in timed sessions to maximize the breadth of ideas produced. In the prototyping phase, participants built basic low-fidelity models, prompting team collaboration, creativity, and iterative problem resolution. In the last phase of the design, participants presented their prototypes to peers and gathered feedback, which stimulated reflection and emotional response.
- Each step of the process collected data. Wearable heart rate variability (HRV) monitors and emotion recognition software captured physiological and expressive signs of stress and emotion. Simultaneously, collaboration, pauses, and task switches were noted by observers. In each session, participants completed the NASA-TLX and PANAS questionnaires. A thorough analysis of the design thinking process, considering all cognitive-emotional factors, was owing to the rich multi-layered data collection strategy.

## 4. RESULTS AND DISCUSSION

Thinking and emotions played important roles part of the design thinking process like ideation and prototyping. Participants' NASA-TLX measures alongside their heart rate variability (HRV) indicated stress or strain in decision making. When prototyping, students tended to showcase high cognitive flexibility, mentally strained, but engaged in divergent and convergent problem solving along with collaborative revising. Emotionally, positive valance as indicated by facial expressions and PANAS scores during the assessment correlated to divergent creative performance and stood out for teams who demonstrated positive and empathic curiosity toward users. On the other hand, while design failure and high stakes feedback could trigger instant frustration and anxiety, these emotions, when managed, foster deeper design reflection and iterative improvements. Emotion or collaboration differs with ideation or cognitive work: high emotionally positive engagement while bored, low emotionally positive neutral states, with negative emotions strain work and collaboration. Effective engagement with design thinking tasks relies on emotional control and cognitive flexibility. Supporting both strategies simultaneously have the potential across sharply defined adaptable learning frameworks in engineering education.

### 4.1 Pedagogical Implications

Education of the future, for example, design thinking, should combine feeling and thinking strategies like self-evaluation, tiered assignments, and empathy tasks to develop and strengthen the creativity, grit, and multifaceted problem-solving practical challenges demand from learners in real life.

### 4.2 Enhancing Design Curricula with Cognitive-Emotional Insights

Bringing into the design curriculum the cognitive-emotional components allow teachers to regulate students' mental workload and the degree of emotional investment. This, in turn, enhances students' creative thinking in resolving problems, motivation, and even their grit.

### 4.3 Adaptive Feedback Mechanisms for Design Education

By looking at effects of cognitive load and emotional state, learners can be assisted using break suggestion, reflection prompting, and task difficulty change, which can optimize learning and emotions simultaneously.

## 5. Ethical and Future Considerations

While developing insights related to a person's learning journeys, emotion and cognition analytics bring to notice ethics on privacy, consent, and data security. There also policies and protective measures. Learning by design must also balance different cognitive and emotional approaches with fairness to prevent inequities. Ethical issues such as uncovered data must be trusted with primary emotion analytics in education. The intertwining of emotion and cognition reveals a more primary and responsible insight that should be prioritized in the next phase of education technology. Models such as these enable the emotional touch not to be a mere afterthought whenever engineering education is tailored to a student's individual needs, ensuring respect in ethics.

### 5.1 Emotional Privacy in Learning Analytics

Students' emotional privacy protection becomes critical when learning analytics integrate emotional data. Safeguarding emotional privacy while increasing autonomy, as well as reducing data misuse, rests on implementing informed consent, anonymization, and rigorous governance.

### 5.2 Equity and Diversity in Design-Based Learning Environments

To maintain fairness in learning, design-based learning needs to take into account various emotional and cognitive bio profiles while ensuring that environments that are too rigid and one size fits all, do not harm learners, neurodiversity, and from diverse backgrounds.

### 5.3 Future Research in Affective-Cognitive Pedagogy

Future research could look into scalable models of responsibly ethical designs which integrate real-time cognitive and emotional feedback data in adaptive systems for engineering education to promote learning, deepen engagement, and foster greater creativity.

## 6. CONCLUSION

This research highlights the importance of emotional and cognitive process factors when it comes to the effectiveness of design thinking in the context of engineering education. The thought processes of the students in terms of cognitive workload, emotional involvement, and creativity in the performance of the specific tasks reveal that design thinking encompasses more than the technical aspect; it is also a cognitive-emotional process. If not managed well, high cognitive load can be detrimental to creativity and collaborative work, teamwork, and creativity; however, positive emotions like curiosity and empathy can foster, and the capacity to generate ideas and innovate. Negative emotions, on the other hand, when acknowledged and managed in a reflective manner, can help in deeper learning and constructive change. These findings reinforce the need to move towards more emotionally responsive, cognitively adaptive, and real-time feedback, and reflectively responsive teaching. Ethically sensitive issues related to the use of biometric data require urgent attention to defend autonomy and privacy. A nurtured balance of the thinking and feeling is what would enable future engineers to address multi-faceted problems in a complex human-centered, dynamic world, build educational frameworks, and undergird responsive empathy, resilience, and creativity.

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