Engineering Empathy and Inclusive Design in STEM-IoT Project: A Case Study of Adaptive Curriculum Strategy in Junior High School

Mulyadi[1*], Rudi Susilana[2], Rusman[3]

[1,2,3] *Indonesia University of Education, Indonesia*

[*]Corresponding author. Email: mulyadi_mentariilmu@upi.edu

ABSTRACT

The increasing complexity of disaster-prone environments in Indonesia highlights the need for STEM learning models that cultivate both technical competence and human-centered design awareness. Yet, limited research has examined how STEM–IoT activities grounded in Design Thinking can simultaneously shape student empathy and teacher adaptability in authentic school settings. This qualitative case study examines how a STEM–IoT Mini Research Project (MRP) grounded in a Design Thinking framework for natural disaster mitigation fosters Engineering Empathy, Teacher Adaptive Strategies, and Student Autonomy. Data were collected through in-depth interviews (teachers and students), participatory classroom observations, and analysis of project artifacts, involving Grade IX students and STEM teachers at SMP IT Mentari Ilmu, Karawang, Indonesia. Thematic Analysis revealed three key findings: (1) Engineering Empathy emerged as a cognitive reasoning process that guided students to produce Inclusive Design solutions, demonstrated through multi-modal warning systems that accommodate diverse user needs; (2) Teacher Adaptive Strategies functioned as real-time instructional decision-making essential for managing the technical complexity of STEM–IoT tasks; and (3) the learning model successfully promoted Student Autonomy and intrinsic motivation throughout the project. These findings suggest that STEM–IoT curriculum innovation should position Engineering Empathy as a central driver of design quality, supported by teacher flexibility to maintain student agency. The study underscores the need for professional development emphasizing real-time troubleshooting and pedagogical adaptability.

Keywords: *Adaptive Strategy; Design Thinking; Engineering Empathy; Inclusive Design; STEM-IoT; Student Agency*

1. INTRODUCTION

The increasing frequency and intensity of natural disasters in Indonesia highlight the urgency of preparing students with both technical competencies and socio-emotional awareness to design meaningful solutions for real-world problems (BNPB, 2022; Sheehy, 2024). This condition positions STEM education as a strategic platform to develop students' ability to integrate scientific reasoning, technological fluency, and human-centered decision-making (Qin, 2022; McCurdy et al., 2020). Recent developments in educational technology show that the incorporation of Internet of Things (IoT) in project-based learning environments can enhance students' problem-solving engagement (Kakoulli & Evripidou, 2024; Ong et al., 2023), but managing this complexity requires structured frameworks such as Design Thinking that emphasize user needs, iterative refinement, and contextual relevance (Penalva Tebar & Nah, 2024).

Design Thinking has been widely recognized as a pedagogical framework that supports empathy-driven innovation in STEM learning, particularly by encouraging learners to understand users' perspectives before designing technical solutions (Bush et al., 2022; Lin et al., 2023). Within this context, the concept of Engineering Empathy extends the scope of empathy beyond emotional sensitivity toward a more cognitive design reasoning process that guides how technical decisions are made to accommodate diverse users (Walther et al., 2017; Fila & Hess, 2016). Prior studies have shown that empathy can influence the quality of engineering design outcomes (Guanes et al., 2021). However, research that examines how empathy manifests in middle-school STEM–IoT projects, especially through Inclusive Design features such as multi-modal warning systems, remains limited (Burns & Lesseig, 2017; da Silva et al., 2025). In addition, implementing IoT-based STEM projects in schools demands substantial teacher adaptability, as teachers must navigate real-time troubleshooting, dynamic curriculum adjustments, and varied student readiness levels (Diana et al., 2021; Arlinwibowo et al., 2023).

Despite the growing interest in STEM–IoT integration, there remains a research gap concerning how students' Engineering Empathy develops in IoT-rich learning environments and how teacher Adaptive Strategies enable students to maintain autonomy when facing technical challenges (Walther et al., 2017; Lunn et al., 2022). This gap is particularly relevant in developing-country contexts, where disaster mitigation offers an authentic and locally meaningful problem domain for STEM learning (Sampurno et al., 2015; Shahidullah & Hossain, 2022). Understanding how curriculum adaptation unfolds in real classrooms is essential for designing scalable and sustainable STEM programs (Johnson et al., 2024; Pierson, 2024).

Therefore, this study aims to investigate how a STEM–IoT Mini Research Project (MRP) grounded in a Design Thinking framework for natural disaster mitigation fosters (1) Engineering Empathy, (2) Teacher Adaptive Strategies, and (3) Student Autonomy in a junior high school context. By analyzing students' design artifacts, classroom interactions, and teacher decision-making processes, this study provides insight into how empathic reasoning emerges in technical design tasks and how teacher flexibility supports sustained student engagement. This research contributes to the literature by proposing a conceptual linkage between Engineering Empathy and Inclusive Design in STEM–IoT projects and by highlighting the pedagogical implications for adaptive curriculum implementation in real-world school settings.

2. METHODOLOGY

2.1. Research Design

This study employed a qualitative case study design to examine how a STEM–IoT Mini Research Project (MRP) grounded in a Design Thinking framework was implemented in an authentic junior high school setting. A qualitative case study was selected to enable an in-depth exploration of learning processes, instructional adaptations, and participants' experiences related to Engineering Empathy, teacher adaptive strategies, and student autonomy within a bounded educational context.

2.2. Research Context and Participants

The study was conducted at SMP IT Mentari Ilmu, Karawang, Indonesia. Participants consisted of eleven Grade IX students enrolled in the STEM–IoT Mini Research Project and three STEM teachers (Science, Mathematics, and Informatics) who directly facilitated the project. Participants were selected through purposive sampling, targeting individuals who were most directly involved in and knowledgeable about the instructional processes and learning dynamics of the project.

2.3. Learning Context: STEM–IoT Mini Research Project

The STEM–IoT Mini Research Project was designed using the Design Thinking framework, encompassing the stages of Empathize, Define, Ideate, Prototype, and Test. Students were guided to develop IoT-based early warning system prototypes for natural disaster mitigation. The learning design emphasized human-centered problem framing, iterative design, and real-world contextualization, allowing both teachers and students to engage in flexible and adaptive learning processes.

2.4. Data Collection

Data were collected using multiple qualitative techniques to capture the complexity of classroom implementation:

1. In-depth interviews with students and teachers (11 interviews in total), focusing on students' reasoning processes, teacher decision-making, collaboration, technical challenges, and learning experiences.
2. Participatory classroom observations conducted over a four-week project period, documenting teacher–student interactions, troubleshooting activities, and design-related discussions.
3. Project artifact analysis, including student worksheets, design sketches, IoT code, testing videos, and final project presentations, to trace iterative thinking and design development.

2.5. Data Analysis

Data were analyzed using Thematic Analysis supported by NVivo 12. The analysis proceeded through three stages: (1) Open Coding to identify initial meaning units across interviews, observations, and artifacts; (2) Axial Coding to group related codes into conceptual categories such as empathy, adaptive scaffolding, problem-solving, and autonomy; and (3) Selective Coding to synthesize categories into the study's three core themes: Engineering Empathy, Teacher Adaptive Strategies, and Student Autonomy. Triangulation across interviews, observations, and artifacts ensured the credibility and trustworthiness of the findings.

3. RESULT AND DISCUSSION

The data analysis identified one main selective theme: S1 — Engineering Empathy as a Pedagogical Engine. This core theme is supported by four axial categories: (1) AC1 (Empathy Engineering); (2) AC6 (Teacher Scaffolding); (3) AC7 (Design Thinking Operationaliza-tion); and (4) AC8 (Socio-Emotional Learning & Resilience).

3.1. Empathy Engineering (AC1): Emotional Grounding for Human-Centered IoT

Empathy emerged as the starting point of the entire process, triggered by the real and audiovisual disaster context. During the empathize stage, students showed affective reactions, imagined themselves as victims, and expressed a desire to prevent loss of life. This process indicates that empathy became a cognitive mechanism that guided how they defined the problem (Davis, 2023; Stoev & Stoeva, 2024).

"I imagined what it would be like *if my mother were there. The device must respond quickly." — SPK-1, Female*

"If the device *is late by just a few seconds, there could be more victims." — SPK-2, Female*

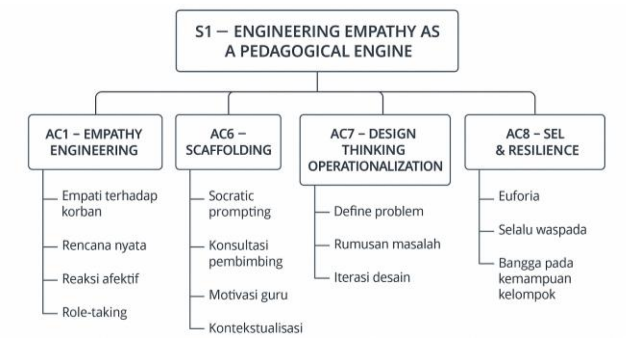

Figure 1. Hierarchy Chart AC1–AC8

The interconnectedness among the subcodes in AC1 (such as "affective reactions," "role-taking," "victims," "realistic planning") illustrates how emotional experiences became the starting point for scientific and technical reasoning. This aligns with the literature on empathy-driven design, which states that emotional engagement early in learning can increase the accuracy of problem definition and the relevance of technical solutions (Zhu et al., 2020; Lin et al., 2025).

"Eventually, that sense of empathy is what fostered their creative thinking... when they encountered an obstacle or challenge, they continued to explore—either by searching for information or asking the supervising teacher." — Guru_1/Male

3.2. Adaptive Teacher Scaffolding (AC6) as Real-Time Curriculum Engineering

Teachers served not only as facilitators, but also as adaptive curriculum designers (Serrière & Daniela, 2025). They used Socratic prompting, individual consultation, enrichment of scientific understanding, and group-dynamics management to transform empathy into design action.

"I stimulated their critical thinking again. If we start from earthquakes, not all earthquakes cause tsunamis... eventually, they searched for which earthquakes trigger tsunamis. Then I asked again, what differentiates tsunami recession from gravitational tide recession? In the end, they searched again..." — Guru_2, Female

In addition to conceptual prompting, teachers also carried out adaptive troubleshooting, namely, real-time instructional adjustments when student groups encountered technical difficulties. These improvisational actions do not appear in the written curriculum documents but emerged as responses to the complexity of IoT.

"I had to change the instructions in the middle because their device malfunctioned. But from that, they actually came to understand why prototypes must be tested repeatedly." — Guru_3, Male

These actions transformed the enacted curriculum into a more responsive learning space while maintaining student agency in the face of technical failure (Barana et al., 2017; Al-Husban & Akkari, 2021).

Table 1 summarizes the distribution of axial coding intensity across teacher and student participants. The visual Matrix Coding shows that Guru_1 and Guru_2 have significantly higher intensity on AC1 and AC2 compared to students, while Guru_3 shows a major contribution to AC4 (scientific reasoning) and AC6 (scaffolding).

Table 1. Matrix Coding for Axial Themes

	AC1	AC2	AC4	AC5	AC6	AC7	AC8
Guru_1	16	13	0	0	0	0	
Guru_2	18	13	0	0	1	0	0
Guru_3	3	2	2	1	2	0	0
SPK_1	1	1	0	0		0	
SPK_2	1	1	0	0		0	
SPK_3	1	1	0	0		0	
SPK_4	1	1	0	0		0	

These patterns confirm that teachers' adaptive strategies constitute the strongest factor linking empathy with IoT-based design processes (Wambsganss et al., 2021).

3.3. Design Thinking as Non-Linear Operationalization (AC7)

Although the curriculum document describes the stages of Design Thinking in a linear sequence, the implementation in the classroom shows that the process unfolded iteratively and circularly, following the emotional flow and reasoning of the students (Chakrabarti et al., 2025).

Table 2. Planned–Enacted–Experienced in Design Thinking

Stage	Planned	Enacted	Experienced
Empa-thize	worksheet	disaster videos, prompting	emotional reactions
Define	one definition	repeated revisions	redefinition of problem
Ideate	brain-storming	scientific prompting	integration of empathy values
Proto-type	one product	iterative	trial–error
Test	not detailed	simulation	reflection

This table shows that Define and Ideate experienced the most cycles.

"When we checked again, it turned out the problem wasn't the sensor, but the wave height. So we changed the problem statement again." — SPK-3, Female

"We went back and forth between ideation and prototyping because it kept failing." — SPK-1, Female

This reflects the non-linear nature of Design Thinking in disaster contexts, consistent with studies in humanitarian engineering (Allison & Palilonis, 2024). In addition to illustrating the iterative nature of Design Thinking, the data also show that the empathy emerging during the early stage directly influenced technical design decisions, especially regarding Inclusive Design features (Yuan & Dong, 2014). When students imagined diverse user conditions during a disaster, they began designing *multi-modal warning systems* combining sound (buzzer), light (flashing LED), and vibration. These technical decisions originated from empathic considerations for users who might be sleeping, unable to see, or unable to hear.

"I thought that if there are people who can't hear, the LED needs to be brighter and the buzzer must not be delayed." — SPK-4, Female

"... that's so there is sound, light, and also text. We wanted it to be fair, Sir. So people who are deaf or blind can also get the early warning." — SPK-3, Female

These findings strengthen the connection between Empathy Engineering and the production of more inclusive technical solutions (Afroogh et al., 2021).

3.4. Socio-Emotional Learning & Resilience as Emergent Outcomes (AC8)

The design process did not only produce technical artifacts but also significant development in socio-emotional aspects. These findings are clearly visualized in the Framework Matrix.

	Case	Planned	Enacted	Experienced
	SPK-1	Appreciate design ability	Pride in group's design skills	Pride in group's design skills
SPK	SPK-2	Always vigilant	Always vigilant	Do not panic; always vigilant
SPK	SPK-3	Unexpected outcome	Felt satisfied after success	Enjoyed creation process
SPK	SPK-4	Devoted in daily prayer	Devoted in daily prayer	Devoted in daily prayer

Figure 3. Framework Matrix — Planned/Enacted/Experienced for Each SPK

Based on the visualization, it is evident that each student demonstrated different forms of socio-emotional development. SPK-1 showed high self-efficacy, reflected in her pride toward the quality of her group's design. SPK-2 demonstrated emotion regulation, meaning she remained alert without excessive panic when facing technical challenges. SPK-3 displayed strong intrinsic motivation by enjoying the process of building the prototype and exploring design features. Meanwhile, SPK-4 expressed a form of spiritual resilience through consistent prayer and personal reflection throughout the project. These findings show that the disaster context and IoT design activities were able to evoke natural socio-emotional responses—not from direct instruction, but authentically emerging among the students (Rao et al., 2022).

3.5. Curriculum as Planned, Enacted, and Experienced

The Planned – Enacted – Experienced in Design Thinking table (see Table 2) shows a clear gap between the curriculum that was planned, the one enacted by the teacher, and the one actually experienced by students.

"The plan is only the beginning. In the classroom, we have to see what the students are like." — Guru_1, Male

"Sometimes what is planned must be changed in the field, must be adjusted..." — Guru_2, Female

Thus, the curriculum cannot be understood solely as a document, but as a living process negotiated between teachers, students, and context. In other words, the students' lived curriculum is far richer and more dynamic than the planned curriculum (Sherbine & Hara, 2020).

3.6. Student Autonomy and Agency in IoT Problem-Solving

Another important finding is the emergence of student autonomy, namely the ability of students to make technical decisions independently during the IoT design process (Wu et al., 2023). This autonomy appeared in how students performed debugging, tested prototypes, and corrected errors without waiting for teacher direction. In some groups, students even led the rhythm of teamwork, showing that agency became a natural part of the project.

"When the sensor malfunctioned, I checked the wiring myself, asked a friend, and only when stuck I went to the teacher." — SPK-3, Female

"When we were searching, we also had some difficulties... eventually we found alternatives ourselves—our creativity, you could say, Sir." — SPK-4, Female

This autonomy grew because the disaster context created a sense of moral urgency, making students feel responsible for producing accurate and safe solutions. Student agency was also strengthened by scaffolding strategies that provided room for trial–error and independent decision-making (Schwartz et al., 2021).

3.7. Integration of Themes: Empathy Drives Adaptation, Which Drives Inclusion

The selective coding results show a chain of interconnected findings:

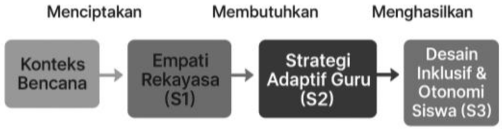

Figure 4. Selective Coding Flow

This pathway becomes a new theoretical model that explains how STEM–IoT curricula can develop social sensitivity, inclusive design capability, and emotional regulation. The model illustrates that empathy is not only a learning objective but the engine that drives the entire process (Makweya & Sepadi, 2024).

3.8. "Project Map" as Narrative Synthesis of Findings

The NVivo coding and visualizations formed a complete picture of the relationships among the themes.

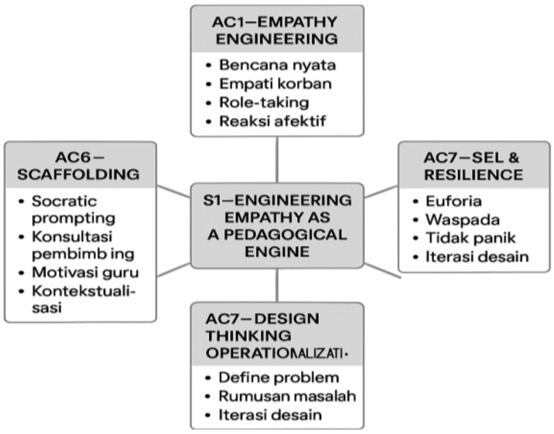

Figure 5. Causality Model of Engineering Empathy and Teacher Adaptive Strategies in the STEM–IoT Project

The Project Map shows that S1 functions as the central organizing system for the entire set of findings. Empathy Engineering (AC1) appears as the primary trigger that drives the design process, while Adaptive Scaffolding (AC6) acts as the connector that enables students to transform empathic understanding into more mature technical decisions. Design Thinking (AC7) serves as the operational mechanism that directs the flow of iteration and problem-solving, whereas Social-Emotional Learning and Resilience (AC8) become the emergent outcomes of the process. Overall, this visualization reinforces that learning does not occur linearly but operates as an interconnected and mutually influential ecosystem.

3.9. Synthesis and Implications (Short Version with Citations)

Overall, the findings indicate that Engineering Empathy operates as a cognitive driver through which students interpret disaster problems and justify inclusive design decisions, aligning with research showing that empathy shapes engineering judgment and problem framing (Walther et al., 2017; Fila & Hess, 2016). Teacher adaptive strategies were essential in converting empathic insight into technical reasoning, consistent with literature on adaptive expertise and real-time instructional decision-making (Hayden et al., 2013). Design Thinking bridged emotional engagement and iterative prototyping, supporting prior evidence that empathic iteration deepens problem-solving (Razzouk & Shute, 2012). The emergence of socio-emotional learning—including resilience, calmness, and intrinsic motivation—aligns with theories of emotionally grounded learning (Dussault, 2024). Finally, the divergence between the planned, enacted, and experienced curriculum reinforces models of curriculum-as-lived, where learning emerges from dynamic negotiation among teachers, students, and context (Martín-Alonso et al., 2021; Remillard, 2018; Burke & Lehane, 2023). These insights highlight the importance of embedding empathy-rich contexts, supporting teacher flexibility, and providing space for authentic student autonomy in STEM–IoT learning environments.

4. CONCLUSION

This study concludes that a STEM–IoT Mini Research Project grounded in Design Thinking can effectively foster Engineering Empathy, Teacher Adaptive Strategies, and Student Autonomy in junior high school learners. Engineering Empathy emerged not merely as an emotional response to disaster contexts but as a form of cognitive design reasoning that guided students to produce inclusive and multi-modal early-warning solutions. Teacher Adaptive Strategies were found to be essential in bridging students' empathic understanding with technical problem-solving, particularly through real-time troubleshooting, responsive scaffolding, and improvisational guidance. These adaptive practices enabled students to sustain engagement while navigating the complexity of IoT prototyping. Furthermore, the project nurtured strong forms of Student Autonomy as learners independently refined problem definitions, conducted iterative testing, and made design decisions grounded in empathy and moral responsibility.

The findings suggest that STEM–IoT curriculum innovation should intentionally position Engineering Empathy as a central driver of design quality, supported by systematic opportunities for teacher flexibility. For schools and curriculum developers, this implies the need to incorporate authentic, context-rich problem domains—particularly disaster mitigation—to strengthen human-centered decision-making in STEM activities. For teachers, the study highlights the importance of cultivating adaptive expertise, especially in real-time instructional troubleshooting, to maintain student agency and problem-solving ownership. For policymakers and teacher education institutions, professional development should emphasize pedagogical adaptability, iterative design facilitation, and the integration of socio-emotional learning through experiential tasks. These recommendations aim to support broader implementation of empathy-driven, inclusive, and autonomy-enhancing STEM programs in diverse educational settings.

ACKNOWLEDGMENTS

The authors express their sincere gratitude to the teachers and students of SMP IT Mentari Ilmu, Karawang, for their meaningful participation and thoughtful contributions throughout the IoT–STEM Mini Research Project. The research team also acknowledges the support of the school leadership and curriculum development unit. All interpretations and remaining errors are solely the responsibility of the authors.

REFERENCES

Afroogh, S., Esmalian, A., Donaldson, J. P., & Mostafavi, A. (2021). Empathic Design in Engineering Education and Practice: An Approach for Achieving Inclusive and Effective Community Resilience.*Sustainability*.

Allison, S., & Palilonis, J. (2024). Design Thinking and Library Practice: Inspiring Initiatives and User-Centered Services, Programs, and Physical Spaces. International Journal of Design in Society, 18(1), 107–120.

Al-Husban, N., & Akkari, A. (2021). Exploring EFL teachers' perceptions of enacted curriculum in Jordan: Towards integration curriculum development with teacher education. Curriculum and Teaching, 36(1), 71–87.

Arlinwibowo, J., Retnawati, H., Pradani, R. G., & Fatima, G. N. (2023). STEM Implementation Issues in Indonesia: Identifying the Problems Source and Its Implications. The Qualitative Report.

Badan Nasional Penanggulangan Bencana [BNPB]. (2025). Data Informasi Bencana Indonesia [Dataset DIBI]. BNPB. Retrieved April 16, 2025.

Bush, S. B., Edelen, D., Roberts, T., Maiorca, C., Ivy, J., Cook, K., Tripp, L. O., Burton, M., Alameh, S. K., Jackson, C., Mohr-Schroeder, M. J., Schroeder, D. C., McCurdy, R. P., & Cox, R. (2022). Humanistic STE(A)M instruction through empathy: leveraging design thinking to improve society.Pedagogies: An International Journal.

Burns, H. D., & Lesseig, K. (2017). Empathy in middle school engineering design process. Proceedings - Frontiers in Education Conference, FIE, 2017-October, 1–4.

Barana, A., Fioravera, M., Marchisio, M., & Rabellino, S. (2017). Adaptive Teaching Supported by ICTs to Reduce the School Failure in the Project "Scuola Dei Compiti." Proceedings - International Computer Software and Applications Conference, 1, 432–437.

Burke, P., & Lehane, P. (2023). *Conceptualising Curriculum Integration: A Synthesis of Theory, Research and Practice*.

Chakrabarti, S., Soni, S., & Kaur, P. (2025). Influence of Cognitive and Emotional Factors on Design Thinking in Engineering Education. TPM - Testing, Psychometrics, Methodology in Applied Psychology, 32(S4), 1158–1163.
da Silva, E. M., Schneider, D., Miceli, C., & Correia, A. (2025). Encouraging Sustainable Choices Through Socially Engaged Persuasive Recycling Initiatives: A Participatory Action Design Research Study. Informatics, 12(1).
Diana, N., Turmudi, & Yohannes. (2021). Analysis of teachers' difficulties in implementing STEM approach in learning: a study literature.Journal of Physics: Conference Series.
Dussault, M. (2024). Fundamental Themes in Social–Emotional Learning: A Theoretical Framework for Inclusivity. *International Journal of Environmental Research and Public Health*.
Fila, N.D., & Hess, J.L. (2016). In Their Shoes: Student Perspectives on the Connection between Empathy and Engineering.
Davis, M. H. (2023). Empathy (H. S. Friedman & C. H. B. T.-E. of M. H. (Third E. Markey (eds.); pp. 751–760). Academic Press.
Guanes, G., Wang, L., Delaine, D. A., & Dringenberg, E. (2021). Empathic approaches in engineering capstone design projects: student beliefs and reported behaviour.European Journal of Engineering Education.
Hayden, H. E., Rundell, T. D., & Smyntek-Gworek, S. (2013). Adaptive expertise: a view from the top and the ascent.*Teaching Education*.
Johnson, C. C., Peters-Burton, E. E., & Moore, T. J. (2024). Overview of The STEM Road Map Curriculum Series. In Habitats in the United States, Grade K: STEM Road Map for Elementary School (pp. 1–9).
Kakoulli, E., & Evripidou, S. (2024). Exploring the Integration of Educational Robotics and the Internet of Things in Learning Environments.
Lin, L., Dong, Y., Xingye, C., Shadiev, R., Ma, Y., & Zhang, H. (2023). Exploring the Impact of Design Thinking in Information Technology Education: An Empirical Investigation.Thinking Skills and Creativity.
Lin, H.-L., Chen, H.-C., & Tsai, M.-H. (2025). The Impact of Social and Emotional Learning Interventions on Learning Motivation, Academic Achievement, Anxiety, Misbehavior, and Well-being. Journal of Research in Education Sciences, 70(3), 167–214.
Lunn, S. J., Bell-Huff, C. L., & LeDoux, J. M. (2022). Cultivating Inclusivity: A Systematic Literature Review on Developing Empathy for Students in STEM Fields. 2022 CoNECD - Collaborative Network for Engineering and Computing Diversity.
Makweya, P. P., & Sepadi, M. D. (2024). The Crucial Role of Empathy in Fostering Inclusive Learning Environments. *Advances in Educational Technologies and Instructional Design Book Series*.
Martín-Alonso, D., Sierra, E., & Blanco, N. (2021). Relationships and tensions between the curricular program and the lived curriculum. A narrative research.*Teaching and Teacher Education*.
McCurdy, R. P., Nickels, M., & Bush, S. B. (2020). Problem-Based Design Thinking Tasks: Engaging Student Empathy in STEM. *Electronic Journal for Research in Science & Mathematics Education*.
Ong, Y. S., Koh, J., Tan, A.-L., & Ng, Y. S. (2023). Developing an Integrated STEM Classroom Observation Protocol Using the Productive Disciplinary Engagement Framework.Research in Science Education.
Penalva Tebar, J. iguel, & Nah, K. (2024). Algorithmic Framework for Design Thinking: Enhancing Innovation in Complex Problem Spaces.Design Research.
Pierson, A. (2024). STEM Curricular Adaptations as Ideological Stances. Proceedings of International Conference of the Learning Sciences, ICLS, 1135–1138.
Qin, J. (2022). On the Reform of Education Methods that Adapt to STEM Development Demand.International Journal of Education and Humanities.
Rao, V., Dzombak, R., Dogruer, D., & Agogino, A. M. (2022). Project-Based Learning in Disaster Response: Designing Solutions with Sociotechnical Complexity.*Proceedings of the Design Society*.
Razzouk, Rim, & Shute, Valerie. (2012). What Is Design Thinking and Why Is It Important? Review of Educational Research, 82(3), 330–348.
Wambsganss, T., Weber, F., & Söllner, M. (2021). Designing an Adaptive Empathy Learning Tool.
Remillard, J. T. (2018). *Mapping the Relationship Between Written and Enacted Curriculum: Examining Teachers' Decision Making*.

Sampurno, P. J., Sari, Y. A., & Wijaya, A. D. (2015). Integrating STEM (Science, Technology, Engineering, Mathematics) and Disaster (STEM-D) Education for Building Students' Disaster Literacy.The International Journal of Learning.

Schwartz, L., Adler, I., Madjar, N., & Zion, M. (2021). Rising to the Challenge: The Effect of Individual and Social Metacognitive Scaffolds on Students' Expressions of Autonomy and Competence Throughout an Inquiry Process. *Journal of Science Education and Technology*.

Serrière, F., & Daniela, L. (2025). A Systematic Review of K-12 Teachers' Adaptive Expertise Development. Bordon. Revista de Pedagogia, 77(3), 77–107.

Shahidullah, K., & Hossain, Md. R. (2022). Designing an Integrated Undergraduate Disaster STEM Curriculum: A Cultural Shift in Higher Education Curriculum Development in Bangladesh.Journal of Ethnic and Cultural Studies.

Sheehy, K., Vackova, P., van Manen, S., Saragih Turnip, S., Rofiah, K., & Twiner, A. (2024). Inclusive disaster risk reduction education for Indonesian children. International Journal of Inclusive Education, 28(11), 2529–2545.

Sherbine, K., & Hara, M. (2020). The curriculum-as-plan as the refrain. *Journal of Curriculum and Pedagogy*.

Stoev, P., & Stoeva, M. (2024). Building Empathy in Students by Developing Cyber-Physical Projects Through Design Thinking. Journal of Physics: Conference Series, 2701(1), 12041.

Walther, J., Miller, S., & Sochacka, N. (2017). A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being: A Model of Empathy in Engineering. Journal of Engineering Education, 106, 123–148.

Wu, T.-N., Chin, K.-Y., & Yeh, S.-T. (2023). *Developing a visual IoT environment analysis system to support self-directed learning of students*.

Yuan, S., & Dong, H. (2014). *Empathy Building through Co-design*.

Zhu, G., et al. (2020). Emotional and cognitive affordances of collaborative learning environments. Computer-Supported Collaborative Learning Conference, CSCL, 1, 382–389.