Validating a Design Thinking Learning Model for Developing IoT Projects through Expert Evaluation

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ABSTRACT

The Internet of Things (IoT) connects sensors, embedded devices, and digital platforms to enable intelligent interactions between people and their environments. Engaging students in IoT projects exposes them to authentic challenges where programming, data analysis, and system design converge. However, many educators struggle to guide learners from design to functional prototypes. The absence of validated pedagogical models that link creative ideation with technical implementation continues to limit the effectiveness of IoT education. This study proposes an initial validated learning model for developing Internet of Things (IoT) projects through a Design Thinking (DT) approach. The model integrates DT principles with the Initiator-Before-In-After (IBIA) teaching sequence and the Flex blended-learning structure. Expert judgment was used to validate the class activities for both lecturers and students based on the proposed conceptual model for developing IoT Projects through DT approach. Six experts specialising in DT, learning innovation, and IoT education evaluated the model using the Content Validity Index (CVI) and the Content Validity Ratio (CVR), complemented by qualitative feedback. Quantitative analysis determined the model's content validity, while thematic interpretation of expert comments informed refinements to strengthen instructional relevance.

Keywords: Design Thinking, Internet of Things (IoT), Expert evaluation, Blended learning, Content validity

INTRODUCTION

Digital transformation is reshaping the ways people learn, work, and interact within society. The growing presence of artificial intelligence, the Internet of Things (IoT), and data-driven systems requires graduates who are capable of thinking critically, designing creatively, and acting responsibly within complex technological environments. These attributes, often described as essential future skills for a digital society, combine technical fluency with creativity, ethical understanding, and social adaptability (OECD, 2023; Vuorikari et al., 2022). In this context, universities are expected to design learning environments that connect disciplinary knowledge with authentic technological practice. One emerging direction is the use of Flex Learning, which blends asynchronous online study with interactive face-to-face engagement. This model allows students to prepare before class through online materials, collaborate during in-class sessions, and consolidate their understanding through reflection and post-activity review.

Design Thinking (DT) has become a central pedagogical approach for cultivating these future-ready capabilities. It encourages empathy, experimentation, and reflection through iterative problem solving that can be applied across both digital and physical learning spaces. The philosophy behind DT is rooted in experiential and constructivist learning theories, where students are viewed as active creators of knowledge rather than passive receivers (Kolb, 2015; Razzouk & Shute, 2012). In a blended learning setting, online modules can support conceptual exploration and background research, while classroom sessions provide opportunities for hands-on prototyping and collaborative feedback. This combination promotes continuous engagement, allowing learners to connect theory with practice and strengthen their sense of agency. Despite its pedagogical strengths, studies that systematically integrate and validate DT within IoT-based project learning remain limited (Nordin et al., 2024; Zainal et al., 2021).

The Internet of Things connects sensors, embedded devices, and digital platforms to create intelligent interaction between humans and their environments (Guerra-Manzanares & Bahsi, 2023; Corpuz, Cruz, Palomar, Tamayo, Bongao, Enojas & Morgado, 2025). When students learn through IoT projects, they engage with authentic design challenges that merge programming, data analytics, and systems thinking. A flexible learning structure supports these activities: asynchronous modules introduce technical foundations and coding tutorials, while face-to-face sessions enable collaborative troubleshooting and prototype development. Such arrangements help learners cultivate problem-solving ability, computational reasoning, and design literacy (Liebkemann, 2021; McCormack, 2021). However, educators often face challenges in guiding students from conceptual ideas to working prototypes. The absence of validated teaching models that link creative ideation with technical implementation continues to limit learning outcomes (Henriksen et al., 2021; OECD, 2023)

Malaysia and other ASEAN countries are shifting from a focus on Fourth Industrial Revolution skills toward cultivating broader future-oriented digital and innovation competencies. National initiatives such as the Malaysia Digital Education Policy (2023), the Malaysia Education Blueprint 2013-2025 and UNESCO's Digital Learning Compass (2023) emphasize quality education, creativity, digital literacy, and ethical engagement in technology-enhanced learning. These initiatives highlight the need for teaching models that integrate both conceptual understanding and technological practice within flexible, blended environments. Universities are therefore encouraged to adopt learning structures that combine self-directed online engagement with collaborative classroom experiences to develop well-rounded, innovative graduates.

The present study responds to this educational demand by validating a structured model for IoT project development using a DT framework for blended learning. The proposed model aligns the three principal DT phases (Inspiration, Ideation, and Implementation) with the Initiator-Before-In-After (IBIA) teaching sequence to ensure continuity between online preparation, classroom collaboration, and post-activity reflection. Expert judgment is used to assess the clarity and relevance of each component using the Content Validity Index (CVI) supported by qualitative evaluation. Through this validation process, the model is refined to ensure alignment with pedagogical objectives and professional practice. The outcome contributes to an evidence-based framework that supports creativity, empathy, collaboration, and technological fluency as key components of future-oriented learning in a digital society.

Related Works

Design Thinking In Teaching and Learning

Design Thinking (DT) is a human-centered approach to problem-solving that emphasizes creativity, empathy, and iterative prototyping. It integrates the way designers think and work into other disciplines to generate innovative solutions to complex problems. DT approach was then popularized and systematized by David Kelley, Tim Brown, and their team at IDEO, a global design and innovation consultancy. They applied Design Thinking in business, engineering, and education contexts, making it widely known as a structured process involving stages such as empathize, define, ideate, prototype, and test (Laverty & Littel, 2022). Now, DT has gained wide recognition as a framework for fostering innovation, creativity, and problem-solving in education (Baran & AlZoubi, 2024). It promotes learner-centred exploration through empathy, ideation, and prototyping, which correspond to higher-order cognitive processes in Bloom's taxonomy (Razzouk & Shute, 2012). Research has shown that DT enables students to approach complex and ambiguous problems while developing collaboration and metacognitive reflection (Henriksen et al., 2021). Figure 1 shows the basic phases of DT.

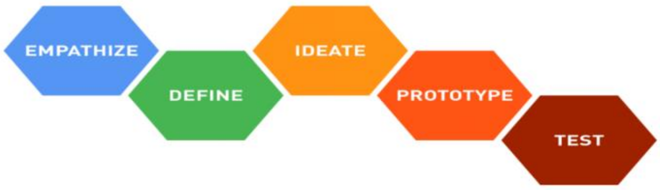

Figure 1: Basic Phases of Design Thingking (Brown, 2008)

In teaching and learning environments, DT bridges the gap between abstract theoretical knowledge and practical application. Studies in engineering, design, and computer science indicate that DT-driven activities enhance students' ability to transfer knowledge across contexts and improve engagement through experiential learning (Wrigley & Straker, 2015).Moreover, Panke (2019) highlighted that DT fosters ethical reasoning and digital citizenship, especially when learners engage in projects involving emerging technologies such as artificial intelligence and the Internet of Things. By placing learners at the centre of problem exploration, DT develops critical dispositions for adaptive expertise, aligning well with 21st-century competencies.

Despite its increasing adoption, the instructional design of DT courses often lacks systematic validation. Many reported applications focus on classroom implementation without evaluating the internal consistency or theoretical alignment of DT stages with measurable outcomes (Jiang & Pang, 2023; Zainal et al., 2021). Consequently, rigorous validation studies are necessary to ensure that DT frameworks remain credible tools for educational innovation.

IoT Project-Based Learning

The Internet of Things (IoT) represents a transformative domain within computing and engineering education, connecting devices, data, and human interactions. IoT-oriented learning requires students to integrate hardware programming, data communication, and system design, which aligns naturally with project-based learning (PBL) principles(Atlam & Wills, 2018; Iqbal, 2023). PBL provides a context in which learners can construct knowledge through authentic challenges, designing prototypes that collect and analyse real-time data (Rodriguez-Sanchez et al., 2024).

Empirical studies indicate that IoT-based PBL enhances both technical and cognitive outcomes. Akiyama and Cunningham (2018) found that students who engaged in self-directed IoT prototype development demonstrated stronger conceptual mastery and collaborative problem-solving skills. Similarly, Purba and Zunidar (2025) reported that IoT projects promote computational thinking and the integration of abstract programming concepts with tangible systems. Yet, educators often struggle to balance creative autonomy with structured guidance, resulting in variable learning quality and incomplete project execution (Trishaank et al., 2024).

Integrating Design Thinking principles within IoT project work provides a structured pathway to balance creativity with analytical rigour. The iterative DT cycle of empathise, define, ideate, prototype, and test offers an adaptable scaffold. Thus, supports problem identification, ideation, and iterative refinement. Early research by Zainal et al. (2021) and Choi et al. (2024) suggests that DT-IoT integration promotes motivation and innovation in students. However, these studies remain exploratory and lack systematic validation through expert evaluation. The empirical validation of the instructional activities, especially through expert review, has not been systematically addressed..

Expert Validation in Model Development

The expert validation is an established procedure for verifying the clarity, relevance, and construct validity of educational models. It provides empirical assurance that a proposed framework accurately represents its theoretical basis and intended learning outcomes. The Content Validity Index (CVI) and Content Validity Ratio (CVR), introduced by Lynn (1986) and refined by Polit and Beck (2006), are among the most widely used quantitative measures for such validation. These tools quantify the degree of expert consensus regarding item relevance, ensuring methodological transparency and content integrity.

Several studies illustrate the significance of expert validation in technology-enhanced education. Juan et al. (2025) validated a competency model for entrepreneurship education using expert panels, achieving strong agreement levels. Likewise, Pueyo-Garrigues et al. (2021) used expert validation to adapt a professional knowledge questionnaire in healthcare education, demonstrating improved reliability. These examples underscore that systematic validation enhances both the credibility and pedagogical value of instructional frameworks. However, only a few researchers within the field of design-based learning have applied structured validation methods to the instructional process itself. Most DT or IoT frameworks are reported descriptively, with minimal statistical confirmation of content validity. Incorporating expert evaluation grounded in CVI and

CVR analysis provides an evidence-based pathway to strengthen educational design research. The present study contributes to this methodological advancement by employing both quantitative indices and qualitative feedback to validate a set of structured activities that merge DT and IoT project-based learning

Conceptual Model

Theoretical Foundation

The conceptual model proposed in this study is grounded in two complementary learning theories: constructivism and experiential learning. Together, they provide the philosophical rationale for linking knowledge construction, reflection, and ethical technological practice in IoT project or prototype development.

Constructivism emphasises that learners actively build understanding through engagement with authentic contexts rather than absorbing information passively. Learning emerges through collaboration, negotiation, and adaptation of prior knowledge information (Piaget & Duckworth, 1970; Vygotsky, 1978). Kolb (2015). The experiential-learning cycle expands this idea by describing how experience, reflection, conceptualisation, and experimentation operate as a continuous process. Within IoT projects, students generate and refine ideas by testing prototypes and reflecting on performance, thereby transforming hands-on experience into knowledge.

Besides constructivism and experiential learning learning theories, DT operationalises these theories by providing a structured process of empathising with users, defining problems, ideating, prototyping, and testing. Each stage engages students in active experimentation and reflective analysis, turning abstract theory into practical competence (Henriksen et al., 2021; OECD, 2023). Moreover, the integration of human-centred design adds an ethical and social dimension, ensuring that technological innovation serves real human needs and promotes sustainability values (Brown & Wyatt, 2015). Within this theoretical convergence, learners acquire not only technical proficiency but also empathy, creativity, and reflective judgement. These qualities are essential for a future-oriented digital society, ensuring relevance to contemporary educational priorities.

The Initiator-Before-In-After (IBIA) teaching strategy provides a structured sequence that reinforces reflection and continuity throughout the DT process. It ensures that learning moves logically from preparation to practice and then to consolidation. Within the proposed model, IBIA functions as the pedagogical rhythm that anchors student activities within each DT phase. The Initiator stage introduces authentic IoT contexts that spark curiosity and situate learning in real-world relevance. Educators present short case examples or demonstration problems that connect classroom concepts to community or industry needs. During the Before stage, students acquire prerequisite knowledge through brief lectures, online modules, or guided readings. This stage prepares learners conceptually for the design tasks that follow. The In stage encompasses the main Design Thinking activities, including problem analysis, ideation, prototyping, and testing. Students apply theoretical knowledge in collaborative settings and receive formative feedback. The final After stage emphasises reflection, peer evaluation, and revision of both artefacts and processes, transforming experience into deeper understanding. The cyclic nature of IBIA aligns with Kolb's experiential-learning model, allowing repeated movement between action and reflection. It also reduces cognitive overload by alternating structured input with exploratory practice. Within IoT education, IBIA supports balanced engagement, ensuring that creativity is grounded in conceptual understanding and that learning outcomes remain measurable and transferable.

Blended learning is an educational approach that combines traditional classroom instruction with online learning experiences. It integrates face-to-face teaching, online collaborative activities, and self-paced learning to create a flexible and personalized learning environment. This approach aims to leverage the strengths of both in-person and digital learning methods to improve student engagement and outcomes Flex model is a type of blended learning where content is delivered primarily online, but a teacher is available on-site to provide support as needed. The model combines online self-paced learning with in-person support. Students have control over their learning pace and schedule (Sukumaran, 2018). The model includes collaborative learning and personalized interventions as shown in Figure 2.

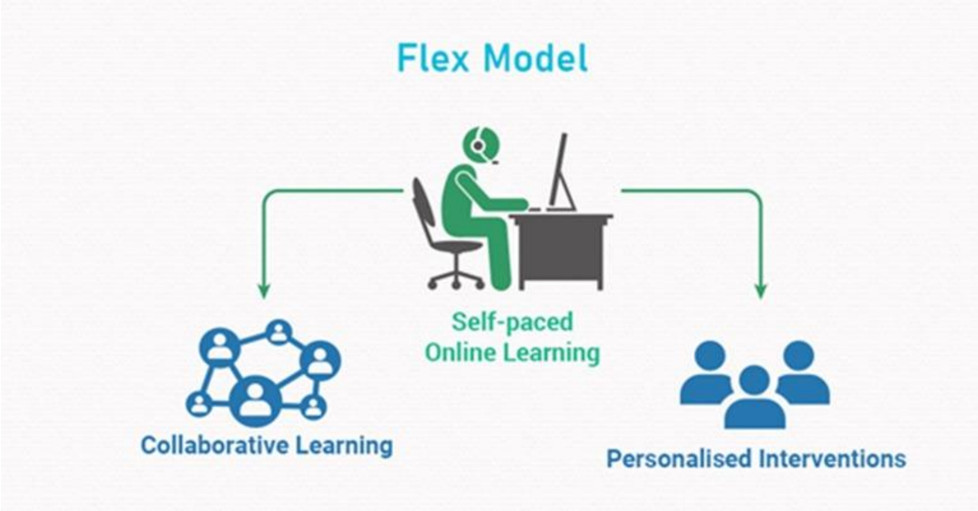

Figure 2: Flex model of blended learning (Sukumaran, 2018)

The key components of the Flex model, as shown in the diagram are:

Self-paced Online Learning: This is the "backbone" of the Flex model where students primarily engage with digital learning materials and activities at their own pace in a physical classroom or on campus. This allows advanced students to move ahead and struggling students to take more time as needed.

Collaborative Learning: While most instruction is online, teachers facilitate group projects, discussions, and other collaborative activities. This helps students develop social and interpersonal skills.

Personalised Interventions: The teacher-of-record is on-site to provide face-to-face support on an as-needed basis. This can include small-group instruction, individual tutoring, and guidance to help students who are struggling or need help. The teacher acts as a mentor and guide rather than the primary deliverer of content

The Flex model of blended learning provides the delivery framework that supports the DT and IBIA processes. In this structure, online components deliver fundamental knowledge such as IoT architecture, sensor programming, or design-thinking theory through asynchronous learning modules. Classroom sessions are reserved for collaborative experimentation, prototype construction, and consultation with instructors. This arrangement aligns with principles of self-regulated learning, allowing students to study theoretical materials at their own pace while using face-to-face time for higher-order application (Garcia Moreno, 2024; Horn & Staker, 2014). The approach also accommodates diverse learning preferences and provides accessibility for students who may face time or location constraints.

By combining flexibility with structured guidance, the model ensures continuity between digital and physical learning spaces. It positions the instructor as a mentor who facilitates inquiry, monitors progress, and provides formative feedback through both online and offline platforms. The Flex blended-learning architecture provides the environmental structure that supports both the DT cycle and the IBIA teaching sequence. It combines online and face-to-face modalities to create a continuous learning experience that connects conceptual understanding with hands-on application. Within this arrangement, digital modules deliver foundational knowledge asynchronously, while classroom time is devoted to collaboration, prototype development, and consultation.

Online components include multimedia lessons, coding simulations, and formative quizzes that allow students to learn at their own pace and revisit complex topics as needed. The physical classroom serves as a collaborative workshop where students test ideas, assemble hardware, and interact with instructors for immediate feedback. This dual structure enables differentiated learning paths and promotes self-regulation, two principles central to learner autonomy (Horn & Staker, 2014).

Research in blended education indicates that flexibility improves engagement and knowledge retention when supported by mentoring and feedback loops (Garcia Moreno, 2024). In the proposed model, the instructor acts

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as a facilitator who monitors student progress across both digital and physical environments. The Flex approach therefore, strengthens the alignment between individual learning, teamwork, and reflective practice. It also enhances accessibility, enabling students to manage their own learning schedules while maintaining structured guidance within the project life cycle. Table 1 shows the roles and learning activities within the Flex Model.

Table 1: Roles and Learning Activities within the Flex Model

Environment	Lecturer Role	Student Activities	Learning Focus
Classroom (face-to-face)	Facilitator and mentor	Prototype, collaborate, receive feedback	Application, teamwork, reflection
Online (asynchronous)	Content curator and monitor	Study tutorials, complete coding tasks, and discuss in forums	Conceptual understanding and preparation

Conceptual validation logic and synthesis

The conceptual model integrates theory, pedagogy, and delivery in a structure designed for both teaching application and empirical validation. Because instructional models represent theoretical propositions about how learning occurs, they require systematic testing to confirm coherence and relevance. The present framework is therefore constructed with explicit mechanisms for validation through expert judgement. Quantitative and qualitative evaluation provides evidence that the model's components are pedagogically sound and practically feasible.

The validation process follows the principles of design-based research, where theory development and empirical testing evolve iteratively. The Content Validity Index (CVI) and Content Validity Ratio (CVR) are applied to measure expert consensus on the relevance, clarity, and appropriateness of each activity (Elangovan & Sundaravel, 2021; Polit & Beck, 2006). Expert commentary further contextualises these scores, allowing refinement of the learning steps and ensuring alignment with constructivist and experiential principles. Validation thus operates as both methodological verification and theoretical refinement, confirming that the framework functions as an evidence-based pedagogical design.

In synthesis, the model establishes a pathway from theoretical foundations to practical implementation. Constructivism and experiential learning define the epistemological base, DT structures the learning process, IBIA provides pedagogical rhythm, and the Flex model delivers an adaptive environment. Together, they form a cohesive framework that supports creativity, technical competence, and reflective digital citizenship as the key attributes of learners in the evolving digital society.

Figure 3 shows the conceptual model for developing IoT projects through the DT approach. The model integrates DT principles with the Initiator-Before-In-After (IBIA) teaching sequence and the Flex blended-learning structure. Anchored in the principles of DT, Flex, and IBIA instructional strategies, the model seeks to cultivate essential 21st-century competencies among students, including creativity, collaboration, technological fluency in IoT, and ethical awareness. These outcomes align with the goal of nurturing learners who are innovative, adaptable, and ethically responsible in a technology-driven environment.

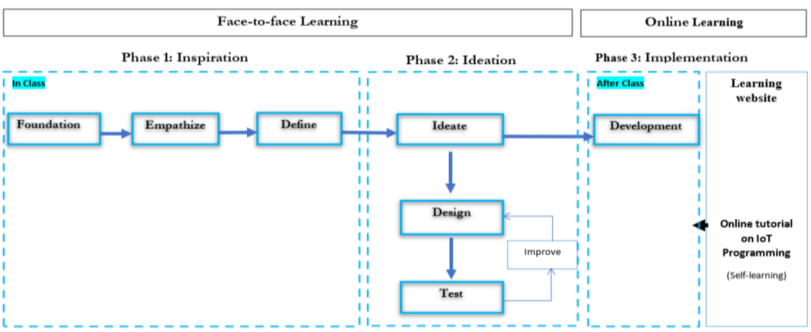

Figure 3: Conceptual Model for Developing IoT Projects Through DT Approach

METHODOLOGY

Research Design

This study employed a design-based initial validation approach to examine the pedagogical soundness and clarity of the proposed framework implemented within a Flex Learning environment. Design-based research is suitable for developing and refining instructional models because it integrates empirical evidence with theoretical reasoning in iterative cycles of improvement (McKenney & Reeves, 2018). In this study, validation combined quantitative techniques, including the Content Validity Index (CVI) and the Content Validity Ratio (CVR), with qualitative expert feedback to ensure both theoretical alignment and practical relevance.

The procedure comprised three sequential stages. First, a validation instrument was developed directly from the conceptual model. Second, six domain experts independently reviewed the learning components and rated their relevance, clarity, and feasibility. Third, the quantitative and qualitative data were synthesised to refine the framework for instructional application. This structured process ensured that the framework was not only conceptually coherent but also feasible for classroom use.

Paticipants

Six experts were selected using purposive sampling, following established guidelines for content-validation research (Lynn, 1986; Polit & Beck, 2006). Three experts specialised in Design Thinking and educational innovation, while three represented IoT and computing education. All participants held postgraduate qualifications and had at least five years of relevant academic or professional experience. Expert selection was based on three criteria: disciplinary expertise in Design Thinking or IoT, familiarity with project-based or blended learning environments, and willingness to provide detailed feedback. This balanced composition of pedagogical and technical experts ensured that the evaluation addressed both educational design and technological integration, enhancing the comprehensiveness of the validation outcomes.

Research Instrument

The validation instrument was designed to evaluate each activity and sub-phase of the conceptual model. It consisted of structured items rated on a five-point Likert scale, where 1 indicated “not relevant,” 2 “somewhat relevant,” 3 “moderately relevant,” 4 “very relevant,” and 5 “highly relevant.” Open-ended questions were also included to capture qualitative comments and improvement suggestions. Items were grouped according to two dimensions: the three Design Thinking phases (Inspiration, Ideation, and Implementation) and the IBIA teaching sequence (Initiator, Before, In, and After). This arrangement enabled precise identification of strong and weak components within each learning phase. The instrument was pilot-reviewed by two independent educators to confirm clarity and alignment before distribution to the expert panel. Appendix A shows the instrument which consists of the activities in a design thinking learning model for developing IoT Projects.

Data Collection

Data were collected electronically to enable participation from geographically dispersed experts. Each expert received an information sheet, consent form, and a digital version of the conceptual model and rating instrument. Participants were given two weeks to complete the review and return their responses via a secure online form. Follow-up correspondence clarified any uncertainties and ensured consistency across interpretations. Quantitative ratings were entered into a spreadsheet for CVI and CVR computation, while qualitative comments were imported into NVivo for thematic analysis. Combining both data types supported triangulation between numerical validity measures and interpretive feedback, thereby strengthening the study’s reliability.

Data Analysis

The analysis involved both quantitative and qualitative components. For quantitative evaluation, the Item-Level CVI (I-CVI) was calculated as the proportion of experts assigning a rating of 4 or 5 to each item. The Scale-Level CVI (S-CVI/Ave) was obtained by averaging all I-CVI values, while the S-CVI/UA measured the proportion of items that achieved universal agreement. Thresholds of 0.78 for I-CVI and 0.90 for S-CVI/Ave were used as indicators of acceptable content validity (Polit & Beck, 2006).

The CVR was calculated using Lawshe (1975) formula, with 0.78 as the minimum acceptable value for a panel of six experts. Qualitative data were analysed thematically, focusing on three aspects: conceptual clarity, pedagogical relevance, and practicality. Expert suggestions were reviewed to identify areas of improvement and to refine the model for instructional implementation. The integration of statistical and thematic evidence allowed for a balanced interpretation of the model's strengths and limitations.

RESULTS

Expert Profiles

Six experts representing the domains of design-thinking pedagogy, learning innovation, IoT engineering, and computing education participated in the review. Each expert independently evaluated fourteen activities that composed the model. Quantitative ratings and qualitative reflections were gathered to examine both the internal consistency and the contextual practicality of the framework. The procedure followed the principles of design-based research, in which knowledge is refined through iterative cycles of analysis and reflection (McKenney & Reeves, 2018). Two-thirds of the experts have the highest academic qualification in their field. This suggests a high level of expertise, research experience, and academic achievement among the group. The expert group comprises two-thirds academicians and one-third consultants. The majority of the experts come from academic institutions (e.g., universities, research centers), while the rest work in a consulting or professional services role. This is important since in decision-making, project validation, or research, this kind of expert mix shows a balance between theory and practice, but with a stronger academic influence. Most of the insights, opinions, or contributions may be shaped by research, theory, and teaching experience. Academicians typically bring deep subject knowledge, long-term research focus, and an understanding of emerging trends. Practical industry input is present means there's still a strong representation of practical, real-world, or industry-focused experience. The team has a balanced expertise from DT also from IoT with an average working experience of 10 years. The panel of experts, each with an average of 10 years of professional experience, provided well-informed insights based on both theoretical understanding and practical application. They have a high level of experience, suggesting that they have had enough time to develop deep expertise, handle complex problems, and gain a solid understanding of their industry or field. They can provide the reliability and maturity in judgment. Their opinions, decisions, or contributions are likely to be informed by practical experience, not just theory. With 10 years of experience, these experts are likely in a phase where they combine updated knowledge with practical insight, making their input especially valuable. The profiles of the experts are as described in Table 2.

Table 2: Experts Profile

Id	Highest Qualification	Position	Field Of Expertise	Working **Experience (Years)**
Expert 1	Doctor of Philosophy	Academician	DT	15
Expert 2	Doctor of Philosophy	Academician	DT	10
Expert 3	Doctor of Philosophy	Consultant	DT	7
Expert 4	Bachelor Degree	Consultant	IoT	14
Expert 5	Bachelor Degree	Academician	IoT	8
Expert 6	Doctor of Philosophy	Academician	IoT	8

Quantitative Validation Results

All fourteen items achieved strong ratings from the expert panel. The Scale-Level Content Validity Index (S-CVI/Ave) was 0.96, exceeding the accepted benchmark of 0.90 for educational model validation. The Scale-Level Universal Agreement (S-CVI/UA) reached 0.83, indicating substantial agreement among the experts.

Individual Item-Level CVI (I-CVI) values ranged from 0.83 to 1.00, confirming that every item met or surpassed the 0.78 threshold for acceptable content validity (Polit & Beck, 2006).

The Ideation and Implementation phases received the highest consistency scores, reflecting experts' confidence in their instructional clarity and feasibility. Slightly lower but still satisfactory ratings were observed in the Inspiration phase, particularly for empathy and contextual exploration activities. These variations were considered a sign of critical engagement rather than disagreement, showing that experts evaluated the activities thoughtfully within their own disciplinary perspectives. Table 3 shows the overall quantitative results.

Table 3: The Overall Quantitative Results

Index	Value	Interpretation With Six Experts
Number of items	14	Full scale assessed
S-CVI/Ave	0.96	Excellent overall content validity
S-CVI/UA	0.83	Good universal agreement; a few items invite revision
I-CVI (range)	≥ 0.83 (reported across items)	All items above common 0.78 cut-off for n=6

The statistical results verify that the structural components and descriptions within the framework were clearly defined and pedagogically coherent. The slight dispersion of scores across phases indicates productive professional judgment rather than error, showing that experts considered the contextual nuances of each activity. Overall, the quantitative findings confirm that the model's structure is internally consistent and conceptually robust.

Qualitative experts Results

While the numerical indices established statistical validity, the accompanying qualitative feedback revealed the specific pedagogical dimensions requiring refinement. Experts' comments are presented verbatim and grouped according to the relevant DT phase.

Inspiration Phase

Experts unanimously agreed on the value of beginning the process with empathy-based problem discovery but encouraged richer contextual examples to support learners' understanding.

"Expose students to more real-life context. Add more examples of projects that have clear problems and the project's application." (Expert 5)

"More examples to grasp the programming concept and the application of IoT." (Expert 3)

These remarks emphasise the importance of authentic contexts as catalysts for engagement and conceptual transfer. Consequently, two concise case exemplars one technical and one social were proposed to precede empathy-mapping activities.

Ideation Phase

Several reviewers highlighted time allocation and tool flexibility as areas for improvement.

"Add more time. Can use mind map as a tool." (Expert 3)

"If possible, not to fix with flash cards or storyboard only for prototype." (Expert 3)

Such comments underscored the need for varied creative tools to accommodate different cognitive styles. Extending the ideation window and introducing alternative brainstorming methods were thus recommended.

Panel members discussed the inclusivity of idea selection and the importance of specifying target users.

"The selection could be done once all members presented their ideas. Thus, everybody could have the opportunity to share the projects." (panel remark)

"Be clear who is actually the end-user?" (Expert 1)

"Student may present about the motivation for having the solution, marketability of the solution, idea validation etc." (Expert 5)

These comments reveal the necessity of ensuring democratic participation and explicit user orientation within team projects. A structured idea-pitch session with a common evaluation rubric was suggested to address these concerns.

Implementation Phase

Feedback for the final phase focused on ensuring hands-on data practice and full exposure to IoT workflows.

"The student could be given an opportunity to deploy the sensors, connect to the cloud, collect the data for few days and analyse it." (Expert 5)

This observation led to the inclusion of a short deployment and analysis sprint, allowing students to experience data collection, interpretation, and ethical considerations in a real operational setting.

Based on the experts' feedback, we developed the themes and suggested refinement as shown in Table 4.

Table 4: Expert Feedback Themes and Resulting Refinements

Theme	Representative Expert Quote	Refinement Implemented In Model
Real-world anchoring	"Expose students to more real-life context. Add more examples …" (Expert 5)	Incorporate two domain-specific exemplars and a one-page context brief before empathy tasks.
Conceptual scaffolds for ideation	"Add more time. Can use mind map as a tool." (Expert 3)	Extend ideation period and allow multiple creative-thinking tools.
Prototype flexibility	"If possible, not to fix with flash cards …" (Expert 3)	Permit paper, digital, or hybrid low-fidelity prototypes prior to hardware build.
Inclusive idea selection	"The selection could be done once all members presented …" (Expert 2)	Require every member to pitch ideas; apply rubric assessing novelty, feasibility, and user value.
User clarity and value proposition	"Be clear who is actually the end-user?" (Expert 1); "motivation … marketability …" (Expert 5)	Add user–problem–value template and desirability-feasibility-viability checkpoint.
Full data lifecycle experience	"Deploy the sensors … collect the data …" (Expert 5)	Introduce a three-day data-collection sprint with ethics reflection and basic analytics.

The qualitative dataset provided detailed insights into the pedagogical realism of the model. Each quotation represented a distinct category of improvement, collectively ensuring that the revised model remains grounded in authentic learning experiences and adaptable to classroom realities.

DISCUSSION

The combination of quantitative and qualitative findings demonstrates that the initial proposed model achieved high reliability and relevance. Statistical indices confirmed strong agreement among experts regarding content validity, while qualitative remarks pinpointed specific instructional enhancements. The collective results verify that the model's theoretical foundations are supported by expert consensus and that its pedagogical features are clearly defined and applicable. These results form the empirical basis for the interpretive discussion presented in the following section.

Interpreting the Validation Results

The validation results confirmed that the Design Thinking–IoT framework developed in this study demonstrates strong content validity and pedagogical coherence. Quantitative indices, including the high Scale-Level Content Validity Index (S-CVI/Ave = 0.96) and strong Content Validity Ratio (CVR = 0.89), indicate that the framework's activities are clearly defined, relevant, and feasible for classroom use. These results are consistent with validation benchmarks reported in educational design research (Elangovan & Sundaravel, 2021; Polit & Beck, 2006). The experts' qualitative feedback further reinforced these findings by highlighting the framework's authenticity, practicality, and adaptability to real-world learning contexts.

The integration of expert critique into the refinement process enhanced the model's pedagogical integrity. Suggestions such as incorporating contextual case examples, extending ideation time, and including a short IoT deployment exercise improved the framework's capacity to balance conceptual understanding with hands-on experimentation. This alignment between quantitative precision and qualitative insight exemplifies the strength of design-based research, which emphasises iterative validation through evidence and reflection (McKenney & Reeves, 2018).

Furthermore, the high level of expert agreement across both pedagogical and technical domains suggests that the framework succeeds in bridging cognitive and applied dimensions of learning. Similar findings have been reported by Henriksen et al. (2021), who observed that DT structures enhance integration between creativity, collaboration, and technical problem solving. In this study, the experts' endorsement indicates that the model's phases of Inspiration, Ideation, and Implementation effectively translate theoretical constructs into practical learning experiences. The framework's blend of flexibility and structure also resonates with findings from blended-learning research showing that adaptable learning environments support deeper engagement and reflective learning (Boelens et al., 2017; Graham, 2006).

Overall, the validation outcomes support the model's readiness for implementation and empirical testing in IoT-based classrooms. The consistency of results across both statistical and interpretive domains provides strong evidence that the framework is both pedagogically grounded and contextually relevant.

Constructivism and Social Mediation

The framework's effectiveness can be understood through the lens of constructivist learning theory, which posits that knowledge is actively constructed through interaction, collaboration, and contextual problem solving (Piaget & Duckworth, 1970; Vygotsky, 1978). The activities embedded in the conceptual model, particularly during the Inspiration and Ideation phases, encourage learners to build understanding collectively rather than absorb information passively. These processes exemplify social constructivism, where meaning emerges through dialogue, negotiation, and shared experience (Reigeluth, 2013).

The experts' recommendation to introduce richer contextual examples aligns closely with constructivist principles. Providing real-world cases encourages learners to link new information with prior experience, promoting cognitive scaffolding and meaningful knowledge construction (Bruner, 1997). The inclusion of group-based ideation and prototype evaluation also supports Vygotsky's concept of the zone of proximal development, where learners progress through guided participation and peer interaction.

By integrating collaborative inquiry within IoT project tasks, the model transforms technical skill development into a socially mediated learning process. Learners not only acquire coding or engineering competence but also develop communicative and metacognitive skills through group reflection. This dynamic aligns with current educational discourse emphasising collaborative intelligence as a key 21st-century competency (OECD, 2023). The constructivist grounding of the model thus reinforces its relevance for developing both disciplinary expertise and interpersonal competence.

Experiential Learning and Iterative Reflection

Experiential learning provides another key interpretive lens for understanding the validated framework. Kolb (2015) conceptualised learning as a continuous cycle of concrete experience, reflective observation, abstract conceptualisation, and active experimentation. Each component of the Design Thinking–IoT model corresponds to one of these stages. The Inspiration phase generates experience through problem exploration; Ideation stimulates abstract conceptualisation; Implementation encourages experimentation and testing; and the After phase within the IBIA sequence facilitates reflection and synthesis.

Experts' suggestions to allow students to deploy IoT sensors and analyse real data directly support this experiential cycle. Such activities promote the translation of conceptual learning into embodied understanding, reinforcing the iterative relationship between doing and thinking. As Wilson and Beard (2013) noted, learning through experience gains meaning when reflection transforms action into insight. The newly integrated short deployment exercise addresses this need by enabling learners to connect the sensory, cognitive, and ethical dimensions of IoT applications.

The iterative structure of the framework also aligns with design-based learning approaches, where experimentation and revision are central to knowledge formation (Razzouk & Shute, 2012). By guiding learners through repeated cycles of testing and feedback, the model cultivates adaptability and resilience which are qualities identified by Di Battista et al. (2023) as critical for future-ready graduates. This dynamic process converts the classroom into a laboratory of reflection, where students refine both their products and their thinking.

Furthermore, the IBIA teaching sequence operationalises experiential learning within the blended environment. The Before stage supports preparation and concept familiarisation, the In stage anchors experiential engagement, and the After stage facilitates reflective documentation. Together, these stages embody Kolb's assertion that experience becomes learning only when acted upon reflectively. Through this alignment, the framework integrates active experimentation with reflective observation, producing a balanced cycle of action and thought.

Human-Centred Design, Ethics, and Societal Responsibility

Human-centred design (HCD) serves as the ethical foundation of the validated framework, ensuring that technological innovation remains aligned with human and societal needs. Brown and Wyatt (2015) argued that design processes grounded in empathy and responsibility foster innovations that are both meaningful and sustainable. The experts' call for clearer user definition and emphasis on social relevance reflect this principle. By embedding empathy mapping and value identification in the early stages of the framework, learners are encouraged to view technology not merely as a tool but as a medium for improving human experience.

The addition of user-problem-value templates and the inclusion of ethical reflection tasks in the Implementation stage advance this human-centred orientation. These refinements encourage students to consider usability, inclusivity, and the social implications of IoT solutions. Ethical engagement of this kind is increasingly recognised as a critical element of engineering and computing education Müller (2020). Integrating such practices within a project-based framework prepares learners to approach innovation with both technical expertise and moral sensitivity.

From a broader perspective, the framework aligns with global education goals that emphasise digital responsibility and sustainability. Antoninis et al. (2023) in Global Edicatio Report and the OECD (2023) both advocate educational models that equip students with the capacity to innovate ethically in technology-rich environments. By situating empathy and reflection as core components, this model supports those aspirations and contributes to the discourse on responsible innovation in higher education.

The validation findings also reveal that experts perceive the framework's ethical dimension as a strength rather than an adjunct. This indicates a growing recognition that design education must integrate societal responsibility into the learning process, not treat it as an external consideration. The Design Thinking–IoT framework thus contributes to a pedagogical shift from outcome-oriented project work to reflective, value-driven innovation. Such integration of ethical literacy with technological fluency represents a necessary evolution for preparing learners to navigate the complexities of digital transformation in society

CONCLUSION

This study set out to validate a pedagogical framework that integrates DT, the Initiator-Before-In-After (IBIA) teaching sequence, and the Flex blended-learning architecture to guide Internet-of-Things (IoT) project-based learning for the digital society. Through a design-based validation process, six experts evaluated the model's clarity, relevance, and feasibility using both quantitative indices and qualitative commentary. The initial validation confirmed strong content validity, with S-CVI/Ave = 0.96 and S-CVI/UA = 0.83, and produced constructive refinements addressing contextual authenticity, creative flexibility, user definition, and data-ethics reflection.

The study demonstrates that pedagogical innovation must be tested not only for theoretical coherence but also for usability in authentic learning environments. The expert-based evaluation strengthened the model's practical components, transforming it from a conceptual design into an empirically grounded framework capable of linking creativity, reflection, and ethical responsibility. The results affirm that a Design Thinking–IoT framework grounded in experiential and constructivist principles can cultivate the cognitive, technical, and moral capacities required of learners in the digital society.

Theoretical and Methodological Contributions

Theoretically, this study advances understanding across three domains of educational research.

First, it deepens the constructivist perspective on technology-enhanced learning by showing that authentic social contexts and collaborative decision-making strengthen conceptual understanding. The proposed model positions IoT learning within human-centred problem solving, transforming knowledge construction into a socially mediated process.

Second, it extends experiential learning theory by embedding iterative reflection into each learning cycle through the IBIA teaching sequence. Reflection before, during, and after practice promotes conceptual consolidation and aligns classroom activity with Kolb's experiential model of learning.

Third, the study contributes methodologically to design-based research by demonstrating that expert validation can serve as a formative mechanism for refining theory. Rather than treating content validity as a final outcome, the validation process functioned as an iterative dialogue between theoretical abstraction and pedagogical practice. This approach reinforces the link between research and implementation, which is central to educational design research (Anderson & Shattuck, 2012; McKenney & Reeves, 2018).

Pedagogical Implications

The validated framework offers educators a replicable structure for integrating innovation, ethics, and reflection into technical curricula. By combining Design Thinking and IBIA within a blended-learning environment, the model allows instructors to orchestrate learning that is both exploratory and structured. It encourages students to take ownership of their learning, to collaborate meaningfully, and to develop empathy for user. These are all essential competencies for digital-society citizenship.

Instructors adopting this framework should emphasise authentic problem briefs that connect IoT technology to community or industry challenges. Assessment should be aligned with process and reflection rather than solely product outcomes. Evidence such as context briefs, idea-pitch rubrics, and data-ethics reflections can serve as authentic indicators of competence. These adjustments encourage learning environments that mirror real-world innovation processes and promote sustained engagement.

Furthermore, the Flex component ensures accessibility and continuity across physical and digital spaces. It allows educators to balance asynchronous conceptual learning with synchronous collaborative prototyping, a blend shown to enhance self-regulated learning and persistence. Adopting such structures can support institutions seeking to redesign courses for hybrid or transnational delivery without compromising pedagogical quality.

Limitations and Future Directions

The current study represents an initial design–validation phase, focusing on the conceptual development and expert validation of the proposed model rather than direct classroom implementation. While the findings provide evidence of content relevance, theoretical alignment, and structural coherence, further research is required to transition the validated model into authentic educational contexts. Several future research directions are proposed to support this progression. The validated model should be implemented in small-scale pilot classroom studies to examine its practical feasibility and usability. This phase would allow researchers and practitioners to observe how the model functions in real classroom settings, including teachers' instructional practices, students' engagement, and contextual constraints such as time, resources, and curriculum alignment. Feedback gathered from teachers and students can be used to refine instructional procedures and implementation guidelines. Despite its strengths, the study's scope was limited to a small panel of six experts within the Malaysian higher-education context. While this number met established criteria for content-validity research, future studies should include a broader and more international panel to explore cultural and disciplinary variations in interpretation. Finally, the model's adaptability should be tested across domains such as robotics, health-technology innovation, and sustainable-energy systems to determine its generalisability. Comparative studies may also explore how Design Thinking-based pedagogies interact with AI-supported learning environments to enhance digital-society readiness.

Concluding Reflection

The initial validation of the conceptual learning model demonstrates that education for the digital society must transcend technical instruction. It must integrate empathy, ethics, and reflective practice as foundational competencies. The high level of expert consensus achieved in this study confirms that creativity and responsibility can coexist within the same pedagogical architecture. The model's blended, reflective, and human-centred structure embodies the educational paradigm needed for societies increasingly defined by intelligent technologies.

Ultimately, this research shows that the future of digital education lies in cultivating reflective innovators and individuals who understand not only how to design technologies but also why and for whom they design them. The validated model provides a pathway for higher-education institutions to realise this vision, ensuring that progress in technological learning remains inseparable from human values, social inclusion, and ethical accountability.

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REFERENCES

1. Akiyama, Y., & Cunningham, D. J. (2018). Synthesizing the Practice of SCMC-based Telecollaboration
2. A Scoping Review. CALICO Journal, 35(1), 49-76. https://www.jstor.org/stable/90016521
3. Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research? Educational researcher, 41(1), 16-25.
4. Antoninis, M., Alcott, B., Al Hadheri, S., April, D., Fouad Barakat, B., Barrios Rivera, M., Baskakova, Y., Barry, M., Bekkouche, Y., & Caro Vasquez, D. (2023). Global Education Monitoring Report 2023: Technology in education: A tool on whose terms?
5. Atlam, H., & Wills, G. (2018). Technical aspects of blockchain and IoT. In (pp. 1-39). https://doi.org/10.1016/bs.adcom.2018.10.006
6. Baran, E., & AlZoubi, D. (2024). Design thinking in teacher education: Morphing preservice teachers' mindsets and conceptualizations. Journal of Research on Technology in Education, 56(5), 496-514.
7. Boelens, R., De Wever, B., & Voet, M. (2017). Four key challenges to the design of blended learning: A systematic literature review. Educational Research Review, 22, 1-18. https://doi.org/https://doi.org/10.1016/j.edurev.2017.06.001
8. Brown, T., & Wyatt, J. (2015). Design thinking for social innovation. Annual Review of Policy Design, 3(1), 1-10.
9. Bruner, J. S. (1997). The culture of education. In The culture of education. Harvard university press.
10. Choi, H., Kim, H., & Kim, N. (2024). Enhancing creativity through a problem-based design thinking project in higher education. Cogent Education, 11. https://doi.org/10.1080/2331186X.2024.2378272
11. Corpuz, J., Cruz, K. J. S. D., Palomar, J. B., Tamayo, J., Bongao, H. L. C., Enojas, M. J. B., & Morgado, J. E. (2025). Household electric monitoring IoT system. Indonesian Journal of Electrical Engineering and Computer Science, 40(1), 85-92.
12. Di Battista, A., Grayling, S., Hasselaar, E., Leopold, T., Li, R., Rayner, M., & Zahidi, S. (2023). Future of jobs report 2023. World Economic Forum,
13. Elangovan, N., & Sundaravel, E. (2021). Method of preparing a document for survey instrument validation by experts. MethodsX, 8, 101326. https://doi.org/10.1016/j.mex.2021.101326
14. Garcia Moreno, H. M. (2024). An Exploratory Case Study of Students' Blended Learning Experiences During Post Emergency Learning.
15. Graham, C. R. (2006). Blended learning systems. The handbook of blended learning: Global perspectives, local designs, 1, 3-21.
16. Guerra-Manzanares, A., & Bahsi, H. (2023). On the application of active learning for efficient and effective IoT botnet detection. Future Generation Computer Systems, 141, 40-53. https://doi.org/https://doi.org/10.1016/j.future.2022.10.024
17. Henriksen, D., Creely, E., Henderson, M., & Mishra, P. (2021). Creativity and technology in teaching and learning: a literature review of the uneasy space of implementation. Educational Technology Research and Development, 69(4), 2091-2108.
18. Horn, M. B., & Staker, H. (2014). Blended: Using disruptive innovation to improve schools. John Wiley & Sons.
19. Iqbal, M. H. (2023). A Review on the Role of IoT in Modern Electrical Engineering Education. Journal of Engineering and Computational Intelligence Review, 1(1), 14-22.
20. Jamaluddin, F., Jamaluddin, A. H., Jamaluddin, F., & Jamaluddin, F. (2025). Malaysia's AI-Driven Education Landscape: Policies, Applications, and Comparative Insights for a Digital Future. arXiv preprint arXiv:2509.21858.
21. Jiang, C., & Pang, Y. (2023). Enhancing design thinking in engineering students with project-based learning. Computer Applications in Engineering Education, 31(4), 814-830.
22. Juan, W., Mukhtar, M. I., & Zhongli, J. (2025). Enhancing Entrepreneurship Education In TVET: A Validated Evaluation Scale for Higher Vocational Institution. International Journal of Research and Innovation in Social Science, 9(2), 4352-4367.
23. Kolb, D. (2015). Experiential Learning: Experience as the source of Learning and Development Second Edition.
24. Laverty, M., & Littel, C. (2022). 4.3 Design Thinking. NSCC Foundations of Entrepreneurship.
25. Lawshe, C. H. (1975). A quantitative approach to content validity. Personnel psychology, 28(4).

26. Liebkemann, S. L. (2021). The Impact of an Interprofessional Web-Based Unfolding Case Study on the Knowledge, Skills, and Attitudes of Students via Online, Asynchronous Modules The University of North Carolina at Chapel Hill].
27. Lynn, M. R. (1986). Determination and quantification of content validity. Nursing research, 35(6), 382-386.
28. Malaysia Digital Education Policy (2023). https://www.moe.gov.my/storage/files/shares/Dasar/Dasar%20Pendidikan%20Digital/Digital%20Education%20Policy.pdf
29. McCormack, C. M. (2021). Information architecture and cognitive user experience in distributed, asynchronous learning: a case design of a modularized online systems engineering learning environment Purdue University].
30. McKenney, S., & Reeves, T. (2018). Conducting educational design research. Routledge.
31. Müller, V. C. (2020). Ethics of artificial intelligence and robotics.
32. Nordin, N. S., Junaidi, J., & Hanid, M. F. A. (2024). Integrating problem-based learning and design thinking: Innovative approaches to enhancing student engagement. Journal of Research, Innovation, and Strategies for Education (RISE), 1(1), 41-57.
33. OECD. (2023). OECD Skills Outlook 2023: Skills for a Resilient Green and Digital Transition. O. Publishing.
34. Panke, S. (2019). Design Thinking in Education: Perspectives, Opportunities and Challenges. Open Education Studies, 1, 281-306. https://doi.org/10.1515/edu-2019-0022
35. Piaget, J., & Duckworth, E. (1970). Genetic epistemology. American Behavioral Scientist, 13(3), 459-480.
36. Polit, D. F., & Beck, C. T. (2006). The content validity index: are you sure you know what's being reported? Critique and recommendations. Research in nursing & health, 29(5), 489-497.
37. Pueyo-Garrigues, M., Pardavila-Belio, M. I., Whitehead, D., Esandi, N., Canga-Armayor, A., Elosua, P., & Canga-Armayor, N. (2021). Nurses' knowledge, skills and personal attributes for competent health education practice: An instrument development and psychometric validation study. Journal of advanced nursing, 77(2), 715-728.
38. Purba, L., & Zunidar, Z. (2025). Enhancing Student Creativity through Project-Based Learning in Science Education. Electronic Journal of Education, Social Economics and Technology, 6, 862. https://doi.org/10.33122/ejeset.v6i2.862
39. Razzouk, R., & Shute, V. (2012). What Is Design Thinking and Why Is It Important? Review of Educational Research, 82(3), 330-348. https://doi.org/10.3102/0034654312457429
40. Reigeluth, C. M. (2013). Instructional-design theories and models: A new paradigm of instructional theory, Volume II. Routledge.
41. Rodriguez-Sanchez, C., Orellana, R., Fernandez Barbosa, P. R., Borromeo, S., & Vaquero, J. (2024). Insights 4.0: Transformative learning in industrial engineering through problem-based learning and project-based learning. Computer Applications in Engineering Education, 32(4), e22736.
42. Sukumaran, S. (2018). Flex-learning-Online or face to face–Learners' freedom of choice. Global Bioethics Enquiry, 28.
43. Trishaank, K., Praveen Kumar, K., & Ram Mohan Rao, P. (2024). Integrating Computational Thinking & Design Thinking in Curriculum Development. International Conference on Work Integrated Learning.
44. UNESCO. (2023). Recommendation on the ethics of artificial intelligence. United Nations Educational, Scientific and Cultural Organization.
45. Vuorikari, R., Kluzer, S., & Punie, Y. (2022). DigComp 2.2: The Digital Competence Framework for Citizens-With new examples of knowledge, skills and attitudes.
46. Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes (Vol. 86). Harvard university press.
47. Wilson, J. P., & Beard, C. (2013). Experiential learning: A handbook for education, training and coaching. Kogan Page Publishers.
48. Wrigley, C., & Straker, K. (2015). Design Thinking pedagogy: the Educational Design Ladder. Innovations in Education and Teaching International, 54, 1-12. https://doi.org/10.1080/14703297.2015.1108214

49. Zainal, S., Yusoff, R. C. M., Abas, H., Yaacub, S., & Zainuddin, N. M. (2021). Review of design thinking approach in learning IoT programming. International Journal of Advanced Research in Future Ready Learning and Education, 24(1), 28-38.

APPENDIX

Appendix A. The Activities In A Design Thinking Learning Model For Developing IoT Projects

Phase 1: Inspiration			
Lecturer's Task		**Students' Task**	**Rating**
Foundation			
A1	Introduce the fundamentals of design thinking and IoT programming	Explore the fundamentals of IoT programming on the internet	
Empathise			**Rating**
A2	Discuss with students the purpose of the assignment/task..	Actively listen to the lecturer's explanation of the task's purpose.	
A3	Expose students to real-life scenarios (Example: Temperature sensing and humidity).	Actively observe the real-life situation	
A4	Divide students into groups to work together as a "design team" (4-5 students in 1 group).	Discuss and assign roles to ensure balanced participation. Each group will assign specific roles, with one student acting as the designer, one as the timekeeper, and the others taking on the role of users.	
A5	Evaluates students for item A4 using the evaluation DT rubric, which focuses on how well students understand users' needs, feelings, and contexts.	Demonstrate their ability to observe, listen, analyze, and reflect on human experiences authentically	
Define			**Rating**
A6	Conducts brainstorming session regarding steps, hardware and software, and materials to develop IoT project to solve the problems.	Focus on generating, organizing, evaluating, and refining ideas — while applying knowledge of technology, design, and user needs.	
A7	Observes and facilitates the session as students carry out their task.	Analyse the identified problems - fill up the Define Problem template, Cause and Effect Diagram (Ishikawa diagram) or other methods.	
A8	Evaluates students for item A7 using the evaluation DT rubric regarding on how well students understand users' problems.	Demonstrate their ability to Analyse the identified problems.	
Phase 2: Ideation			

Lecturer's Task		**Students' Task**	**Rating**
Ideate			
A9	Conduct group discussions.	Used tools such as mind map to visually organize and expand creative ideas. The group critically evaluated all proposed solutions and selected the most feasible and innovative idea among the three alternatives for further development.	
Design			
A10	Observes and facilitates the session as students carry out their task.	Design a prototype using flash cards/storyboard and present their solutions	
A11	Evaluates students using the evaluation DT rubric regarding how viable the students proposed the solution	Demonstrate their ability to design solutions.	
Test			
A12	Give feedbacks on prototype design.	Get feedback from the lecturer and peers on prototype design.	
Phase 3: Implementation			
Lecturer's Task		**Students' Task**	**Rating**
Development			
A13	Observes and facilitates the session as students carry out their task.	Develop an IoT prototype (Example: Temperature Sensing and Humidity System)	
A14	Evaluates students using the evaluation DT rubric regarding how viable the students prototype.	Demonstrate their ability to develop the solutions	