

The Use of Design Thinking in the Development of IoT Projects

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ABSTRACT

One of the difficulties in the teaching and learning of the Internet of Things (IoT) is the lack of exposure to IoT concepts and inadequate teaching methods and tools. The use of Design Thinking (DT) when developing IoT projects can promote solution-based thinking and enhance creativity in problem-solving. The process of DT involves five phases: Empathize, Define, Ideate, Prototype, and Test. The objective of this study was to evaluate the DT tools and process for developing IoT projects. This study involved 22 Information Technology undergraduate students. The Define Problem Statement template, POV template, User Feedback, and Affinity Diagram were among the DT tools introduced to the students. Using a survey form, each student assessed the efficacy of the DT tool and process. Student feedback revealed that the DT process and tools significantly enhanced their understanding of IoT projects. An expert assessment using a DT rubric was also carried out by a lecturer having a master's degree in information and technology to assess students' performance using five criteria. Students need to do two rounds of Affinity Diagram activity. The DT rubric results show students' average scores increased from 2.52 to 3.48, indicating an improvement in students' IoT project development using DT.

Keywords: Design thinking, IoT project, Empathize, Define, Ideate, Prototype, Test.

INTRODUCTION

The era of digitization is being ushered in by the Fourth Industrial Revolution (4IR), which spreads through almost every facet of contemporary life. It is projected that by 2030, the

introduction of 4IR will boost productivity in all sectors by thirty percent. The 4IR introduction will lead to more skilled labor, more high-value goods, and better services in the future.

Young people are the backbone of a country. They are vital to the process of building a nation since they are the asset of the next generation [1] [15]. To prepare a highly skilled workforce, it is imperative that the youths are instilled with the desired skills. Youths are different from the older generations in terms of their traits and abilities. Past research has shown that they are more receptive to innovative and creative technologies. They have a higher motivation to use the internet and greater proficiency with digital devices [10]. Since they had more exposure to Internet of Things (IoT) devices than the older generations, they are more familiar with the technology and more driven to embrace it [13]. Alqahtani et al. (2024) conducted a survey targeting students to explore the factors that influence their willingness to adopt Internet of Things (IoT) technologies and to identify key determinants that affect students' attitudes and intentions towards the integration of IoT in their academic and professional contexts [26].

The teaching and learning of Programming for IoT can be tough. When teaching students, the basics of programming and developing their programming skills to tackle real-world situations, lecturers often face challenges and setbacks [2]. Students sometimes find it difficult to transform their ideas for addressing problems into executable code and to comprehend and visualize the logical flow of programs. Utilization of interactive activities, visual programming tools, and real-world examples that complement the interests and experiences of students can help lecturers to overcome these problems [3].

Programming abilities comprise a variety of elements, such as creating algorithms, debugging code, comprehending grammar, analyzing requirements, and using the program development environment [5] [11]. To program computers at an advanced level, one must possess some fundamental abilities. Students should progressively learn the fundamental grammar, structure, and style of a programming language [20].

Students' final-year projects centered around the Internet of Things (IoT) offer students opportunities to explore a broad spectrum of applications and technologies. The projects might involve developing smart architecture systems, which integrate IoT to enhance building efficiency and functionality. Students could also focus on home automation systems by utilizing IoT to create interconnected devices that improve household convenience and energy management. Additionally, environmental monitoring projects could leverage IoT to track and analyze environmental conditions, contributing to sustainability efforts and data-driven decision-making. Such projects not only demonstrate technical proficiency but also address real-world challenges through innovative technological solutions [5].

Among the challenges in developing IoT systems are the limited exposure to IoT concepts and the lack of appropriate methods and tools for learning IoT. Design Thinking (DT) provides a human-centered approach to education that emphasizes the needs and experiences of learners. By incorporating DT principles, educators can craft more engaging and impactful learning experiences that empower students to thrive in a constantly evolving world [9]. Therefore, the purpose of this research is to assess the effectiveness of DT tools and processes in developing IoT projects among students.

LITERATURE REVIEW

Design Thinking in Education

Design Thinking (DT) is a systematic and innovative method for problem-solving that can be applied across various disciplines through a user-centered approach [25]. In the DT process, students work on targets that must be clearly defined and address unstructured problems without predefined solutions. The effectiveness of DT in imparting 21st-century skills and attributes to students underscores its educational value in solving design problems [8] [22]. The DT methodology is grounded in principles, such as empathizing to comprehend user needs, defining the needs, conducting trials, prototyping, obtaining user feedback, refining the process, and expressing ideas creatively through more than just words and symbols. Several studies have explored the use of DT in learning programming and developing IoT projects [5] [16] [21] [22] [23].

Design Thinking Process

Design Thinking is a non-linear, iterative methodology employed by teams to understand users, question the assumptions, redefine problems, and develop innovative solutions for prototyping and testing [6]. It is particularly effective for addressing ill-defined or ambiguous problems [2]. DT comprises five phases: Empathize, Define, Ideate, Prototype, and Test, as shown in Figure 1.



Figure 1: Design Thinking Process

1. **Empathize:** Promotes comprehension of users' needs and viewpoints. In the realm of programming education, this might entail acquiring an understanding of the difficulties and obstacles that learners encounter while attempting to understand programming concepts.
2. **Define:** Articulate and develop the learning objectives and goals related to programming or educational materials. It is essential to delineate the problem in accordance with the interests and needs of the participants in the program.
3. **Ideate:** Foster creative problem-solving during the development of programming exercises, projects, and assignments to generate three optimal solutions from which one can be selected.
4. **Prototype:** Construct a sample of the chosen solution to address the identified problem. Prototypes can be initially sketched using tools such as flashcards.
5. **Test:** Evaluate the proposed solutions by testing them and presenting the prototypes to users to gather feedback. Based on whether the problem is resolved or not, the stages of problem definition, design, and prototyping may be revisited and revised.

RESEARCH METHODOLOGY

Research Design

This research utilizes a quantitative methodology through a survey questionnaire for data collection. Quantitative studies offer several advantages, including objectivity, the ability to conduct statistical analysis, generalizability to larger populations, reliability through consistent results, precision in measuring variables, and the capacity to handle larger sample sizes, enhancing overall insights.

Research Population and Sampling

This research involved final-year students enrolled in the undergraduate program taking a Diploma in Information Technology at Kolej Professional Baitulmal Kuala Lumpur, Malaysia. Twenty-two students participated in the survey, consisting of 13 male and nine female students divided into five groups. Additionally, one information and technology lecturer who taught the final project course participated in this research.

Instrumentation

A structured survey questionnaire utilizing a five-point Likert scale was distributed among students to evaluate the effectiveness of the Design Thinking (DT) process and associated tools in the context of developing Internet of Things (IoT) projects. The survey aimed to gather quantitative data on how well these methodologies facilitated students' project work and overall learning experience. The Likert scale allowed for a nuanced assessment of various aspects of the DT process, including its utility, efficiency, and impact on the students' project outcomes. The response options range from 'Strongly disagree' to 'Strongly agree'.

In addition to the student survey, a Design Thinking rubric was employed by a lecturer to provide an objective evaluation of students' progress in understanding and applying concepts related to IoT projects. This rubric was designed to assess various dimensions of student learning, including their grasp of key IoT principles, their ability to implement DT methodologies, and the quality of their project outcomes. The use of the rubric allowed for a comprehensive assessment of student improvement from an expert perspective, offering insights into the effectiveness of the DT tools and processes as perceived by educators.

The combination of student survey data and lecturer assessment provided a robust framework for evaluating the impact of Design Thinking methodologies on the development of IoT projects. This dual approach facilitated a thorough examination of both subjective student experiences and objective educator evaluations, contributing to a well-rounded understanding of the DT process's effectiveness in educational settings. Through this study, valuable insights were gained into how Design Thinking tools and strategies influence student learning and project development in the field of the Internet of Things.

Data Collection

Students were required to complete a series of four tasks that integrate the Design Thinking (DT) process using an Affinity Diagram, which employed sticky notes for organizing ideas. The Affinity Diagram is a method designed to facilitate brainstorming and the systematic organization of ideas, information, and data into coherent groups or categories. This method is particularly effective for managing large volumes of unstructured information or addressing complex problems, as it promotes creative thinking, encourages collaborative efforts, and

supports decision-making based on a structured understanding of intricate information [7]. Two rounds of creating Affinity Diagrams were conducted. During the first round, lecturers guided the students through the DT process, helping them familiarize themselves with the method. In the subsequent round, students independently executed the tasks, allowing them to apply their learned skills autonomously. This iterative approach, involving two distinct rounds, enables students to explore and develop innovative solutions that are closely aligned with user needs and insights. By iterating through the Affinity Diagram process, students can refine and enhance their ideas continuously, thus reducing the risk of failure and increasing the likelihood of achieving successful outcomes. Ultimately, students developed a prototype of their IoT project independently over the course of three days.

Task 1:

Generate Ideas and Display Ideas (Empathize) The initial task required students to identify the needs associated with the IoT project they were developing. The lecturer presented real-life problem scenarios, and students were instructed to brainstorm without judgment, ensuring that all ideas were shared and considered. This task emphasized the importance of empathizing with user needs and fostering an open, non-judgmental brainstorming environment.

Task 2:

Sort Ideas (Define) In the subsequent task, students categorized and defined the problems using the Define Problem Statement form. This template helps students to articulate the problem in a structured manner, specifying an ideal situation such as “We want to be able to [destination] so that [population] will be able to [gain],”.

Following the initial stages of problem identification, students advanced to brainstorming solutions by crafting their Point of View (POV) statements.

Task 3:

Create Header Cards (Ideate) In the ideation phase, students were tasked with selecting the most viable solution from three shortlisted ideas. They were allotted 45 minutes to create a mind map, a technique that aids in generating and organizing ideas through visual representation. Mind maps facilitate the free flow of thoughts by visually depicting interconnected concepts and ideas. This method enhances creative thinking by enabling students to explore various perspectives and structure their ideas effectively, which ultimately fosters a more productive brainstorming session.

Task 4:

Draw a Finished Diagram (Prototype and Test) During the prototyping phase, students presented their solutions using storyboards. These storyboards were then reviewed by their peers, who provided feedback on whether the prototype effectively addressed user needs. This peer review process involved detailed and honest critiques, with students highlighting both the strengths and weaknesses of the prototype. Based on the feedback, students revised their prototypes, incorporating suggestions to better align with user requirements. The revised prototype was then presented again for further evaluation, leading to the development of the final version.

The concluding phase of the project involved the independent development of IoT projects by students. The lecturer supported this phase by allowing students to utilize any suitable programming environment to implement their projects. This phase emphasized the application of learned concepts and skills in a practical setting, enabling students to complete their IoT projects independently and apply the iterative design process they had practiced. The DT worksheets, including the Empathy Map, Point of View (POV) statements, and User Feedback forms, along with the notes taken during the brainstorming sessions and the prototypes developed throughout the DT process, were evaluated using the DT Rubric by the lecturer who taught the final project course. At the end of the task, students were given a set of questionnaires to evaluate the effectiveness of the DT tools and process using a 5-point Likert scale ranging from 'Strongly disagree' to 'Strongly agree'.

Data Analysis

The data obtained from the survey with students using questionnaires and the expert assessment with a lecturer using DT rubrics were analyzed in Microsoft Excel using the descriptive analysis method.

RESEARCH FINDINGS

Characteristic of the Lecturer for Expert Assessments using DT Rubric

The lecturer who assessed students' performance when conducting two rounds of the Affinity Diagram activity was the one who taught the students their final project course. The lecturer has a master's degree in information technology with 12 years of experience in teaching.

Results from Expert Assessment with Lecturers

Design thinking worksheets (Empathy Map, POV statements, User Feedback), note sheets used in the brainstorming process and prototypes developed during the DT process were examined by a lecturer using a DT Rubric.

In Table 1, the scores obtained from the criteria of the DT rubric are analyzed based on two (2) rounds of Affinity Diagram activities.

Table 1: Groups' Scores from Each Criteria of DT Rubric

Phase	DT 1					DT 2					X Phase (Average DT1 & DT2)				
	G 1	G 2	G 3	G 4	G 5	G 1	G 2	G 3	G 4	G 5	G1	G 2	G 3	G 4	G 5
E	2	2	2	2	3	3	3	3	4	4	2.5	2.5	2.5	3	3.5
D	2	2	2	1	3	3	3	4	2	4	2.5	2.5	3	1.5	3.5
B	3	3	4	2	4	4	3	4	3	4	3.5	3	4	2.5	4
P	4	3	2	1	3	4	4	3	3	4	4	3.5	2.5	2	3.5
T1	3	3	2	2	3	4	4	3	3	4	3.5	3.5	2.5	2.5	3.5
T2	14	13	12	8	16	18	17	17	15	20					
X	2.8	2.6	2.4	1.6	3.2	3.6	3.4	3.4	3	4					
X2	2.52					3.48									

* G: Group, E: Empathy, D: Defining, B: Brainstorming, P=Prototyping, T1=Testing, T2=Total Score, X: Groups' Average Points for All Design Tasks X2: Average Points for All DT

Table 1 shows the scores obtained from the criteria of the DT rubric of the 5 different groups (group members change in each design task) related to DT tasks and the average scores of the five groups for each design task. The average score of the groups from the first DT Task was 2.52 and for the second DT Task was 3.48. The scores show an increase when Design Thinking was used in their project task. This result proves that DT can give a positive outcome for students in their learning of IoT programming, which aligns with previous research [8].

Demographic Information of Survey Respondents among Students

The demographic profile of students who participated in the survey, as shown in Table 2, includes various categories that provide insights into their educational background, personal characteristics, and academic status. The research was conducted with 22 final-year students from the Diploma in Information Technology program at Kolej Profesional Baitulmal Kuala Lumpur.

Table 2: The Demographic Profile of Students Who Participated in The Survey

Gender	Total	Percentage
Male	13	29%
Female	9	41%

Results from the Survey with Students

At the end of the Design Thinking (DT) task, students completed a questionnaire designed to assess the effectiveness of the DT tools and process. The results are presented in Table 3.

Table 3: Student Scores Regarding DT Tools and Process

No	Statements	Average	Mode	Std
Q1	During a brainstorming session, I understand the needs of	4.1	4.0	0.61
Q2	I start the design process by getting information from others.	4.0	4.0	0.65
Q3	I can demonstrate an understanding from other perspectives.	4.1	4.0	0.68
Q4	I can synthesize the given information and prioritize the	4.0	4.0	0.62
Q5	I can generate new ideas based on input from others.	4.3	4.0	0.63
Q6	I can reach out to extraordinary ideas through simple ideas	3.9	4.0	0.64
Q7	I can use many techniques such as mapping and trees to	4.1	4.0	0.77
Q8	I can create a physical or visual presentation of an idea.	4.2	4.0	0.73
Q9	I can present an idea that can be evaluated and developed.	4.0	4.0	0.72
Q10	I managed to identify a suitable real-life application for	3.9	4.0	0.75
Q11	I managed to arrange the feedback into operational results.	3.9	4.0	0.71
Q12	Overall, I found that DT is effective for the development of	4.2	4.0	0.70

Regarding the effectiveness of Design Thinking (DT) in idea generation and presentation, all participants concurred that the brainstorming sessions were instrumental in clarifying the needs of their IoT projects (Q1, Q6). They acknowledged that the Define Problem Statement form and the Point of View (POV) template significantly facilitated the creation of new ideas by integrating feedback from others (Q2, Q3, Q4, Q5). Additionally, participants found the mind map to be an effective tool for organizing and presenting their ideas (Q7, Q9). They also agreed that their ideas could be effectively represented both visually and physically (Q8, Q11). The overall findings indicate a consensus among participants that the DT tools and processes are

highly effective in the development of IoT projects, as they assist in identifying appropriate real-life applications to address future needs (Q10, Q12).

DISCUSSION

The findings obtained in this study proved that Design Thinking (DT) can assist students on the Internet of Things (IoT) project development and enhance their understanding. Among 12 items in the survey questionnaire, the majority received a mean score above 4.00, indicating the overall positive perception among students regarding the use of DT in IoT project development. The expert assessment done by a lecturer on students' performance in developing IoT projects using DT was also encouraging. Based on the five criteria in the DT rubric used by the lecturer, the average scores of students displayed an increment in students' performance and understanding of IoT projects using DT.

Design Thinking (DT), a human-centered approach to innovation and problem-solving, has increasingly been applied in educational settings to enhance learning outcomes among youth in Asia. Recent studies have underscored its effectiveness in fostering creativity, critical thinking, and practical skills among young learners in this region [5]. In recent years, Design Thinking (DT) has been increasingly integrated into undergraduate curricula in Malaysia, particularly in the context of Internet of Things (IoT) projects [9] [17]. This approach is designed to enhance students' ability to solve complex, real-world problems through a user-centered and iterative process. The results obtained in this study supported the recommendation by scholars in the use of DT for teaching and learning activities [24].

The application of Design Thinking to IoT projects in Malaysian higher education has been shown to significantly benefit undergraduate students. Incorporating DT methodologies into IoT-related coursework allows students to develop a deeper understanding of the both technological and human-centered aspects of their projects [12] [17]. Their research highlights how DT encourages students to empathize with end-users, prototype solutions, and iteratively refine their designs, leading to more innovative and practical IoT solutions. From the expert assessment of this study, the higher scores obtained by students in the second round of the DT task compared to the first task shows students' improvement in their understanding of IoT projects and DT processes, including empathizing with users, designing prototypes, and refining their designs.

A study by Rahman et al. (2023) investigated the impact of Design Thinking on IoT project-based learning at Malaysian universities [20]. Their findings suggest that DT not only improves technical competencies but also enhances students' problem-solving and teamwork skills. Students who engaged in IoT projects using DT were found to be more adept at identifying user needs, developing functional prototypes, and integrating feedback to improve their designs [14]. This study not only assesses students' performance through expert judgement but also students' perception regarding the effectiveness of DT through survey questionnaires. Hence, the results of this study provide a deeper understanding of the effectiveness of DT for IoT project development. The results of this study supported prior research regarding the role of DT in bridging the gap between theoretical knowledge and practical application [18].

This study demonstrates that the application of Design Thinking in undergraduate IoT projects in Malaysia provides significant educational benefits. It enhances students' technical and

problem-solving skills, aligns with user needs, and fosters essential socio-emotional competencies, thereby contributing to a more holistic and effective learning experience.

CONCLUSION

This study investigated the efficacy of Design Thinking (DT) phases, such as the Empathize, Define, Ideate, Prototype, and Test phases applied in the context of developing Internet of Things (IoT) projects. The research was conducted with 22 final-year students from the Diploma in Information Technology program at Kolej Profesional Baitulmal Kuala Lumpur and one information and technology (IT) lecturer. The study aimed to assess how the DT tools and processes influenced students' capabilities in IoT project development.

The analysis revealed that students utilized several DT tools effectively, including the Define Problem Statement template, the Point of View (POV) template, the User Feedback mechanisms, and the Affinity Diagram. These tools played a crucial role in enhancing students' understanding of IoT project development. For instance, the Define Problem Statement template and POV template facilitated the clarification and articulation of project goals and user needs, which are essential for generating relevant and innovative solutions. The use of the Affinity Diagram helped students systematically organize and categorize their ideas, while User Feedback provided valuable insights into the effectiveness of their prototypes.

The results of the study indicate that the application of DT tools and processes substantially improved students' comprehension of the complexities involved in IoT project development. This improvement underscores the potential of integrating Design Thinking methodologies into the curriculum of technical education programs. By offering a structured framework for addressing complex problems, DT not only aids in teaching intricate technical concepts but also fosters creativity and enhances problem-solving skills among students.

Given these positive findings, it is advisable for educators to consider the incorporation of DT methodologies into their instructional strategies. Doing so could better equip students to meet the challenges of the IoT industry, where innovative thinking and effective problem-solving are crucial. Furthermore, incorporating DT into educational curricula may lead to more robust and practical learning experiences that align with industry demands.

To build on these insights, future research should examine the long-term effects of Design Thinking on students' performance in real-world IoT projects. Additionally, exploring the applicability of DT methodologies across various educational settings and disciplines could provide a broader understanding of its benefits and limitations. Such research would contribute to refining DT approaches and enhancing their integration into diverse educational contexts, ultimately improving the preparation of students for professional roles in technology-driven industries.

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