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PROCEEDINGS

Training the Trainers in Elementary and High Schools on IoT Using Design Thinking Approaches

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***Abstract*— This article describes how the authors apply and implement teaching methods using design thinking approaches to train in IoT (Internet of Things). The purpose of this study is to determine how well of design thinking with IoT topics to teachers and students, and how we could improve teaching or coaching strategies. Participants in this study are the researcher as the trainers, 20 to 30 teachers from different schools and 20 to 30 on each high school student (Grade 9 to Grade 12) as the trainee perform group projects. By collecting observations from trainee's activity outcome on each step of design thinking approach to deliver problem solving projects with IoT, the researcher applies narrative analysis to interpret patterns or characters on each activity. Each approach involved with activities which develop teachers or students to make their own learning and understanding problem and complete their IoT prototype projects within 4-5 days. Not only electronics devices and embedded systems and programming are used but also recycled materials. LEGO alike blocks are setup for learning activities corresponded to levels of students and available school resources. Different sets of learning activities in this article are adjusted attributable to education levels and individual school resources. From the analysis after the trainings, the conclusion shows how the researcher can improve by applying appropriate hardware/software in learning activities on different education levels and apply the design thinking more efficiently in teaching or coaching teachers and student in schools.**

Keywords—IoT, Design Thinking, Learning Activity, STEM Education, Programming

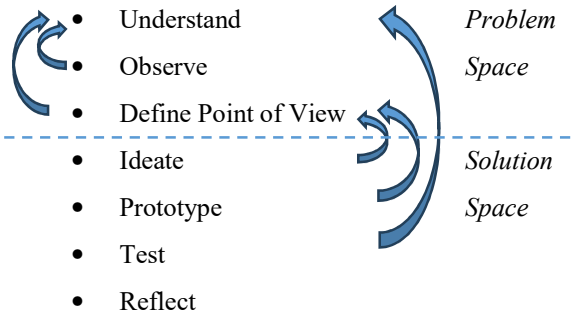
I. Introduction

STEM Education in Thailand in schools has been implemented for several years. Current revised version of scientific subjects curriculum (2017) [1], there are many subjects related to electrical engineering knowledge such as computer programming, fundamental of electrical circuits, and IoT (Internet of Things) which mainly involved with STEM education in school as a core topics. Since STEM education is expected to be used in schools, some advanced topics such as Embedded System, IoT which need preparation time for teacher to get more hand on experiences to perform teaching to students. Therefore, many schools request expertise from university to transfer knowledge on such topics in this early stage of STEM education in Thai schools. The challenge is to set up training facility or training courses in short period of training days. The researcher had been requested from many schools around the area of Nakornpathom Province, so the researcher decided to use design thinking concepts to make a training /coaching courses for teachers and students. Our goal is to transfer design thinking approaches activities for teachers and students. The researcher hopes that teachers might use this approach and develop appropriate learning activities for their students in the future by themselves. This article will describe those activities and analysis result for upgrading or improvement issues on our further training techniques.

II. Design Thinking Overview

A. Problem Space and Solution Space Approaches

In design thinking cycle [2] consists of 7 steps shown in below processes, beginning process from "Understand" through "Reflect" process.



Design thinking makes use of an iterative procedure from problem statement to problem solution. The objective is to generate many ideas as possible with the help of various creativity techniques. In our training, the researcher split processes into 2 groups of activities – Problem space, and Solution Space

In Problem space session, the researcher trained teachers and students to experience on asking who is stake holders, what /where/ why/ when/ how and in-depth of the problem about impact, occurrences, cause and effect, how to handle and how to avoid in systematic way of handling and also exploring existing approaches that solves that problem.

In Solution space, the researcher trained teachers and students to experience on tools (hardware and software) to ideate on solutions and try to create prototype and test process and draw back to understanding of problem again which can verify their consumptions.

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B. Teachers and Students Training

Training teachers and training students has slightly different approaches. Training for teachers emphasized on learning activities content and focus on collaborative on expertise of teachers. In our case, most of teachers were from IT (Information Technology), Mathematics, and Sciences fields so in problem space session the researcher had to focus on activities that make teacher brainstorm on problems that teachers can communicate and set up suitable problem for solving and proper resources utilization for students.

Training students on problem space are more relax start with broad problems which lead to creativity and freedom then the researcher keep on raising more narrow problems to make students realize more on resources, time, and budgets.

Training teachers on solution space session, the researcher focused on integration of software tools by using simple problem model and simulate it. If hardware is involved, the researcher demonstrates how it works. Finally, the researcher let teachers do work together to try all software tools also hardware tests. After discussion, questioning and doing their own experiment, teachers are required to present their problems and solutions.

Training students on solution space session, the researcher focuses on all safety and beginning with simulation tools as priority. After they experienced the simulation then the researcher let them work on hardware components and measurement equipment by which monitored by training staff on each workbench.

By design thinking process, the researcher had to make sure that teachers and students are doing iteration on process such as from "observe" process has to verify with "understand" process along with "define point of view", and "prototype" process must verify with "ideate" process, test process has to verify with initiate step (understand process)

III. Design Thinking Activities based on IoT projects

In the training, the researcher stated our goal that student groups must come up with IoT projects that can solve specific problems. That specific problem may come from schools, teachers' ideas, workplace, environment, or system /tools improvement. After briefing our objective, the researcher performed these following activities:

A. Warm-up Activitites

Ice breaking , Doldrums prevention, Creativity

It is very important that group of people that join and will work together which have different knowledge and abilities, they should know each other right before working with ideas and brainstorming. These activities lead them to know one another, creating positive atmosphere, remove social barriers, and preventing afternoon drowsiness, reduce pressure to succeed, also fun and share a laugh. The researcher used these techniques in the starting period of each session or in between session depending on how atmosphere were. Activities are:

Clapping game, drawing emotion or objects and guessing, helping one another making things by LEGO alike blocks, etc.

Figure 1. Teachers experienced Warm-up activities

B. Design Thinking[2] *– Problem Space processes session*

This session takes 3-4 hours to complete these steps

- Understand process
  - Problem statement, 5W+H Questions
  - User interview / Stake holder map
  - Ask 5x Why / Design principles
- Observe process
  - Trend analysis
  - AEIOU
    Activities, Environmental, Interaction, Objects, User
  - Persona / User profile
- Define point of view
  - Context mapping
  - Storytelling
  - Vision cone
  - Critical Items diagram

For students from elementary school, the researcher did not go through in detail of problem space processes much. Only a few techniques such as asking "What" "When" "Where" "Who" "How" are used and along with MindMap tools to gathering information on problem they focused. Also using search engine to explore existing solutions.

C. Knowledge and Re/Up-Skill on IoT Development tools

This session concern more technical practice and implementation. It takes 4-6 hours to complete these following steps:

- Safety
- IoT concept with workshop
  - Embedded System
    - Kidbright[3] / Microbit [4]
  - Block code Programming
    - Kidbright / KB-IDE[5] / Microbit
- Basic Measurement Instrument with workshop
  - Multimeter
- Sensors and Interfaces with workshop
  - Single sensor input
    - 1-wire, I2C/SPI demonstration
  - Single output device
    - GPIO
  - Programming with devices
- Networking Fundamental with workshop
  - IP network
  - IoT Protocol / MQTT
- Integration with Network by simple problems

Figure 2. High school students explore IoT devices from search engine

Most of Thai schools have computer with internet network facility so they can explore and find out related information for their project resources also coding examples. For IoT development re/up-skill session, the researcher set up 1 student per 1 computer and 1 embedded system and sensors / components set in case of less students in training session. But if in case of inadequate computers or there are large group of students 2 to 4 students per 1 computer with 1 set of embedded system with sensors and components. The objective of this re/up-skill on IoT development tools is to enhance hand on skill on real components which some school already took the class for electronic components and instrument [6], introduction to IoT [7] in their curriculum. This activity might re-skill for students or teachers who have experiences and up-skill for those who start to implement IoT development.

D. Design Thinking – Solution Space processes session

This session takes 24-72 hours to complete these steps based on resources and equipment.

- Ideate process
  - Brainstorming
  - 2 x 2 Matrix
  - 6-3-5 Method
  - NABC
    Need, Approach, Benefit, Competition
- Prototype process
  - Focused on experiments prototype
  - Future Vision prototype
  - Functional prototype
  - Solutions in detail
- Testing process
  - Testing sheet
  - Feedback capture grid
  - Solution interview
  - A/B Testing
  - Structured usability testing
- Reflect
  - I like, I wish, I wonder, What-if
  - Create a pitch
    - Story
    - Problem
    - Customers
    - Solution/Idea
    - Business model
    - Next steps
    - Summary

The researcher has chosen some practical activities on solution space processes which fit on student perception and understanding. In elementary level, the researcher chose some activities that to make them understand basic factor of prototyping [8] such as human desirability, economic feasibility, and technical implement ability. Along with interdisciplinary team members which emphasizes two dimensions – In-depth technical knowledge as well as a broad general knowledge (or breadth of knowledge) called T-profile team. This level were assigned to solve some un-realistic problems such as imaginary creatures or objects with IoT capabilities to communicate with other team objects or creatures by using LEGO alike blocks make some structure (Figure 3). In high school level, the researcher assigned more realistic/real-world problems for them to perform prototyping with LEGO alike blocks, recycled materials such as used paper, straws, plastic bottles, trash bin. At the end of training workshop, they delivered and pitch their product outcomes (Figure 4).

Figure 3.Elementary level Creatures and IoT on microbit

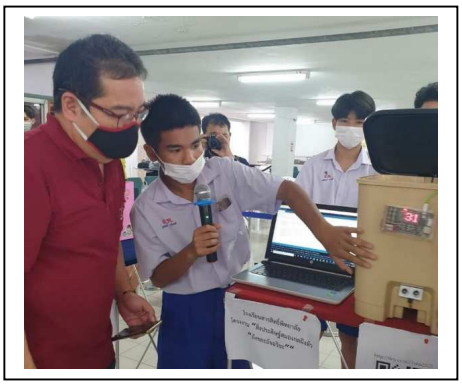

Figure 4. High school level – Trash bin to IoT gadget

IV. Analysis

The researcher conducted design thinking with IoT workshops for more than 10 schools in Nakornpathom area since 2021 by which repeatedly occurred on each school onsite or online (in case of COVID19). By collecting data from observation including exit slips, questionnaires, and suggestions from the trainee. The researcher used inductive

and deductive approaches to perform narrative analysis in each activity in the design thinking process as follows.

Inductive approach in following activities:

Problem space processes which involved questioning, observation, brainstorming, and mapping relationships.

Deductive approach which conducted framework to the trainee in following activities:

Warm-up activities – Setting rules and regulations.

Solution Space – IoT concept and programming and STEM software tools orientation, and prototyping tools

The researchers observed the trainees and interpreted their experiences and motivations as a group outcome story and compared to what we expected from project outcome which related to IoT solutions.

V. CONCLUSIONS

From the analysis, the researcher can conclude some issues that related with our training method on IoT subjects in 3 following categories:

A. Design Thinking process

1) Problem statement: This step still need to be focused because most of outcome project that did not solve the purpose of problem entirely came from define problem clearly in systematic ways. Problem topic should be broad more than narrow to solution in order to let teachers or students think for more alternatives of issues rather than think about existing solutions.

2) Problem space: Need more time to practice and more case studies should be examined. Activities on "Understand","Observe","Define Point of View" should be more in practice.

3) Solution space: Need more practical approaches to implement and best practice sample on prototyping and testing process.

B. IoT resources for schools

1) IoT components: Need components, sensors that easy for students to understand and suitable attraction for level of students.

2) Internet Network: Some school has insufficient network capacity , speed and connections payload for IoT devices along with stronger security policy.

3) Fundamental of IoT and related technology: Principle of IoT and related content should be extended for training for non-IT/technology fields such as mathematic or pure science teachers.

4) Thai language Media and Reference resources on IoT and related materials: There are some barrier on english language in techical terms in software tools or in IoT development procedures. The trainers should prepare for more translatation on software instruction to Thai language in some specific points.

C. Knowledge depth on IoT and learning attrations

In the training process the researcher evaluates our approaches on 5 abilities from learners on Thai school learning standards [8] which consist of:

a) Ability to communicate
b) Ability to think,analyze and organize
c) Ability to solve problems
d) Ability to apply skills for living
e) Ability to apply technology

From 10 schools training on STEM and IoT development, the researcher concluded by relationship between academic level and IoT components correspond to learning attraction and abilities gain up shown in Table I.

TABLE I. IoT components and learning abilities

IoT components	***Primary/Elementary school***	***High school***
Output by visual and Audio	Symbol, Iconic, Colorful	Show Status Conditions
Output by motion	Interaction Open/Close states	Degree of Motion
Input by sensors or switches	Simple colors Tasks related	Automated along output process
Programming	Block code Basic flow and decisions	Multiple cases Not complex decisions
Multiple input/output integration	1-2 input/output components	Depend on problem cases
Networking	Peer-to-Peer Device-to-Device	Among devices and mobile app

By overall, the researcher might summarize a way to choose IoT topics (hardware and software development skills) that appropriate for student levels in this Figure 5 relationship.

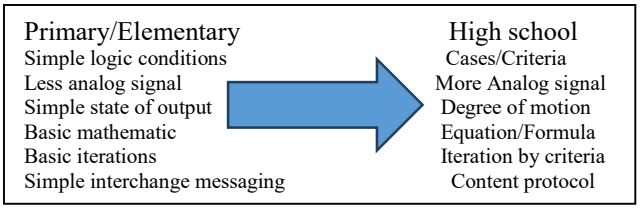

Figure 5 Relationship of difficulties on IoT topic in training

D. Suggestion

Training IoT topic for trainers or students in primary/elementary/ high school need to choose suitable hardware and software to improve skills and make understanding which corresponded to level of school and teachers who are new to IoT technology. As shown in Table II may lead the training the trainers' facility for IoT development for school having more efficient in future.

TABLE II. Need for next training improvement

IoT components	***Primary/Elementary school***	***High school***
Output by visual and Audio	Level display Colorful devices Voice-assistant	Customized+ Colorized display
Output by motion	Open/Closed stage with feedback	Easy Speed control module
Input by sensors or switches	Illuminated switch state-analog output	Customized switches pad
Programming	Thai / English interface menu and instructions	Easy plugins/add-on module

TABLE II. Need for next training improvement		
IoT components	***Primary/Elementary school***	***High school***
Networking	Auto-detect content type in communication	Simple mobile app for development
Safety	Better circuit protections Audible/Visible Alarming	

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