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# Systematic Review on Teaching and Learning for IoT Programming

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***Abstract*—Teaching and learning Internet of Things (IoT) programming is challenging. The literature regarding teaching and learning for IoT programming still lacking. Therefore, we conducted an updated and comprehensive review using a systematic literature review (SLR) to report recent research findings regarding teaching and learning for IoT programming. Five databases were selected for this SLR to identify related journals, of which 21 papers were reviewed systematically. This review answered five research questions regarding the level of study being taught for IoT programming; the tools used for IoT programming; the teaching and learning approach used; and the methods and instruments adopted for data collection.**

***Keywords*—Internet of Things (IoT), systematic literature review, IoT programming**

## I. INTRODUCTION

The Internet of Things (IoT) is an environment where "things" are physical objects embedded with sensors, hardware, software, and other technologies. They are linked over the Internet to exchange and connect data with other devices. It is also for systems creating an intelligent and distributed connected environment [1]. IoT is also referred to as "smart assistant things," which can be used in many applications such as home appliances, vehicle networks, health care devices, infrastructure, production, and all other entities. These connected "things" are fixed with various sensors able to provide information about the current environment, air pollution, the level of heat, and temperature [2].

IoT has gradually developed over time as different technologies have combined into a single platform. Embedded systems, remote sensor networks, and control frameworks are traditional domains that contribute to IoT development. The adoption rate of IoT devices is very high where over 15 billion connected IoT devices currently, and experts expect this number to grow to 22 billion by 2025 [3]. IoT is not a different technology, scientific discipline, or paradigm. Instead, it is a combination of existing and established areas such as communications networks, computer security, artificial intelligence, computer security, and embedded programming.

As more devices become connected, it is essential to ensure that today's students, as future human resources, have the right talents and skills to drive the technology forward. There are many challenges in teaching and learning IoT programming. Students need to obtain practical experience in developing IoT systems [4]. [5] reported that the challenges in IoT system development are the need for heterogeneity of devices, division of roles and the scale of IoT systems. IoT programming is complex because it requires networked devices, such as gateways, servers, and IoT devices. Learning and teaching IoT programming will be further complicated as IoT devices are implemented using software and hardware [6]. The difficulty of effectively training sufficiently trained IoT programmers has been critical [10], [11], [35]. IoT programming is associated with a few programming but not limited to Embedded Systems Programming, IoT Application Development, IoT Platform Development, Sensor and Actuator Programming and Cloud Services Integration. In this study, IoT programming referred to programming in developing software applications that interact with and control IoT devices and systems. It involves creating code to manage communication, data processing, and control logic for various IoT devices and their interactions within a network.

So far, literature regarding pedagogies of teaching and learning approaches for IoT programming has not been explored extensively or systematically reviewed. Therefore, this article conducted a comprehensive, updated, and systematic review to report the latest research findings on teaching and learning approaches for IoT programming. From this study, the findings can assist teachers or curriculum designers in developing effective teaching and learning approaches regarding IoT programming.

This paper, Part 1, introduces the study. Part 2 describes the methodology used for this review, Part 3 presents the results and discussion, and finally, the conclusion in Part 4.

## II. METHODOLOGY

Systematic literature review (SLR) is a method used to identify, evaluate, and interpret all available research evidence, aiming to answer specific research questions [12]. SLR is a form of secondary study that uses a well-defined methodology. SLRs, instead of unstructured methods such as simple literature reviews, are potentially biased. SLR results are more systematic and unbiased in obtaining results [8][13]. The review process follows SLR guidelines [12], [14] to make the literature search as comprehensive as possible. For this study, the SLR comprises three stages: planning, conducting the review, and reporting the result, as shown in Fig. 1.

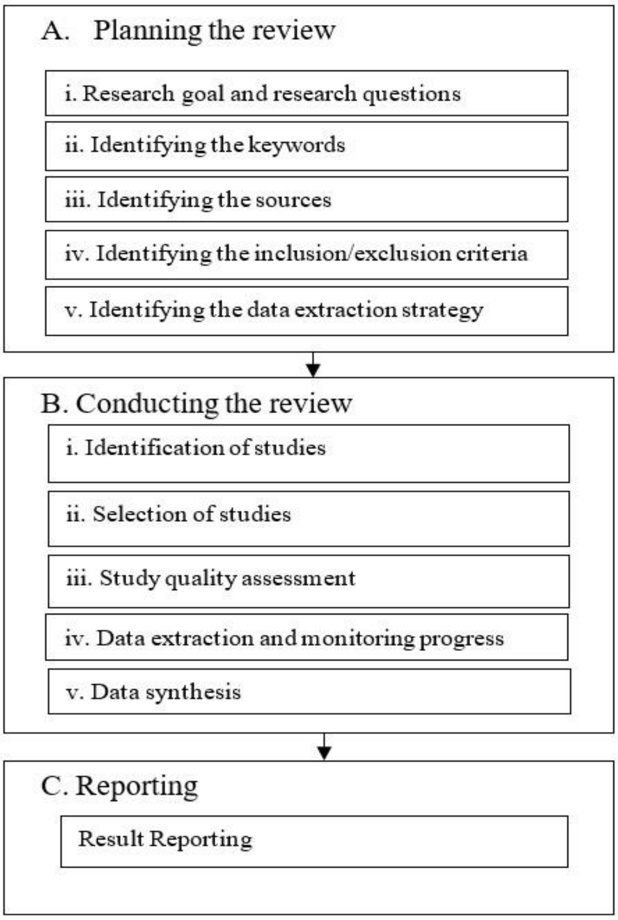


Fig. 1. SLR stages

### A. Planning the review

In this phase, the review protocol is identified, including the research questions, keywords, sources, inclusion/ exclusion criteria and data extraction strategy.

i. Identifying Research Questions

This SLR aims to find the details of teaching and learning pedagogies, approaches, and data collection methods used for IoT programming courses. The research questions related to teaching and learning are:

RQ1: What level of study offers an IoT programming course?

RQ2: What programming used to develop IoT projects?

RQ3: What pedagogies, teaching, and learning approaches are used for IoT programming courses?

The research questions from the research methods aspect are:

RQ4. What methods are used in data collection for studies related to teaching and learning IoT programming?

RQ5. What instruments are used in data collection for studies related to to teaching and learning IoT programming?

ii. Identifying the keywords

Based on the research questions mentioned above, the key phrase ("IoT programming" OR "embedded programming") AND "education" was used. The synonyms of the keywords for "education," which were "teaching and learning," were also utilized. The search string was formulated based on the main terms and their synonyms, and the Boolean as shown below and the search keywords were used to find relevant studies in the paper's title, keywords, and abstract:

("IoT programming" OR "embedded programming") AND ("education" or "teaching and learning").

iii. Identifying the sources

Five databases were selected for this SLR subscribed to by the institutions: ACM Digital Library, IEEEXplore Digital Library, Science Direct Journal, Springer Link Journal, and Taylor and Francis Online. These databases were selected as they dispense the most critical and impactful full-text journals and conference proceedings related to programming.

iv. Identifying the inclusion/ exclusion criteria

Inclusion and exclusion criteria were applied to ensure that only relevant literature was accepted into the SLR. Exclusion criteria are papers not in English (Only abstracts written in English), and the full text is unavailable. The inclusion criteria were that papers must be white, full-text, and review papers published from 2010 to 2021. Concerning the year of publication, we only found significant studies related to our research topic before 2010. Therefore, the distribution of reviewed papers published from 2010 to 2021.

v. Identifying the data extraction strategy

After implementing the inclusion or exclusion criteria as illustrated in the previous step, information such as citation, the context of the study, the tools or programming used, and teaching and learning approaches were documented to answer the research questions.

B. Conducting the review

i. Identification of studies

The search process was separated into two stages: primary and secondary. The papers were identified in the selected databases using the search string in the primary search. In the secondary search, the selected primary studies' references were reviewed to determine any additional related studies—this process aimed to ensure that the primary search phase did not miss any relevant literature. Table 1 illustrates the results of the primary studies search. After passing the primary study search through five databases, 248 papers were selected. In the secondary stage, a backward search was conducted for the selected papers of the primary studies.

TABLE 1. Databases and number of papers from primary search

| ***Databases*** | ***Number*** |
|---|---|
| ACM Digital Library | 82 |
| IEEEXplore Digital Library | 148 |
| Science Direct Journal | 16 |
| Springer Link Journal | 1 |
| Taylor & Francis Online | 1 |
| Total | 248 |

### *i. Selection of studies*

This step narrowed down the number of documents found in the previous search phase. The eligibility criteria were applied to determine which of the studies identified in searches were pertinent based on the paper title, and all irrelevant papers were discarded. The discernment was conducted by applying filters related to IoT programming. Then, the abstracts of the filtered papers were assessed, followed by the introduction and the conclusion/discussion of the filtered papers. This step consisted of a more thorough selection of the documents.

After overseeing the first level of eligibility criteria, 18 primary studies related to IoT programming for education were obtained. A secondary search was conducted in eighteen studies, which involved reviewing references in selected primary studies to identify additional relevant studies. Five studies were identified from the primary search references from this secondary search phase. The final number of selected studies is 21 studies.

### *ii. Study Quality Assessment*

This step involved assessing the quality of the 21 selected studies. The selected studies support the extraction of the information for synthesis and the result from the analysis. A quality assessment checklist was adapted from [41]. The following scale was used for the quality assessment: Yes=1, Partially 0.5, and No=0. Table 2 presents the criteria that were employed for assessing the paper quality.

TABLE 2. Criteria for quality assessment

| ***Criteria*** | ***Statement*** | ***Answers*** |
|---|---|---|
| Q1 | Are the aims clearly stated? | Yes/No/Partially |
| Q2 | Are the methods used in each paper clearly described? | Yes/No/Partially |
| Q3 | Do the objectives lead to conclusions? | Yes/No/Partially |
| Q4 | Is the findings clearly described? | Yes/No/Partially |
| Q5 | Are the links between data, interpretation, and conclusions are clear? | Yes/No/Partially |

It was concluded that the higher the study score, the more excellent the study quality, concurrent with its ability to answer the research questions. The total scores for each article were calculated, and the percentage was determined by dividing the total score by five. These 21 papers were selected as the final papers. Fig. 2 shows the overall procedure of this SLR and the results for each step.

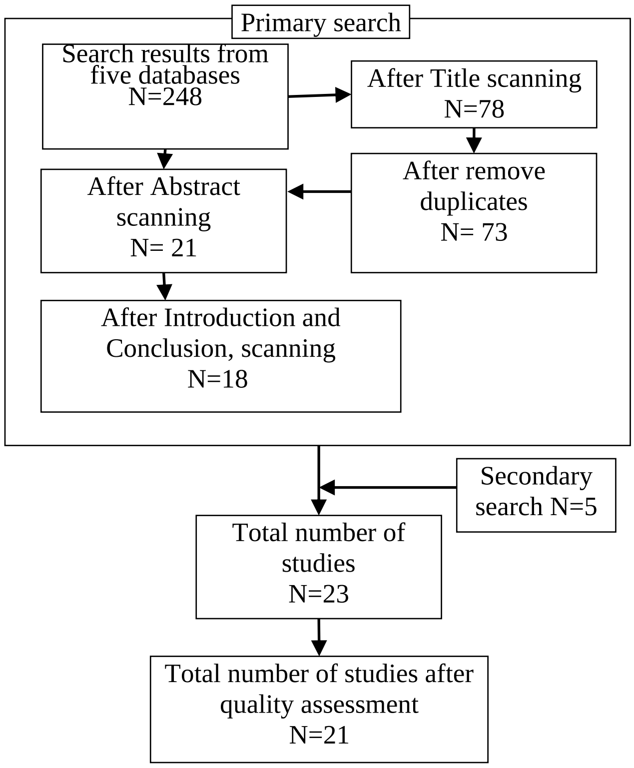


Fig. 2. Result of the SLR process

### *iii. Data Extraction*

Twenty-one studies related to IoT programming showed that research in this field had been conducted in most of the world's regions from 2013 to 2021, as shown in Table 3.

TABLE 3. The results of the primary studies search

| Study ID | Year of study | Country of study | Reference |
|---|---|---|---|
| S1 | 2018 | Japan | [15] |
| S2 | 2020 | Italy | [16] |
| S3 | 2020 | Turkey | [17] |
| S4 | 2013 | United Kingdom | [18] |
| S5 | 2019 | Thailand | [19] |
| S6 | 2019 | Amsterdam | [20] |
| S7 | 2021 | Taiwan | [11] |
| S8 | 2018 | Hyderabad | [21] |
| S9 | 2020 | South Africa | [22] |
| S10 | 2018 | Norway | [23] |
| S11 | 2016 | India | [24] |
| S12 | 2019 | US | [25] |
| S13 | 2020 | Brazil | [26] |
| S14 | 2020 | Canada | [27] |
| S15 | 2018 | China | [28] |
| S16 | 2020 | Israil | [29] |
| S17 | 2017 | China | [30] |
| S18 | 2019 | Kingdom of Arab Saudi | [31] |
| S19 | 2019 | Malaysia | [32] |
| S20 | 2018 | India | [33] |
| S21 | 2019 | Italy | [34] |

## III. RESULTS

The research questions related to teaching and learning are shown below.

*RQ1: What level of study offers an IoT programming course?*

61.9% of IoT programming is taught at the tertiary education level, including college, university, and vocational institutions. The IoT programming course was offered for students aged 18 and above (S1, S2, S7, S8, S9, S11, S14, S16, S18, S19, S20, S21). Other than that, it was found that secondary education also introduced learning of IoT programming for students aged 16 to 18 (23.8%) (S3, S5, S10, S13, S15). Besides secondary and tertiary levels, IoT programming was also exposed to groups of people with varying levels of education 14.3% (S4, S6, S12). The findings revealed that IoT programming was taught to various levels of study ranging from high secondary, tertiary, and mixed levels of education, as shown in Fig 3.

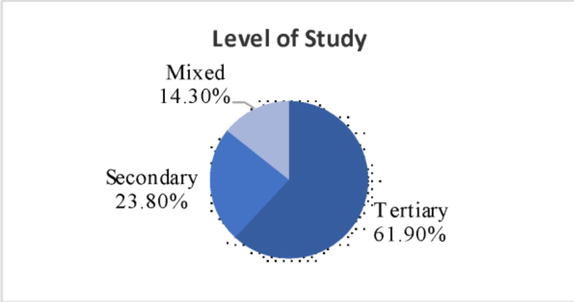


Fig. 3. Level of study

*RQ2: What programming used to develop IoT projects?*

To answer RQ2 regarding the tools or programming used to develop IoT projects, the results show that the majority of participants use Arduino (30%), followed by Raspberry (15%) and Block programming (11%). However, many journals did not mention the tools and programming used (22%). Some studies used Java, Python, MATLAB, and Visual programming. Table 4 shows the tools or programming utilized to teach IoT programming.

TABLE 4. Tools/programming to develop IOT projects

| Tools or Programming | Study ID | Total |
|---|---|---|
| Arduino | S1, S3, S9, S13, S15, S17, S18, S21 | 8 (29.6%) |
| Raspberry Pi | S1, S17, S18, S21 | 4 (14.8%) |
| Block programming | S5, S14, S15 | 3 (11.1%) |
| Java | S11, S22 | 2 (7.4%) |
| Python | S16, S19 | 2 (7.4%) |
| MATLAB | S6 | 1 (3.7%) |
| Visual Programming | S14 | 1 (3.7%) |
| Not Available (NA) | S2, S4, S7, S8, S10, S20 | 6 (22.2%) |

*RQ3: What pedagogies, teaching, and learning approaches are used for the IoT programming courses?*

There were various pedagogical, teaching, and learning approaches applied to teach IoT programming. The most common approach was Design Thinking (DT) 23.8%, followed by Project-based (19.1%) and Problem-based Learning (PBL) (14.3%). However, many papers still need to specify the teaching and learning approaches used. Table 5 shows the teaching and learning approaches used to teach IoT programming.

TABLE 5. Teaching and learning approach

| ***Teaching and Learning Approach*** | ***Study ID*** | ***Total*** |
|---|---|---|
| Design Thinking (DT) | S3, S7, S9, S11, S15 | 5 (23.8%) |
| Project-based | S6, S10, S20, S21 | 4 (19.1%) |
| Problem-based Learning (PBL) | S1, S12, S16 | 3 (14.3%) |
| Not Available (NA) | S2, S4, S5, S8, S13, S14, S17, S18, S19 | 9 (42.9%) |

PBL is a pedagogy that is focused on active students [36]. The focus of PBL is not on solving problems but on gaining experience, social interaction, and communication, in addition to counting group cooperation as professional competence. PBL is a student-centered learning approach that involves groups of students in work together to solve real-world problems; it differs from direct teaching methods, where a teacher presents facts and concepts about a particular subject to a class of students. PBL not only improves teamwork, research skills, and communication, but students also sharpen problem-solving and critical thinking skills that are important for lifelong learning. In applying PBL, the teaching role shifts from a more traditional model that follows a linear, sequential pattern where the teacher presents relevant material, tells the class what to do, and provides details and information for students to apply their knowledge to the given Problem. With PBL, the teacher performs as a facilitator; students drive learning to solve a given problem. In this review, Akiyama used PBL to implement an IoT prototype system through self-construction and to present and discuss IoT system service ideas in a PBL-style class. The teacher's help is essential to create products such as electronic wiring parts in construction practice.

The studies used Design thinking (DT), almost 23.8% (S3, S7, S9, S11, S15). DT is a human-centered approach that aims to find innovative and creative solutions to various social and commercial problems using design tools and mindsets [37]. During the process of DT, learners work on targets that need to be clearly defined and unstructured problems with no stated solutions [38]. The effectiveness of DT in bringing 21st-century skills and characteristics to students creates the educational value of design problems [39]. The DT process relies on the principles of empathizing to understand user needs, define the needs, make trials, prototype, receive feedback from users, redesign the process [39] and express ideas through creative ways besides using words and symbols [17].

19.1% of the studies used Project Based Learning (S6, S10, S20, S21). Project Based Learning is a form of student-centered teaching with three constructivist principles, learning in the form of specific contexts, students are actively involved in the learning process as well as achieving their goals through social interaction and sharing of knowledge and understanding [40]. During Project Based Learning (S21), about 40 undergraduate students were involved in the survey during their IoT project development [34]. The survey results found that inexperienced IoT developers need help finding structured documentation that novices might understand and the inherent complexities of subsystem integration and integration with third-party services. As (S6) mentioned, IoT cannot be taught only utilizing traditional lecture classrooms. Therefore, the subject will be taught using practical assignments and extensive tutorials, followed by a team-based project component [20].

About 42.9% of studies should have explicitly mentioned the pedagogies being implemented (S2, S4, S5, S8, S13, S18, S19). However, for the teaching and learning approach, all the studies emphasized group discussion. Each group consisted of 5 to 7 members discussing existing systems or prototypes and understanding how the previous aspects apply to domains [16].

From the evaluation aspect, RQ to answer are:

*RQ4. What methods are used in data collection for studies related to teaching and learning IoT programming?*

Based on this review, quantitative, qualitative, and mixed research methods are used to collect data for learning IoT programming. In this review, the dominant research method is quantitative (61.9%), followed by mixed method (33.3%), while only 4.8% use qualitative methods. Table 6 shows the research methods used.

TABLE 6. Research methods

| ***Quantitative*** | ***Qualitative*** | ***Mixed*** |
|---|---|---|
| S5, S6, S8, S9, S10, S12, S13, S14, S16, S17 S18, S19, S20 (61.9%) | S1 (4.8%) | S2, S3, S4, S7, S11, S15, S21 (33.3%) |

Quantitative research means collecting and analyzing numerical data to describe characteristics, find correlations, or test hypotheses. Quantitative research is a way to learn about a specific group of people, known as a sample population. The purpose of quantitative research is to generate knowledge and create an understanding of people. Quantitative research is used by social scientists, including communication researchers, to observe phenomena or events that affect individuals. Quantitative research relies on observed or measured data to examine questions about a sample population. There are four main types of quantitative research: descriptive, correlational, causal-comparison, quasi-experimental, and experimental [41], [42].

The goal of qualitative researchers is to gather a detailed understanding of human behavior and the outcomes that lead to such behavior [43]. In other words, the qualitative research method examines and answers how, where, what, when, and why a person will act in a certain way toward a particular thing. Smith [15] defines qualitative research as empirical, where the researcher collects sensory data about the phenomenon being studied and works on it by organizing it and holding it against ideas, hypotheses, and category definitions to test it. Typically, qualitative research methods focus on a small number of valid participants as a source of information [15]. The most popular methods are individual interviews, group discussions, observations, and action research.

*RQ5. What instruments are used in data collection for studies related to to teaching and learning IoT programming?*

For further details, this review explored instruments used for data collection. In this SLR, quantitative research's most common data collection method is a survey followed by experimental, test, and rubric. Qualitative research was an observation, followed by an open-ended survey and interview. Instruments for data collection are shown in Table 7.

TABLE 7. Instrument For Data Collections

| Study ID | *Quantitative* | | | | *Qualitative* | | |
|---|---|---|---|---|---|---|---|
| | *Survey* | *Test* | *Rubric* | *Experimenta* | *Interview* | *Observation* | *Open ended survey* |
| S1 | | | | | | √ | |
| S2 | √ | | | | √ | √ | |
| S3 | | | √ | | √ | √ | |
| S4 | √ | | | | | √ | |
| S5 | √ | √ | | | | | |
| S6 | √ | | | | | | |
| S7 | √ | | | | | | √ |
| S8 | | | | √ | | | |
| S9 | | | | √ | | | |
| S10 | | √ | √ | | | | |
| S11 | √ | √ | | | | | √ |
| S12 | | | | √ | | | |
| S13 | √ | | | √ | | | |
| S14 | | | √ | √ | | | |
| S15 | | | | √ | | √ | |
| S16 | √ | | | | | | |
| S17 | √ | | | √ | | | |
| S18 | | √ | | | | | |
| S19 | | √ | | √ | | | |
| S20 | | √ | | | | | |
| S21 | √ | | | | | | √ |
| **Total** | **10** | **6** | **3** | **8** | **2** | **5** | **3** |

For the data collection, some researchers used more than one instrument. For example, for the quantitative method, ID S13 and S17 combined survey with experimental; S5 was used to survey and test while S19 was used to test and experimental, as shown in Table 8.

TABLE 8. Instrument Used for Quantitative Methods

| **Instrument** | **Study ID** |
|---|---|
| Survey | S6, S16 |
| Survey + Test | S5 |
| Survey + Experimental | S8, S9, S12, S13, S17 |
| Test | S18, S20 |
| Test + Rubric | S10 |
| Test + Experimental | S19 |
| Rubric + Experimental | S14 |

The survey instrument was used for a variety of purposes which usually covered a large number of participants. In study S16, the researchers conducted a feasibility study regarding the current system and what the future system will do, called the Concept of Operation (ConOps). The assessment was based on a student survey of 250 students from two course. In S6, 32 students involved in the survey regarding how the course was delivered, the lecturers' performance, practice rating, and general satisfaction with the course using the PBL approach and the project development using Raspberry Pi single-board computer.

Study ID S5 combined the survey and test, where the test consisted of 20 comprehensive questions about IoT programming. The duration for each question was limited to 2 minutes. The paired t-test was calculated to analyze the before and after test results after completing the course. The survey and test are intended to know the relationship between teaching using ArViz as an IoT teaching tool and the improvement of students' knowledge or skills. Study ID S19 used a test to know the score of 707 business students and 1613 engineering students across four semesters from 2017 spring to 2018 spring. Students' performance in Applied Mathematics (APM), and Precalculus (PRC), Python Programming Language course (PYT) were collected. While in study ID S20, Open-end activity (OEA) and examinations were performed. In the OEA, there are two activities conducted. In the first activity, students needed to develop an IoT prototype system. In the second activity, an alternative was given to the students to perform task A or task B. Task A comprised a technical report writing for the IoT system developed and task B is required students to build the user interface for IoT.

From this SLR, survey and experimental were found the most common data collection for quantitative research. For example, study ID S8 applied active learning environments to promote students' critical thinking regarding IoT programming. In the class, the teachers demonstrated the IoT projects resulting in the students being actively engaged in developing the IoT project. After completed the experiment, survey instruments to assess students' critical thinking were conducted. In study S9, the students conducted a project assignment to build automated plant watering or irrigation system for wireless-based solutions using the DT approach. In study ID S12, students conducted experiments to develop different end-user programming interfaces using a basic implementation of IoT programming. In study ID S13, the researchers used quantitative methods, which combined survey and experiment where usability testing was conducted to evaluate block-based programming tools. Survey questionnaires were used to evaluate students' perceptions of participation in the activities. Study S17 proposed an instrumentation laboratory to support the new learning framework for problem-solving activities in STEM research. The researchers conducted the survey regarding the effectiveness of hands-on and team-oriented learning approaches. Data collection using rubric and experimental was applied in study ID S14. Usability evaluation through Cognitive Walkthrough was implemented for engineering students regarding their competencies of logical thinking and abstraction of complex concepts in IoT programming.

In this SLR, only one study used a qualitative method using observation, as shown in Table 9. In study ID S1, observations were made on how students constructed IoT systems after self-study and attending class using the PBL approach. There were 16 third and fourth-grade students involved in this observation, divided into five groups.

TABLE 9. Data collection for qualitative methods

| ***Qualitative*** | ***Study ID*** |
|---|---|
| Observation | S1 |

Besides utilizing quantitative and qualitative methods, researchers also used mixed methods, which combined the quantitative and qualitative methods, as shown in Table 10.

TABLE 10. Data collection for mixed methods

| ***Quantitative*** | ***Qualitative*** | ***Study ID*** |
|---|---|---|
| Survey questionnaire | Observation | S4 |
| Survey | Interview and Observation | S2 |
| Survey | Open ended survey | S7, S21 |
| Survey and Test | Open ended survey | S11 |
| Rubric | Interview and Observation | S3 |
| Experimental | Observation | S15 |

Mixed methods research is a type of research that combines qualitative and quantitative research techniques into one study. The majority of mixed methods in this SLR for quantitative research used surveys and other qualitative methods such as observation, interview, and open-ended surveys. For example, study ID S4 used survey and observation to evaluate the effectiveness of teaching approach. This approach combined concepts from Pervasive Interactive Programming, the Internet-of-Things, the iCampus, Living Labs, and the hierarchical 'Smart-Box' model.

Study ID S2 implemented a method to support non-technical persons to design IoT-based automated systems for Smart Interactive Experiences (SIEs). An experimental study was carried out for the user study to understand how the interaction paradigms supported non-technical users. The study was conducted in three phases. In the first phase, each group invented an interactive IoT application following a scenario that asked them to act as museum curators. The museum curators had to plan a new exhibition to disseminate the value of the archeological investigation. The first phase aided the ideation of the smart interactive visit by approving brainstorming techniques. In the second phase, all groups used the three systems to design the smart interactive visit. Participants filled in questionnaires to compare user satisfaction with all of the systems. In the third phase, once all three groups completed the second phase, the participants joined in a focus group discussion. The discussion revolved list of topics, such as the experience using the systems. Custom attributes are also supported by the suggested algorithm integrated into the system. The data collection instruments were transcriptions of audio recordings and notes from the second phase. The notes taken by the observer on significant behaviors or externalized comments of the participants during the second phase answer the open questions involved in the questionnaire and audio recordings. Transcriptions of the focus groups and notes were taken by the observer on significant externalized comments made by the participants throughout the focus groups.

In S7, the researchers explored how DT in an iOS programming course can enhance the student's learning motivation and solve practical issues and critical thinking over mobile apprication development. In the program, students were mandatory to answer situational motivation questionnaires after and before DT was implemented. Study ID S21 surveyed 40 novice students using the Likert's scale questionnaire on the difficulty of tasks and time spent. The open-ended questionnaire was used for respondents to comment on the task's difficulty according to five interconnected subsystems (Sensors, Gateways, Back-end, Actuators, and End-user).

In ID S3, the researchers studied 25 gifted students on how the DT approach can be used in teaching programming. Data were gathered through interviews and observations usinng the DT Rubric. S15 studied how to cultivate Creative Thinking and scientific engineering practice skills using DT and Scaffolding Instruction by teaching Mblock for Arduino course. Three groups of 10 to 12 members were requested to solve the problems raised by the researchers. In the brainstorming session, the teaching background and the task topics of this lesson were discussed. Students implemented the earlier designed program flow and line simulation link diagram through hands-on operations. This task will stimulate students from the land of imagination to innovation in the learning proses [11].

## IV. CONCLUSION

This systematic literature review provides comprehensive review using systematic literature review (SLR) to report recent research findings regarding teaching and learning for IoT programming. Details from teaching and learning approaches and data collection were identified regarding the teaching and learning of IoT programming. The highest level of study that offers IoT programming is at the tertiary education level, including college, university, and vocational courses. Regarding the tools or programming used for teaching and learning, the results show that most participants used Arduino. There were variety of pedagogical and teaching and learning approaches applied to teach IoT programming, and the most popular approaches were PBL and DT. The quantitative method was the most common method for data collection, followed by the mixed and qualitative methods.

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